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Ramstad

With Alfa Lift nearing completion and the Dogger Bank (A&B) contract in hand, Torgeir Ramstad, CEO, OHT discusses his company & the future of Offshore Wind

Dogger Bank
Inside the the World's Largest Offshore Windfarm

Subsea Tiebacks
A Troll with a Kinder Surprise

Simulation
Cutting the Corner on Machine Learning

VOL. 46 / NO. 2

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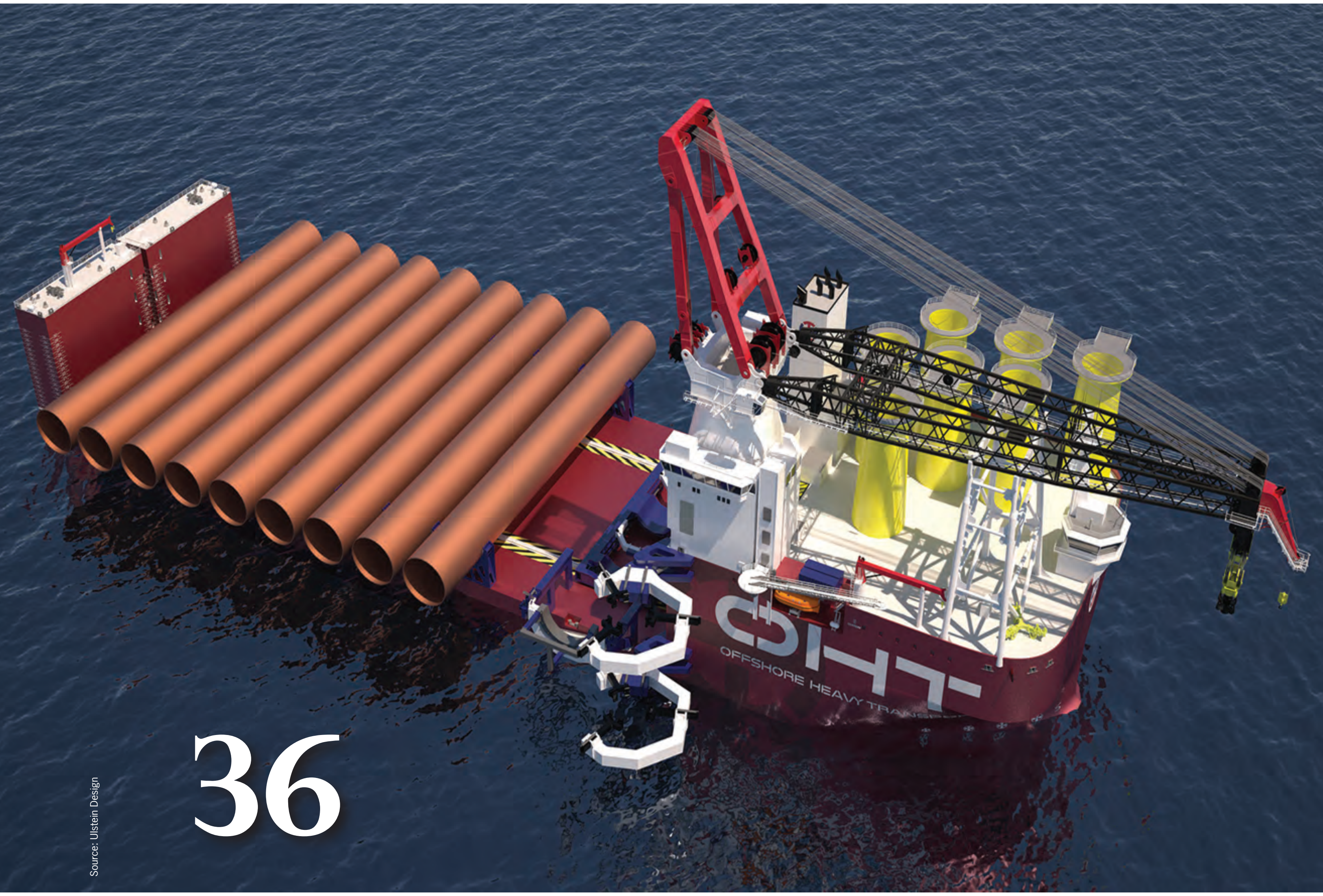
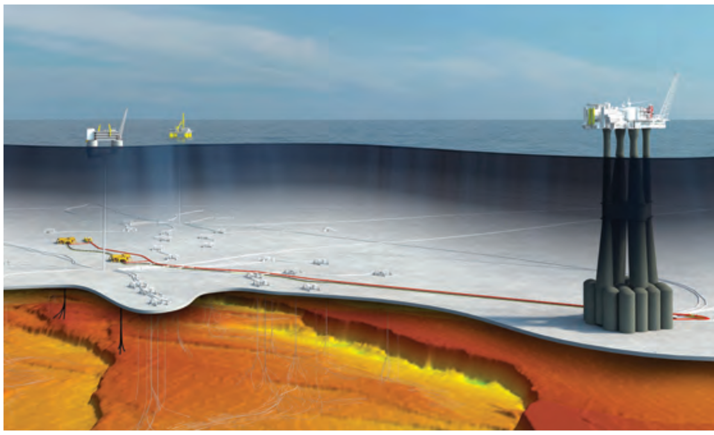
FEATURES



ON THE COVER: Torgeir Ramstad, CEO, OHT, discusses his company and its role in the offshore wind market. Source: OHT

FEATURES



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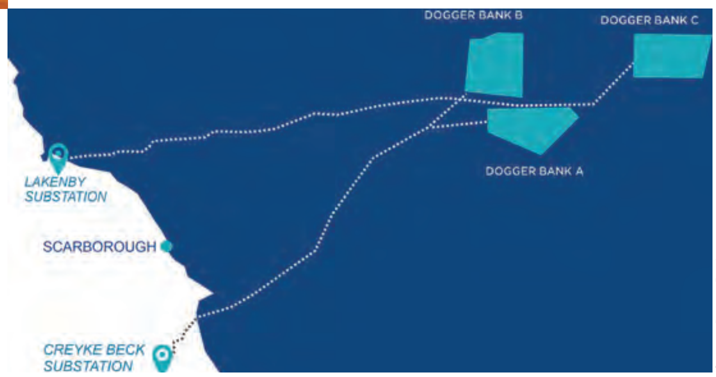

Source: DoggerBank.com

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BY THE NUMBERS

RIGS

Worldwide

Rig Type	*Available*	*Contracted*	*Total*	*Utilization*
Drillship	23	49	72	68%
Jackup	156	288	444	65%
Semisub	34	46	80	58%

Africa

Rig Type	*Available*	*Contracted*	*Total*	*Utilization*
Drillship	1	8	9	89%
Jackup	23	13	36	36%
Semisub				

Asia

Rig Type	*Available*	*Contracted*	*Total*	*Utilization*
Drillship	6	5	11	45%
Jackup	52	92	144	64%
Semisub	17	6	23	26%

Europe

Rig Type	*Available*	*Contracted*	*Total*	*Utilization*
Drillship	5	1	6	17%
Jackup	19	30	49	61%
Semisub	9	20	29	69%

Latin America & the Caribbean

Rig Type	*Available*	*Contracted*	*Total*	*Utilization*
Drillship	2	19	21	90%
Jackup	2	3	5	60%
Semisub	2	9	11	82%

Middle East

Rig Type	*Available*	*Contracted*	*Total*	*Utilization*
Jackup	30	112	142	79%
Drillship	1		1	0%

North America

Rig Type	*Available*	*Contracted*	*Total*	*Utilization*
Drillship	7	16	23	70%
Jackup	25	31	56	55%
Semisub	2	5	7	71%

Oceania

Rig Type	*Available*	*Contracted*	*Total*	*Utilization*
Drillship		0	0	
Jackup	1	1	2	50%
Semisub	1	3	4	75%

Russia & Caspian

Rig Type	*Available*	*Contracted*	*Total*	*Utilization*
Jackup	5	6	11	55%
Semisub	2	3	5	60%

This data focuses on the marketed rig fleet and excludes assets that are under construction, retired, destroyed, deemed noncompetitive or cold stacked.

Data as of March 2021.
Source: Wood Mackenzie Offshore Rig Tracker

DISCOVERIES & RESERVES

Offshore New Discoveries

Water Depth	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*
Deepwater	12	16	16	20	13	2
Shallow water	66	74	52	81	39	9
Ultra-deepwater	16	12	17	18	7	1
Grand Total	**94**	**102**	**85**	**119**	**59**	**12**

Shallow water (1-399m)
Deepwater (400-1,499m)
Ultra-deepwater (1,500m+)

Offshore Undeveloped Recoverable Reserves

Water Depth	*Number of fields*	*Recoverable reserves gas mboe*	*Recoverable reserves liquids mbl*
Deepwater	558	43,914	21,802
Shallow water	3,235	424,329	142,572
Ultra-deepwater	327	41,072	25,734
Grand Total	**4,120**	**509,315**	**190,108**

Contingent, good technical, probable development.

The total proven and probably (2P) reserves which are deemed recoverable from the reservoir.

Offshore Onstream & Under Development Remaining Reserves

	Water Depth of fields	*Remaining reserves gas mboe*	*Remaining reserves liquids mbl*
Africa	609	19,983	12,321
Asia	870	16,401	7,799
Europe	759	12,303	13,487
Latin America and the Caribbean	201	6,071	38,382
Middle East	128	78,732	145,194
North America	545	3,007	13,889
Oceania	86	11,335	1,359
Russia and the Caspian	59	17,024	14,510
Grand Total	**3,257**	**164,858**	**246,941**

Onstream and under development.

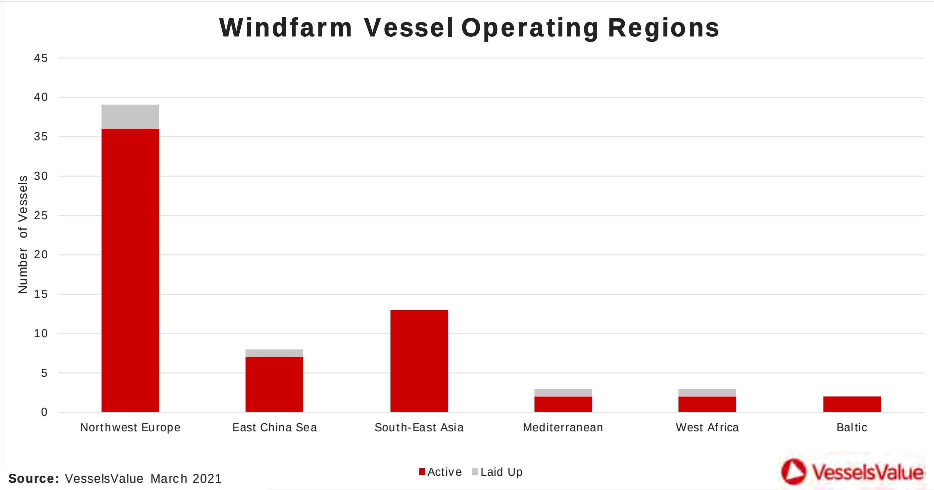
The portion of commercially recoverable 2P reserves yet to be recovered from the reservoir.

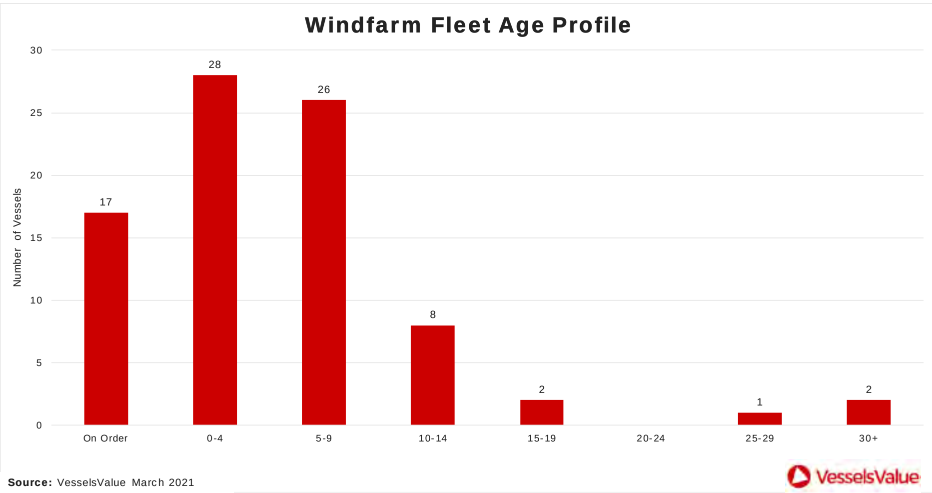
Source: Wood Mackenzie Lens Direct

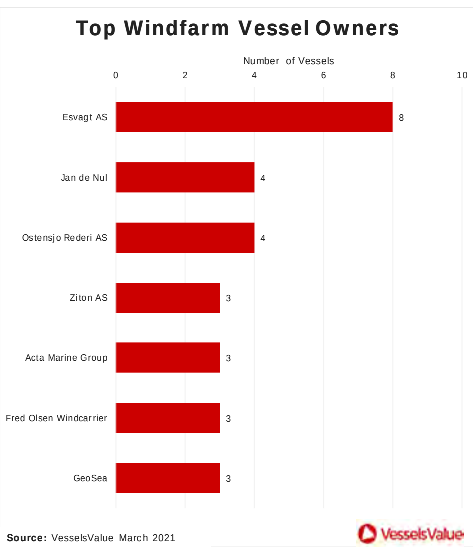
SECTOR IN FOCUS
WIND FARM VESSELS

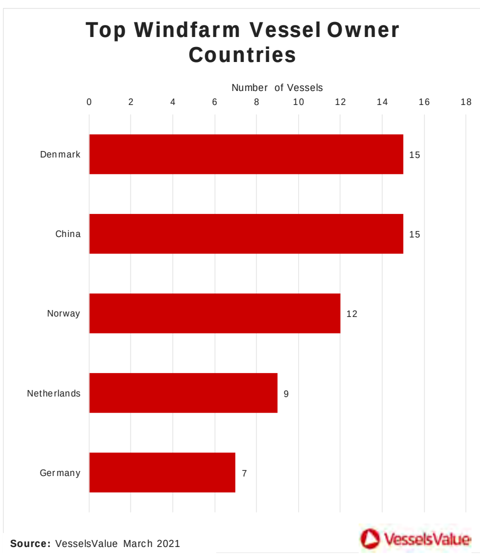
Data & Statistics powered by VesselsValue

April 2021









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Mesineni

Mulligan

Maslin

Pallanich

Tomic

OPPORTUNITIES IN WIND ABOUND

While COVID has delayed or taken away so many aspects of our daily professional lives, from a pure business perspective it is interesting to see many of the manifestations as a result. In our regular interviews with business and technology leaders across the sector, the picture painted is broadly similar: the first two months of March and April 2020 was like a sucker punch to the gut; no one really knew what happened and it was difficult to catch your breath. 'Uncertainty' was the only known regarding the future. After that, though, people and businesses globally do what they've done since the beginning of time: they learn, they adapt, they transform and ultimately, they get back to business. This does minimize the pandemic nor imply it has not been without monumental challenge or sacrifice, personal and professional.

One aspect that I personally miss is the one-on-one interaction with people in the industry. I'm somewhat old school in this respect, as I've traveled the globe for more than 30 years and without question, the best results, the best stories, invariably came from taking the time to meet with an executive, a company, in their place of business. That in-person process came with a number of drawbacks, namely the time and cost to fly to distant places, a process that has been replaced for now with a seemingly endless string of video calls and interviews. There are certain advantages, with our cover interview with **Torgeir Ramstad**, CEO, OHT, as a prime example. On the day I interviewed Ramstad for our *Offshore Engineer TV* web channel, I had already "traveled" for interviews to Shanghai and Germany, before hitting Norway for our OHT interview and finishing in Vancouver, BC. And that was before lunch!

Ramstad was an insightful and interesting interview, as I think you'll agree, as he has is the past five years help to pivot OHT from a company focused mainly on offshore oil and gas to a company headed toward a nearly pure offshore wind player, building on spec a pair of technologically advanced and innovative maritime assets designed to give it a leg up in the global push toward offshore wind. Starting on page 36 read about OHT's transformation, including its role in helping to lay the foundation, literally, for the world's largest offshore windfarm: Dogger Bank.

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SIMULATION
Cutting the corner on Machine Learning

By Shilpa Mesineni, ABS Senior Engineer II for the Digital Class Capabilities Team

As the offshore oil and gas industry becomes more competitive, it actively pursues increased efficiency through innovative approaches while streamlining production, reducing costs, and improving safety. Many companies are looking at digitization to insulate themselves from market shocks, remain profitable at lower oil prices, and generate competitive advantage during recovery. The path forward lies in leveraging machine learning-based technologies that are maturing quickly and are being adopted across the value chain. The use of Machine Learning (ML) models is particularly promising for the resolution of problems involving processes that are not completely understood or where it is not feasible to run mechanistic models at desired resolutions in space and time. With these growing technologies and solutions to complex science and engineering problems require novel methodologies that can integrate physics-based modeling approaches with state-of-the-art ML techniques. This paper provides an overview of the use of physics-based simulation models to test, correct, and retest ML algorithms under a range of scenarios and at a scale not practicable with physical testing.

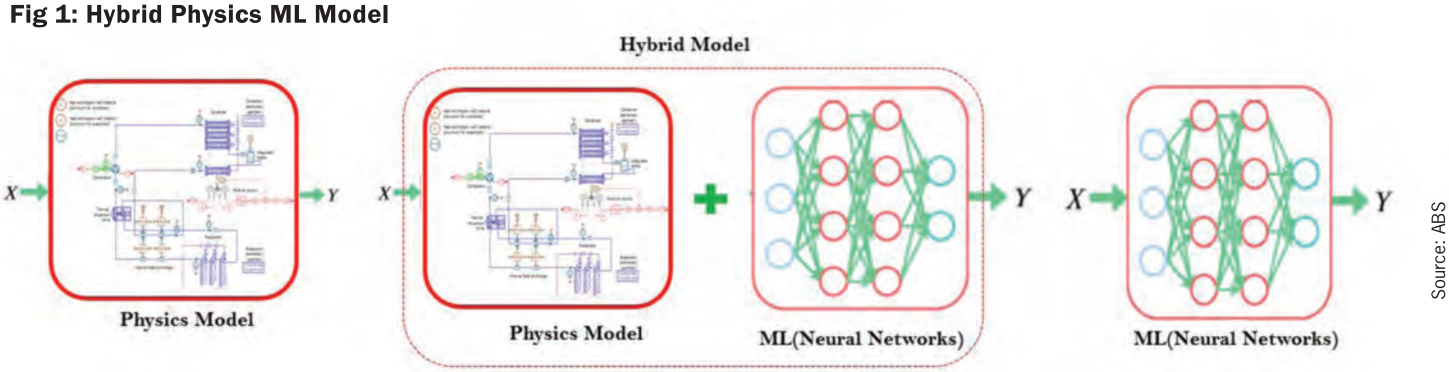
MACHINE LEARNING (ML)

ML is the use and development of computer systems that use algorithms and statistical models to analyze and draw inferences from patterns in data to learn and adapt automatically through experience. It is seen as a subset of artificial intelligence. ML algorithms build a mathematical model based on sample data, known as "training data", in order to make predictions or decisions without being explicitly programmed to do so. ML models search through a sample space of possible mathematical models, utilize methods to discern and adapt between such model choices with data to arrive at final model that best describes the data. This decision is based often times on pre-defined criterion to guide the search process.

CHOOSING THE RIGHT ML MODEL

ML models are beginning to play an important role in advancing discoveries in complex engineering applications that are traditionally dominated by mechanistic models. Selecting the right ML algorithm to accommodate the complexities of a real system that are not completely understood can be challenging. No single ML algorithm fits all scenarios. There are several factors that can affect the selection of a ML algorithm, including the complexity of the problem, type of data (structured, un-structured, texts, time series, images, etc.), and latency requirement for decision making (real-time, or offline analysis). A high volume of real-world data and testing is usually required but the data may not always be available. How-

Fig 1: Hybrid Physics ML Model



ever, the absence of high-quality labelled data may result in inaccurate ML algorithms. In such scenarios, solving complex problems requires novel methodologies that can integrate prior knowledge from physics-based models with ML techniques.

HYBRID PHYSICS ML MODEL

The hybrid modeling approach is a way of combining physics-based models with ML where both can operate simultaneously and can be decoupled in some way to improve the performance separately. See **fig1** on the previous page.

IMPROVING PREDICTIONS BEYOND PHYSICS

First principal physics-based models are extensively used in wide range of engineering applications. However, physics-based models require strict boundaries and assumptions to create an idealized approximation of reality. These approximations can be hindered by incomplete knowledge of certain processes or unaccounted physical phenomena which can introduce additional bias. Often, the input parameters may have to be estimated through observed data.

When provided enough data, ML neural network models have shown to outperform physics-based models where complexity prohibits the explicit programming of the system's exact physical nature. ML models can find structure and patterns in complex problems where physical processes are not fully understood. In resolving and improving the performance of complex engineering systems, physics-based models can be combined with state-of-the-art ML models to leverage their complementary strengths. Such integrated physics-ML models are expected to better capture the dynamics of complex systems and advance the understanding of underlying physical processes.

HYBRID ML MODEL APPROACHES

There are many ways to combine physics-based models with ML models, to train the ML model or to solve complex engineering applications. The three most common hybrid approaches (combining ML with SIM models) are discussed below:

1. *ML after simulation run*
2. *ML prior to simulation*
3. *ML assisted simulation*

ML AFTER THE SIMULATION RUN

The results from the physics-based simulation model can be used as data input for the ML model in a system of approaches. This can be used in advanced ML algorithm training, such as fully autonomous operations. The simulation results incorporate known knowledge and constraints from physics domain (e.g. parameter correlations, decision metrics, importance and weighting on parameters, etc.) into the ML algorithm to constrain the learning space. You train the models not only with real system (Physics Models) but let the ML "drive" through complex solutions.

ML PRIOR TO SIMULATION

ML models can be used to provide parameterization inputs to physics-based models. In a system of systems, ML may be applied on certain systems, but other connected systems may be represented with a physics-based model. Complex physics-based models often use an approach for parameterization to account for missing physics. In parameterization, specific complex dynamical processes are replaced by simple physics approximations whose associated parameter values are estimated from data. The failure to correctly identify parameter values can make the model less robust, and errors that result can also feed into other components of the entire physics-based model and deteriorate the modeling of important physical process. The ML model can be used to learn new parameterizations directly from observations and/or model simulation. A major benefit that can come from using ML based parameterization is the reduction of computation time compared to traditional physics-based simulations.

ML ASSISTED SIMULATION

This architecture explores the best combination of using ML and data emanating from the physics-based simulations. In this approach ML can be integrated into physics-based simulation by connecting the output of the Simulation model

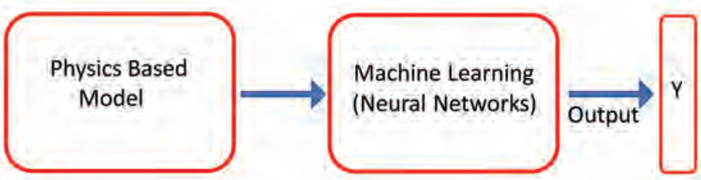


Fig 2: ML after SIM

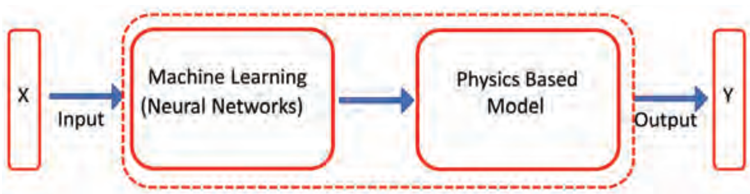


Fig 2: ML Providing parameterization input to SIM

Source: ABS

into particular nodes of the ML or by making the ML model learn aspects of the physics-based system and apply that learning directly. This approach effectively provides data-driven decisions to the entire system of systems.

DATA DRIVEN ML CONTROL FOR DP

Dynamic Positioning (DP) can be one example where the operation of vessel systems can benefit from ML algorithms.

Ships that are involved in safety-critical operations related to drilling, cargo-transfer, subsea crane operations and pipe-laying typically have an extended actuator setup to allow for redundancy in case of system errors. During such operations, the vessel is required to control its position and heading. DP of ships is a control mode that seeks to maintain a specific position (station keeping) or perform low-speed maneuvers.

A data driven control ML approach can be applied to resolve the problem of DP in an over-actuated ship subject to environmental forces. This control approach improved the overall ships performance criteria leaving the human decision to the top of the hierarchical DP control structure.

A hybrid modelling theme as discussed in this paper, that combines the ML data model with the prior knowledge physics-based model can help find solutions and improve the performance.

SIM TOOL TO TRAIN AND TEST ML

Physics based SIM models can help, to train and test the ML algorithms by:

1. *Simulating near real world data*
2. *Testing different ML algorithms*
3. *Testing the quality of the data sources*

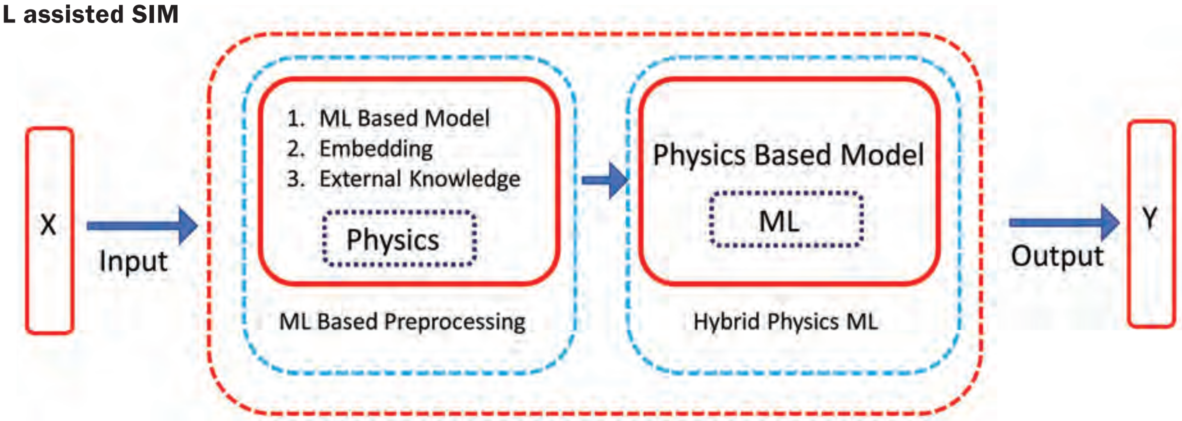
This approach provides full control over the data provided to the ML, both parameters contained within the data and the volume and frequency of the data. The SIM tool neural network module as shown in **fig 5 & fig 6**, can help to train and test the ML algorithm. If output of the ML is not acceptable changes can be made to the algorithm and the ML module can use these changes to upgrade and segment the rules in the ML model. This process continues until a satisfactory output is obtained. The Neural Network Builder in SIM tool creates neural networks from simulation models or external data sets. Neural networks provide a functional and compact representation of input-output relationships which mimics the complex behavior of the underlying model. Creation of a neural network is executed in 3 main steps as shown in **fig 6**:

1. *Import of simulation results from a physics model*
2. *Use results from sim model for training of multi-layer networks*
3. *Validation of trained networks with fidelity metrics and plots*

Once trained, the network can be exported as a submodel or as an ONNX file.

The Marine and Offshore industries are adopting state of the art ML concepts to improve vessel efficiency and performance. This paper describes the combination of ML and physics-based simulation as a hybrid approach fostering intelligent analysis of applications that can benefit from a combination of data-driven and knowledge-based approaches. Choosing the right ML algorithm to accommodate the complexities of a real system is challenging. A high volume of real-world data and testing is usually required in choosing the ML, but the data may not always be available. In this paper ABS describes how SIM tools can be used in solving the problem of real-world data hunt by connecting prior knowledge physics-based models with an ML model. We explain how these sim tools can be used to train the ML, test the ML, and make corrections and retest the ML algorithm under a range of scenarios at a scale not practicable with physical testing. A hybrid model workflow connecting physics-based model to train the multi-layer neural network (one of the most known ML algorithms) is shown as an example. ABS as a Class Society believes simulation will play an important role as the industry adopts ML.

Fig 3: ML assisted SIM



Source: ABS

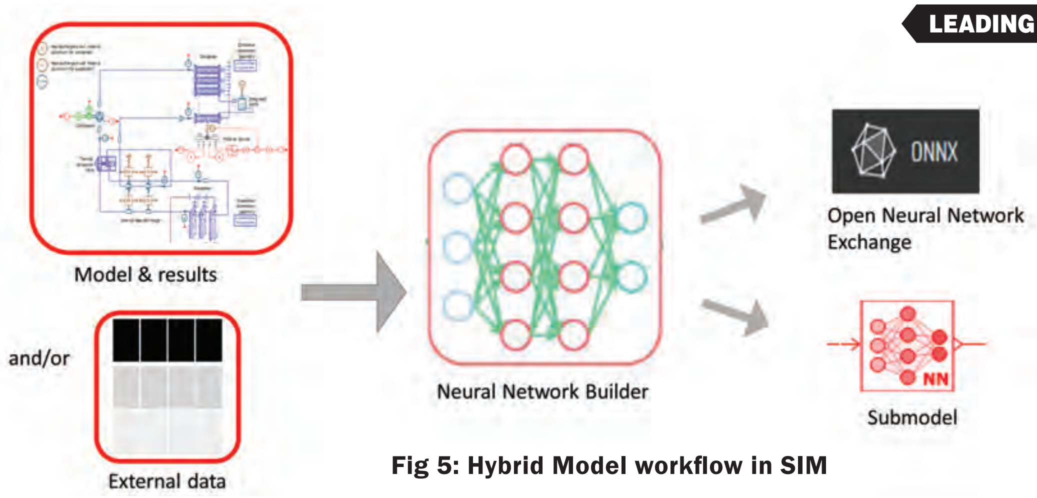


Fig 5: Hybrid Model workflow in SIM

Source: ABS

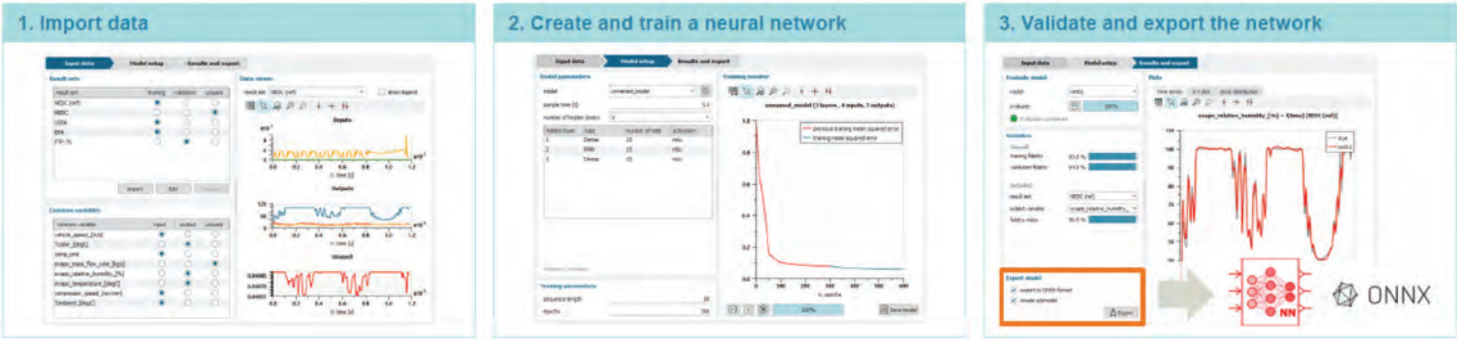


Fig 6: Example of a Neural Network Builder using SIM tool.

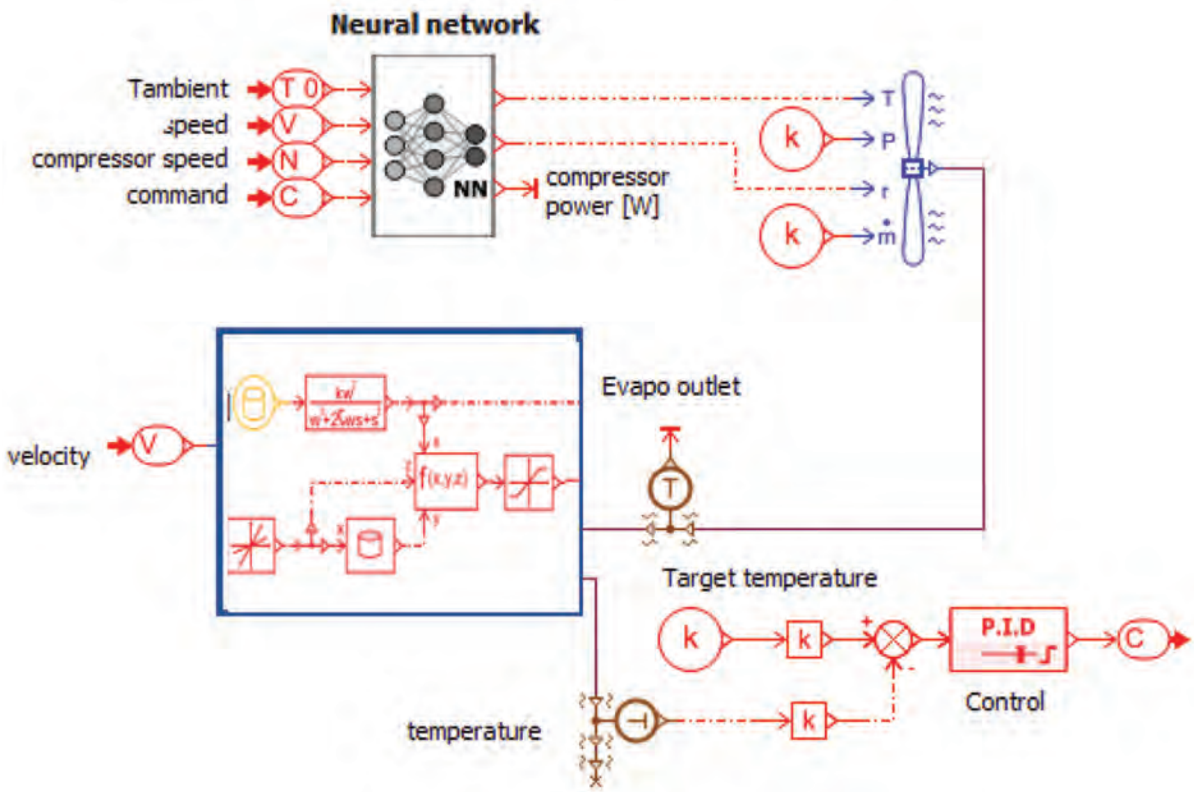


Fig 6: Example of a Neural Network Builder using SIM tool.

Source: ABS

PROFILES IN TRAINING:

KEN CHAPMAN

Senior Instructor Maersk Training

Ken Chapman has led as deep and as broad of a maritime and offshore life as possible, an accrued experience and knowledge including being part of the team that had to coordinated during one of the offshore oil and gas industry's worst disasters ever: the Piper Alpha. Today he reflects with Offshore Engineer on how these experiences helped drive him into a career in training, today as the Senior Instructor, Maersk Training.

By Greg Trauthwein

Ken, to start can you give an overview of your career with insights on your current position?

My working life started in the Merchant Navy (MN) (the U.S. equivalent of the Merchant Marine) working for Bibby Line as a deck cadet in 1975. My father was a Captain in the MN, my uncle a Chief Engineer. This choice of the MN was not popular my father and he advised against it, saying the MN was a thing of the past in the UK. As it happened, he was right to a certain extent. By 1979 I was made redundant due to the downturn of the British Fleet. After trying various jobs onshore, I started work with BP as an oil and gas operator in Sullom Voe Oil Terminal. Island life suited me but not my wife, so a change was called for, and I went back to sea working on Standby Vessels and AHTS vessels.

After a year or so there was a downturn in the N. Sea, and I was forced to make another change. This resulted in work onshore in areas different to MN or shipping, but I believe my experience was well-used onshore and led me to join HM Coastguard, based in Aberdeen MRCC, as a SAR coordinator.

This is probably the period that influenced me the most and my future. I was involved in one of the most significant events in the Oil & Gas industry, as I was part of the team that had to coordinate the Piper Alpha disaster; which was probably the worst night of my life and it changed me in so many ways. *(*The Piper Alpha offshore rig suffered an explosion on the night of July 6, 1988, claiming the lives of 167 crew members).* Although not on the scene, I think the whole team was affected by the events that unfolded that night. Even now, writing about it makes me feel uneasy. However, I have turned negative into a positive and use that training experience in the past and today.

After a few years in HM Coastguard, the industry offshore was picking up, and I was fortunate enough to go back to the industry working on the drilling rigs. Why? Working HM Coastguard was one the most rewarding jobs but was poorly paid. I opted to go offshore, for financial reasons, as a Ballast Control Room Operator in 1990, and for the next 25 years I was fortunate to work for the same employer, albeit in dif-

Source: Maersk Training

ferent forms – which is now Transocean.

With Transocean, I held a variety of posts BCO, Barge Supervisor, Rig Safety Training Coordinator. In 2000, I was appointed as HSE Advisor for the North Sea; this job was to bring me ashore and to be honest, I was ready for it. It also allowed me to join a brilliant training team to develop what some people call my 'baby', the Multi-Purpose Marine Simulator (MPMS), now known as the Operational Training Simulator in Maersk Training.

During my time as an HSE Advisor we started this project to build the simulator, and it involved a team of people from Transocean and a software firm based in Aberdeen called Pisys. Pisys were superb in putting delivering the vision to bring the various aspects of the Marine side of training in the drilling industry into one complex, rather than farming training out to training providers who delivered a generic set of courses. In 2001, after a $1million investment, my 'baby' was born. It was used to deliver Stability courses on Semi Sub Drilling rigs and some basic Jack Up courses, and of course, Major Emergency Management (MEM) courses.

This is where the Piper Alpha's influence really came home to roost, and training became my passion. Over the years, we developed the simulator to include more semi-subs and Jack-Up models, and under Maersk Training, it can also simulate production platforms, a gas terminal, FPSO, and has the facility to provide training in rig moves. The simulator also, I believe, was the first to demonstrate and train personnel in handling Rack Phase Difference on Jack-Up installations. I believe that Transocean and all the companies that came together to make up the group were way ahead of some in their wish to train their own personnel in their training centers, and I was part of that for nearly 15 years.

During that period in the training department, I developed and trained in various subjects from Marine Operations for Jack-Up installations, Stability for MODU's, MEM, Advanced courses for Jack-Up such as Jack-Up lessons Learned and was involved in the introduction of assessing all the companies OIM's and Captains worldwide in the management of major emergencies, this we called the PIC Assessment. And this was all driven by Transocean's aim to be the best drilling contractor in the world, and I was part of that with my personal wish to make my training the best and prevent another incident like the Piper Alpha.

In 2015 Transocean divested itself of its training centers and handed its training over to Maersk Training globally, and I was passed over with the MPMS to the new company. The transition was not the easiest for me or Maersk Training, but in time they learned from us, and we from them, and I am still here and proud of what we do. In Maersk Training, I have also developed and gained accreditation with certain bodies for the courses I deliver. I have developed courses such as the OIM Controlling Emergencies for other companies assessed in Europe as well as the middle east and developed courses like the Assisted Position Mooring Management Course for Premier Oil.

Maersk Training "By the Numbers"

Employees	637
Course days 2019	80,000
Training locations	18
Vendors	500+
Onsite locations	50+

I intended to retire this year, but after discussion with my manager, we decided that I will instead work on reduced hours. A gentle easing into retirement is better than the prospect of me being at home full time - my wife's words, not mine!

I can understand how something as dramatic and traumatic as Piper Alpha would be formative in your passion for training.

As mentioned before, the Piper Alpha was a point in my life that changed me. Then, joining Transocean and being given the opportunity to develop the MPMS simulator confirmed that training was what I needed to do. I knew this from training I gave in HM Coastguard, but now this was a chance to do it full time. I believe it is one of the main reason ways can really prevent incidents; how we train people is a key factor. I also believe that if we can get people to do the actual practical training on simulators, it is one of the best ways of learning. Sitting in class and doing theory work is a vital part of it, but if we can get people to do practical work or exercises, it will always reinforce the theory much better than sitting in a class doing a written exam. Of course, there has to be a balance, but if you ask people if they would prefer eight hours day sitting in class or a balance of theory with practical exercises, I think the majority will go for the latter.

Using the start of your career to today as bookends, can you discuss how 'training' is most the different, and most the same?

The use of computers and simulators, without a doubt, has been the biggest step forward, and I believe the best improvement. There were not many simulators, possibly radar simulators, and a few ship handling simulators in my early days. These usually made of model ships rather than the high-end graphics we see today on modern computer-based simulators. But as I mentioned, there is still a lot of training that needs to

Some of the people who come in for training and assessment may not have been in that position of scrutiny for some time, so I always try to make the candidates comfortable. But this does not mean we make it easier. When it comes down to it, I have a personal baseline: **"Would I trust this person to look after my loved ones on board a vessel or an installation?"**

Source: Maersk Training

Ken Chapman

Senior Instructor, Maersk Training

be done in the class. There is no replacement for theoretical education, but blending theory with practical, real-life simulation is the way forward.

What do you consider to be the greatest challenge to deliver and assess effective training?

Adapting to the differing cultures and attitudes I have had the pleasure of working with and ensuring the candidate is comfortable, especially when it comes to assessments and ensuring they are happy with the environment. Some of the people who come in for training and assessment may not have been in that position of scrutiny for some time, so I always try to make the candidates comfortable. But this does not mean we make it easier. When it comes down to it, I have a personal baseline, "Would I trust this person to look after my loved ones on board a vessel or an installation?" Whether it be a written assessment or visual assessment, my goal is to find them competent from the start. Still, if necessary, I will find people who are not yet competent. I always try to have a plan in place for those who need to re-sit their assessment before leaving my care. Hence, they have an idea when and where they will return and what they need to do to improve their situation. It doesn't always happen, but we try to make the candidate leave with a positive frame of mind.

The offshore industry has been in a prolonged downturn. Can you discuss if and how the downturn impacts your training procedure?

Training in a downturn is not new to me. The oil industry is very cyclic, and yes, this downturn has been the longest and the deepest but you have to recognize that one of the first things companies do during a downturn is to minimize costs, which has usually affected personnel training; nothing required by law is lost. Still, individuals who may be developing their career are sometimes put on hold.

This is where I personally try to step in and help. If I have contact with an individual, I may offer some advice on how they can continue to prepare for courses or assessments to come when the downturn is over. We see signs of improvement already, recruitment is actively picking up, and with the introduction of a vaccine for COVID, I can see our business picking up even more.

In addition, we are using online or virtual training more and more, but again COVID and the downturn has impacted us in numbers. Once we get back to a sense of normalcy, I think online training will stay to a certain extent, but when it comes to us assessing some competencies, I feel we need to have that personal contact.

What long-term changes do you project to training delivery and assessment as a result of the pandemic.

Technology is moving along so fast that the use of video meetings is making the world smaller and bringing us closer to our students in some respects. However, I am old school in some ways as I like to interact with candidates, get to know them and have that personal relationship, however small. But that is me. I am 63, in the twilight of my career, and still learning. The day I stop learning is the day I will retire.

2021 The Year When Offshore Wind Takes Off in the U.S.

As of mid-March 2021, there were at least 30 offshore wind projects in the planning stage representing an $87.5bn CAPEX and $2.8bn annual OPEX opportunity that are forecast to be developed within this decade.

By Philip Lewis IMA/WER

All graphics: WER Database

After several false starts, 2021 is the year when the offshore wind industry begins to realize its potential. At least 30 offshore wind projects are forecast to be developed within this decade. Ports, fabricators, component manufacturers, vessel operators, engineering firms and lenders will benefit from the $87.5B CAPEX, $2.8B annual OPEX, and $12.5B DECEX opportunity.

Despite being the 2nd largest global market for onshore wind, the United States is today a minor player in offshore wind in comparison to the European and Asian offshore wind markets. Two operational projects for a total 42MW of installed capacity were installed in the USA at the end of 2020 versus a global offshore installed base of 34GW.

2021 will deliver a step change in offshore wind activity in the US as the journey accelerates to develop the 27.6GW project pipeline within this decade.

These are the findings shared in a recent report on the US offshore wind market in this decade by World Energy Reports (WER).

The 170+ page report examines the business conditions likely to drive offshore wind project development in the US within this decade, forecasts the number, CAPEX, OPEX and timing of projects, and provides a roadmap to accessing these market opportunities.

OFFSHORE WIND OVERVIEW

From the first eleven 450kW WTG 5MW Vindeby Windfarm, commissioned in 1991 in Denmark, offshore wind has grown to reach 34GW cumulative installed capacity by the end of 2020 provided by 18 countries.

Summary Forecast for US Offshore Wind Projects

Summary Forecast ($bn)	GW	CAPEX	Annual OPEX	DECEX
Short-term projects	9.0	28.9	0.9	4.0
Mid-term projects	10.3	32.5	1.1	4.8
Longer-term projects	8.3	26.1	0.8	3.6
Total	27.6	87.5	2.8	12.5

Europe has played the leading role to date, accounting for 73% of capacity and a significant industrial base for wind farm component manufacture and logistics capabilities.

China has recorded a surge in capacity since 2015 to reach 23% of global capacity by the end of 2020.

The largest three markets at the end of 2020, the UK, China, and Germany, accounted for ~78% of global installations.

Whereas the European, Chinese, Taiwanese, and Vietnamese markets will continue to remain strong throughout the decade, we expect to welcome South Korea, Japan, and the USA to the stage of global scale players within this decade.

In the mid- to long-term, we are tracking offshore wind projects in 38 countries.

As the industry matures in key markets, CAPEX and OPEX costs are falling making offshore wind more competitive.

Reducing from a global average $170/MWh in 2010, 2016 to 2018, European and US auctions have seen strike prices in the $60/MWh to $110/MWh range. The strike price represents the all-in-cost per MWh to develop an offshore wind project. It reflects the guaranteed revenue for the operator.

US wind projects will enjoy some of the costs benefits achieved from the growth of the European offshore wind industry. The utility scale projects due to come online over the coming five or so years in the United States will generate revenue in a range of $70/MWh to $137MWh. These pricing levels have been reached much earlier than has been seen in the European and Taiwanese industry.

One of the drivers for offshore wind cost reduction is the development of larger turbines, which help to reduce overall foundation, cable, and maintenance costs. Projects in the US will mostly deploy the largest commercially available turbines.

OFFSHORE WIND IN THE UNITED STATES

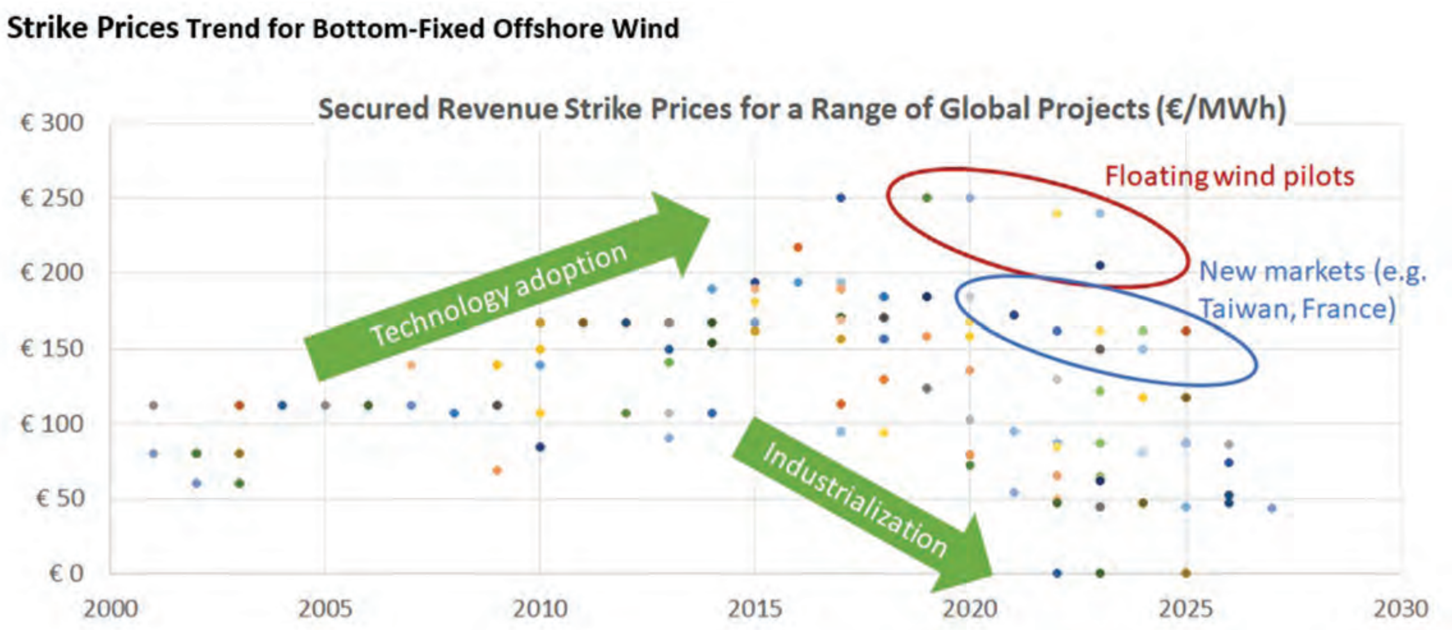
The current US nameplate power generation capacity is ~1,200GW. The US DOE's NREL has quantified the offshore wind net commercially feasible resource at 2,060GW. This is almost two times today's total electricity generation capacity. Wind resource is available in 29 states along the Atlantic, Pacific, Gulf of Mexico, and Great Lakes coasts.

This decade will see utility scale projects in the relatively shallow and near shore waters of the northeast and mid-Atlantic. These projects will mainly adopt the bottom-fixed solutions found in the established European and East Asian markets.

We are also forecasting the demonstration of offshore wind technology in the Great Lakes and two floating wind pilots in the Atlantic within the decade.

THE MAIN PLAYERS

The federal government promotes and regulates offshore wind in the US. Around 90% of the identified commercially feasible offshore wind potential is in federal waters. One offshore wind project, the Coastal Virginia pilot, is operational in federal waters. The main federal agency, BOEM, is reviewing construction and operations permits for 11 projects for



9GW. The approval of the first of these projects, Vineyard, has been significantly delayed due to the extended environmental impact assessment review process. However, it is expected that Vineyard will receive construction and operations approval within the first half of this year. This in turn will unblock the queue of project seeking review and approval. A further 9 projects for 10.3GW are preparing their applications for construction and operations approval and another 8 projects for 8.3GW are assessing and surveying the sites to establish construction and operations plans. It is the states who drive demand through policies targeting renewable energy procurement. 30.5GW of specific offshore wind procurement targets have been announced and close to an additional 1.4GW of procurement commitments have been made. A group of 16 developers will deliver the project forecast. This group include leading European developers, renewable energy asset investment companies, US utilities and European oil & gas companies.

A 27.6MW PROJECT FORECAST

As of March 2021, there are 11 projects for 9GW in the federal construction and operations review queue. These should be the first projects to receive approval and move to the construction phase in the short-term. We are forecasting most of this capacity to come on stream between 2023 and 2027.

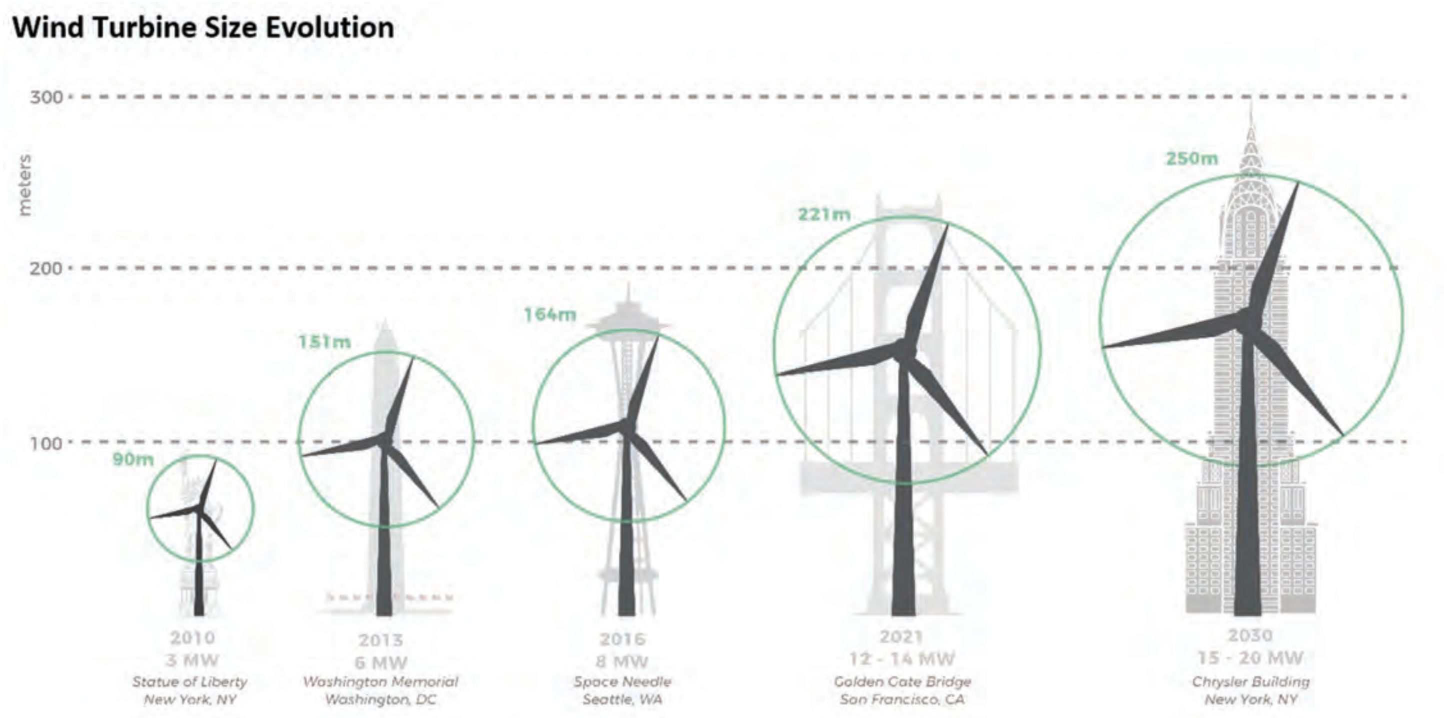
The mid-term forecast represents those projects that are undertaking site assessment work and are expected to start submitting construction and operations plans for review and approval within this year. Developer planning indicates commissioning of these projects between 2025 and 2030. Given the current federal permitting review delays, we anticipate some movement on these commissioning dates.

The longer-term forecast brings together projects on secured federal leases that are at earlier stages of site assessment. These all need to be commissioned before 2035 to meet state procurement targets.

It should be noted that the current identified projects will not deliver enough capacity to meet northeast and Mid-Atlantic state procurement targets by 2035. More project capacity will be identified from existing federal leases and from new Atlantic leasing activity, expected to be rolled at the end of this year or early next year.

A $87.5BN CAPEX AND ANNUAL $2.8BN OPPORTUNITY

Our bottom-up forecast model breaks the $87.5bn of CAPEX into component spend. We are forecasting close to $60bn to be spent on material supply, manufacturing and/



or fabrication of turbines, cables, foundation structures and other equipment.

We anticipate around $25bn will be spent on installation and commissioning activities. The Jones Act supports US built, owned, and operated vessels. This means that foreign flag installation vessels will not be able to shuttle components from US ports to the construction site, as is the practice in the developed European and East Asian markets. There is limited Jones Act compliant turbine, foundation, and cable installation capacity. This can lead to project delays or increased costs as developers compete for scarce foreign flag tonnage and comparatively high-priced Jones Act new buildings or select less efficient/cost competitive combinations of foreign flag installation vessels and domestic feeder vessels.

There will be a significant investment in US port infrastructure because of offshore wind developments. Around 50 ports along the northeast and Mid-Atlantic coast have been identified as potential candidates to support construction and marshalling activities. Over $1bn of investment commitments have already been identified. As with offshore oil and gas projects, a significant amount of lifetime project cost in an offshore windfarm is represented by routine planned operations and maintenance. For an offshore windfarm this is typically 40-45% of the lifetime cost. Our forecast identifies around $2.8bn of annual recuring OPEX once the identified projects are commissioned.

Wind farm operators will set routine inspection and maintenance schedules, chartering in long-term vessel support for the activities. The tonnage will be mostly Jones Act Vessels. Certain vessel categories can be modified/redeployed for the existing Jones Act fleet. Other requirements call for new buildings.

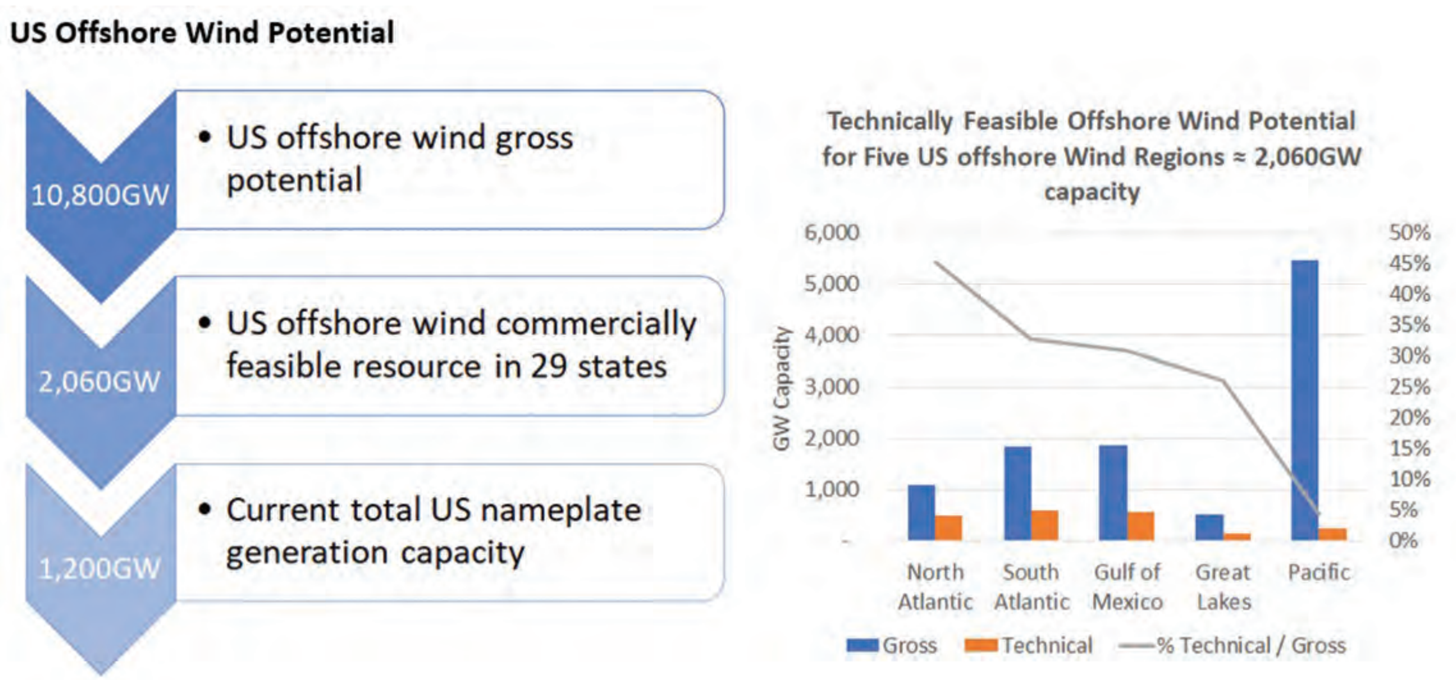
OFFSHORE WIND GOING FORWARD

States are continuing to discuss with federal agencies the development of future offshore wind activity.

In the coming years, we expect to see new federal leasing activity in the Atlantic and Pacific. We also anticipate further investigation by states of the potential in the Great Lakes.

Competitive floating wind solutions are certainly required to open the potential off the continental and Hawaiian Pacific coasts. But many are often surprised to learn that the first floating projects in the US will be in the Atlantic. In terms of technology development, our project forecast already includes two floating offshore wind demonstration projects to be commissioned off the Atlantic Coast. Details off all the projects in the forecast are provided in our report found here:

https://usoffshorewind.worldenergyreports.com/OffshoreWindPowerUS



A TROLL WITH A KINDER

The Troll A platform, offshore Norway.

Source: Øyvind Gravås and Espen Rønnevik, from Equinor

SURPRISE

Equinor's Troll Phase 3 project has been described as a real Kinder surprise. It's Equinor's most profitable project ever and comes with a minimum CO2 intensity for an offshore project. ***Elaine Maslin takes a look.***

Later this year, Norway's Equinor is due to bring on stream its "most profitable project ever". With a breakeven of less than $10/barrel, it's indeed a low-cost project. It's also got a low carbon footprint; the project is set to deliver about 2.2 billion barrels of oil equivalent with a CO2 intensity of 0.1 kilo per barrel.

The project is Troll Phase 3, which will produce the gas cap over the Troll West oil column, in about 330 m water depth, 80 km off Bergen in the Norwegian North Sea. The NOK 7.8 billion (US$900 million) Troll Phase 3 project will extend the plateau production for gas from Troll for about seven years and the expected productive life by about 17 years. The development includes two subsea templates, eight new big bore production wells, a 36-inch pipeline back to the Troll A platform and a new processing module on Troll A.

Rune Mode Ramberg, subsea, umbilicals, risers and flowlines (SURF) manager on the project told the Underwater Technology Conference (UTC) late last year about the project. "Troll Phase 3 is a really good kinder surprise," says Ramberg, who is now SURF manager on Equinor's Northern Lights carbon capture and storage (CCS) project. "The amount of energy we are able to deliver is huge. It's more than the amount of energy we have delivered from Phase 1 of Johan Sverdrup." But, critically, he says, it's also doing it with a low carbon footprint, thanks to Troll A having been powered from shore from day one. "Troll A has been producing oil and gas since 1996, without any burning of gas offshore," he says, "it's been powered from shore the full time." In addition burning natural gas compared to coal generates 50% less CO_2, says Ramberg.

"This is also a really good example of how subsea tieback projects can be really economic, with only minor topside modification, we have been able to use the installed capacity using the subsea technology to get all the gas back to Troll A. This is a really good example how profitable subsea solutions/ tie-backs can be in our projects." The project has also benefitted from forward thinking by Shell, as the development operator for Troll A, resulting in pre-installed critical equipment now being utilized by the Troll Phase 3 project.Troll – a big project from day one.

Despite the low break-even price and carbon intensity, it's still a big project. Everything about Troll is big. It contains some 40% of the total gas reserves on the Norwegian continental shelf (NCS). It's also one of the largest oil fields on the NCS, producing 400,000 barrels per day at its peak in 2002. The Troll A gas platform, standing on a massive concrete support structure, is the tallest structure ever moved by humans over the surface of the earth, according to the Guinness Book of Records.

But it could have been bigger. A lot of thought also went into the design of Troll A. Processing was moved from offshore to Kollsnes, onshore, so that the facilities could be smaller. Troll A was also built to be powered from shore with Norway's green hydropower electricity – and it remains so. Thought also went into the future phases of Troll – including having pipe bends ready to be used to tie in new subsea pipelines; they were stored from day one, ready and waiting at the bottom of the massive concrete riser shafts the facility stands on.

"Back in the 1990s, they were really ahead of their time," says Line Hoff Nilsen, Troll A platform manager. "They planned for connecting more pipelines to the platform; a

The H-Frame used to install the 36in spool.

Source: Equinor

fantastic example of forward thinking. At the bottom of the riser shaft there are several pipe bends waiting for this day. It would not have been possible to put them in place today, as there is no access now."

Contracts and operations

Troll Phase 3 was approved in 2018. It will see the gas cap on Troll west finally developed. It had been deliberately held back to balance and stabilize the oil column, so that oil recovery at Troll West Could be maximized.

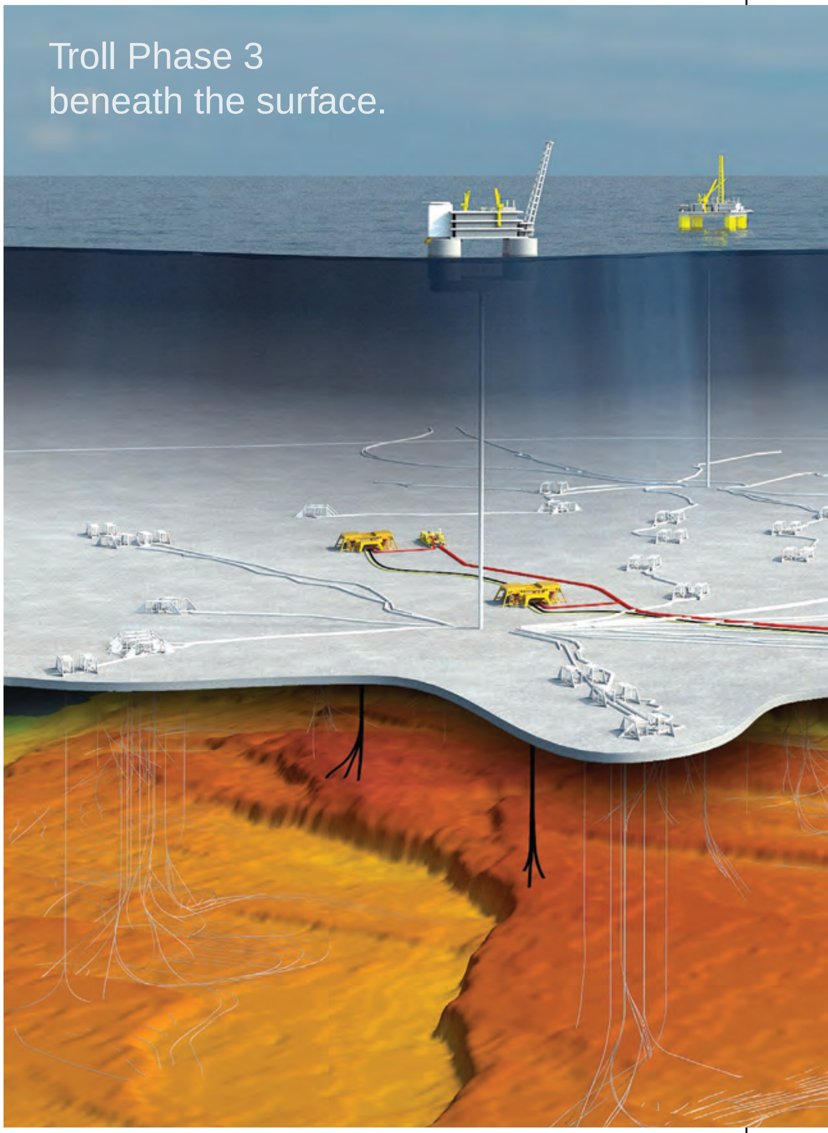
Aker Solutions was awarded the contract for the subsea production systems, Nexans was contracted for 27km of umbilicals with power, fiber optic and hydraulic cores, as well as a MEG services line for chemical injection. DeepOcean was contracted for marine operations, including installing the two integrated template structures (ITS – into which the Xmas trees are installed) with manifolds, two pipeline foundation structures (with 11m-deep legs for installation in soft soil), pipeline end manifolds (PLEMS) and spools, as well as laying the MEG line and umbilical lines, tie-ins and commissioning. Allseas was contracted for the 26km pipe lay and IKM got a pipeline detailed design award. The linepipe for the 36 inch pipeline was delivered by Marubeni.

Aker Solutions was also awarded a contract for engineering, procurement, construction and installation contract of a new 1200-tonne processing module on Troll A following Aker Solutions' front-end engineering and design work. The process module was built at Aker Solutions yard in Egersund, Norway.

The eight new wells were drilled during 2019-2020, using the semisubmersible drilling rigs COSL Promoter and Transocean Equinox in order to produce the 347 billion cubic meters of gas. The new NOK 1 billion, 40m-long, 10m-wide process module (designed to slot into a space on Troll A) was installed in August 2020; six months delayed due to lowering staffing levels because of the Coronavirus pandemic.

The world's largest pipelaying vessel, Solitaire, was used to lay the 26 km of new large bore 36-inch pipeline between Troll A and the Troll Phase 3 well sites. Some 400 people worked on the vessel, 24/7, welding and laying pipe, with eight pipeline supply vessels constantly providing new sections of pipe

Source: Equinor



to continue the operations, notes Steinar Helle, Troll Phase 3 construction and commissioning manager.

A large bore subsea production system was used to take the gas from the reservoir through to the production facilities to help minimize the pressure loss, so the existing power at Troll A didn't need to be increased, notes Ramberg.

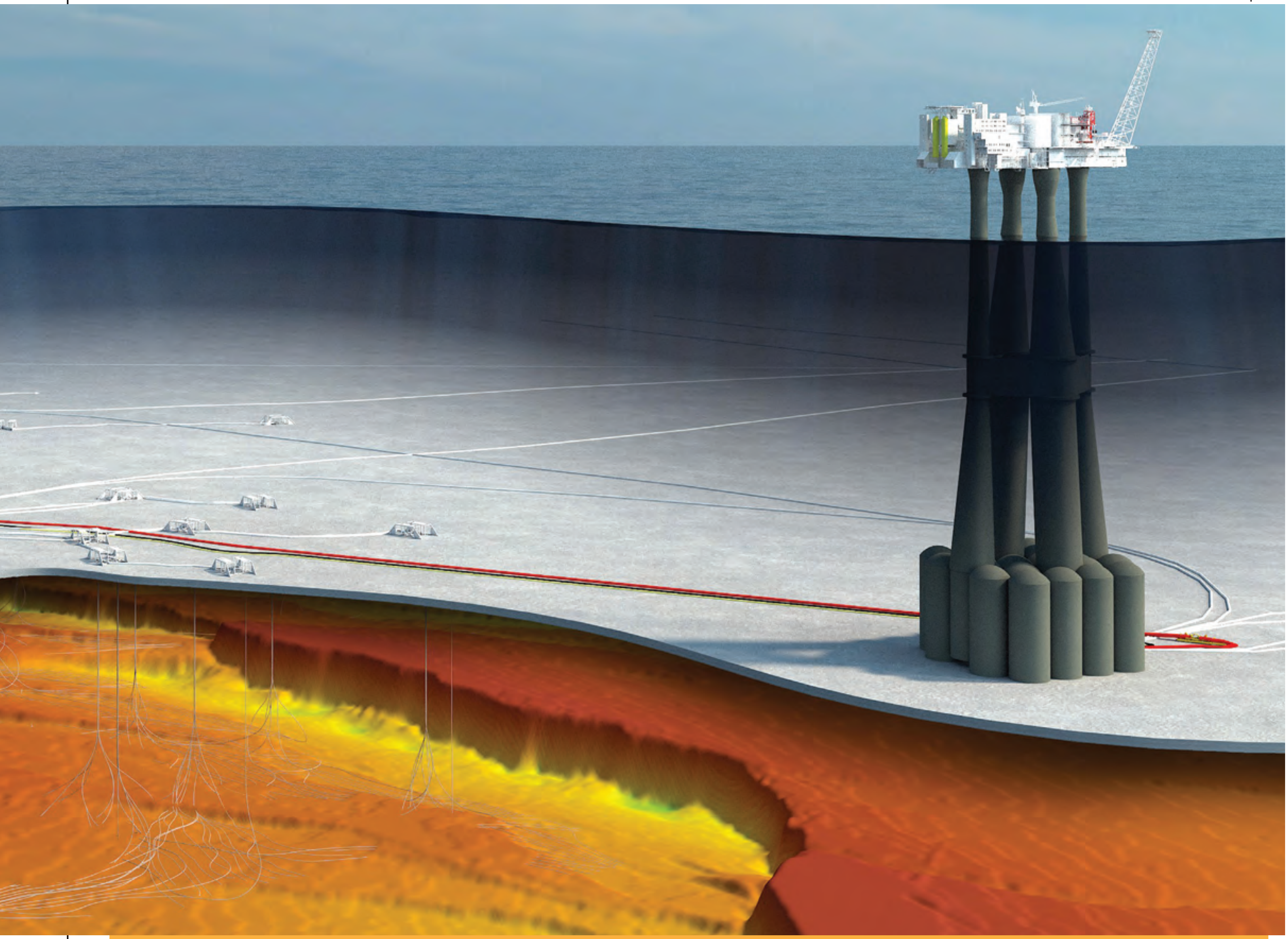
A 400m section was laid and pulled into Troll A through a pre-installed conduit using a 900mm wire fed up to a winch on the platform deck. The pipe was then connected to pre-installed risers using the pipe bends already available at the bottom of the riser shaft. Once the rest of the pipeline was installed it was then connected to the 400 m section via a 90m-long, 36-inch diameter spool piece with 100-tonne dry weight.

According to DeepOcean the 36in spool and the 20in spool installed at the well site end of the 36inch pipeline, were some of the largest spools it has ever manufactured and installed. "It was a world record being able to connect these two pipelines. DeepOcean had to use both the Edda Freya's vessel cranes simultaneously (for lifting and lowering this spool piece)," says Ramberg.

The spools were installed using a subsea H-frame lifting tool in to align the two pipelines – tools, including a pig launcher and receiver, which had been used at Aasta Hansteen some years ago. The umbilical and MEG line were piggy backed together and pulled through a J-tube installed at Troll A.

In total, the project clocked up about 650 vessel days, says Ramberg. "It was a huge program, but a lot of pipe and steel went into the ocean," he adds. "Troll Phase 3 is a genuine kinder egg, providing a huge amount of energy with a very small CO_2 footprint and it's shown the subsea tieback is very profitable. Subsea technology is a part of the solution."

Source: Equinor



“Troll Phase 3 is a pretty unique project, and unlikely to be repeated. It’s also not a huge surprise if it rates as Equinor’s most profitable ever,” says Robert Morris, principal analyst, upstream, at Wood Mackenzie. “Using our Lens Upstream platform, we estimate the project will generate an IRR in excess of 60%, under our current pricing assumptions. That is the highest of any major upstream project to be sanctioned back in 2018. Costs and prices have obviously changed since then, but among all projects in Wood Mackenzie’s pre-final investment decision (FID) upstream project tracker (which benchmarks all major pre-FID projects globally), it would also rank well above average for subsea tiebacks of the future [i.e. those in the project pipeline but not yet sanctioned].

“Troll Phase 3’s extremely attractive economics are more a sign of a high-quality project than a function of low subsea costs. For context, it is a gas blowdown project: after years of injecting produced gas to support oil production, this new phase will result in gas finally being produced and sold. In cost and scope, very little new investment has been required to access huge reserves. You could think of it as similar to a 50 million barrel subsea tieback in the North Sea, except that the reserves base is more than 2 billion boe. So the unit development cost is incredibly low, at just US$0.40/boe.”

A LEADING LIGHT SUBSEA

By Elaine Maslin

There are not many of the leading edge subsea processing projects Rune Mode Ramberg has not been involved in at some level.

The list includes Tyrihans subsea pumping, Tordis subsea separation, studies on the Ormen Lange subsea compression project, Jack St. Malo boosting, Åsgard subsea compression, Troll Phase 3 and now the subsea scope on the Northern Lights carbon capture and storage (CCS) project. In terms of subsea technology, there's not much in this space that doesn't come across his desk.

But despite the advances he's seen in subsea processing, he says more needs to be done to help the industry - as a whole - learn about what has been achieved and what the possibilities are in this space.

"What's needed is to spread the knowledge that we have a lot of operating hours and experience," he says. "There are still people in oil companies that are making decisions, thinking that subsea pumping is immature." The experience and learnings to date will also help drive costs down. For example, while Åsgard subsea compression cost a lot, so much more is now known and understood that future projects can - and will - be much simpler and cheaper, he says.

Ramberg studied at the Norwegian University of Science and Technology (NTNU), in Trondheim. His interest then was in rotary dynamics. He worked on areas that were not mainstream at the time, such as the dynamic behaviour of multiphase pumps, and went on to do a PhD on multiphase pumps, supported by a scholarship from Statoil (now Equinor).

In 1997, he started work at Statoil, on rotating equipment. After working on the Norne FPSO commissioning and start-up, focusing on the turbines and compressors, he was soon back on multiphase pumping, initially topsides, on Gullfaks, but then also qualifying subsea pumps for Tyrhans and then as Statoil's man on Shell's Ormen Lange subsea compression project.

Ramberg then had a secondment at Chevron, working in Houston on subsea pumping on the Jack St. Malo development. He stayed on in Houston as technology manager for Statoil, working on the Paleogene in the US Gulf of Mexico, before moving back to Norway, as Statoil's chief engineer, subsea, in time to see through Åsgard.

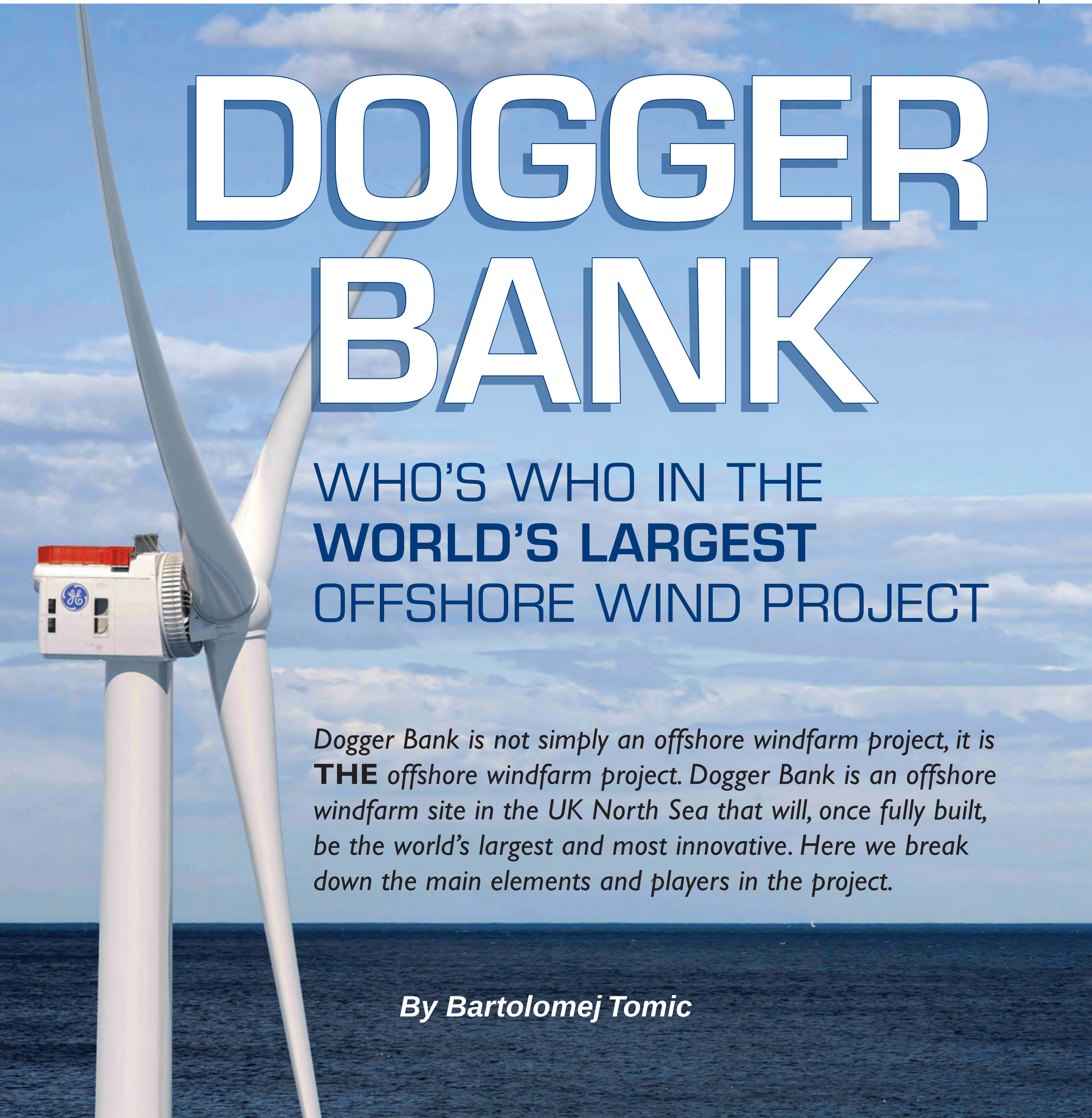
While Ramberg has been involved at the front end of subsea technology development, technology shouldn't be for technology sake, he says. "We need technology for a business case not technology for technology sake," he says. "To be cost effective going forward, we need to solve the problem, use the right tools. Sometimes technology is the right tool."

It's also time to start simplifying some of the systems that have been introduced. "We can see now that multiphase pumping is mature, there's a lot of experience gained, we know the stuff now," he says. "Now it's about simplification."

For Åsgard, for example, the system was qualified, but Statoil still invested in spares. There was a business case, at the time. "But costs can now come down dramatically, because we know so much more," he says. Furthermore, Åsgard has a big cooler and a big separator. "I'm not sure we need those on the next project," he says. "That's huge simplification. There're a lot of things to learn."

On future projects, power distribution could also be simplified. "On Åsgard, there are four power cables, one for each pump. In deep water, you would want one big cable and then distribute the power on the seafloor. That will come," says Ramberg. "I really believe in the electrification of the seafloor in the bigger picture of digitalization."

"All-electric is an excellent example of what Equinor Statoil is trying to do to go further," Ramberg adds, "reducing our carbon footprint, improving safety, getting electric signals in to the well and being able to have an IP address on the valve offers a huge difference in accuracy. We can then hold back water down there with inflow valves. If you don't produce water, you don't need pipelines for producing the water. There's a huge set of consequences. It's not tomorrow, but it's not far away," he says.



DOGGER BANK

WHO'S WHO IN THE **WORLD'S LARGEST** OFFSHORE WIND PROJECT

Dogger Bank is not simply an offshore windfarm project, it is **THE** *offshore windfarm project. Dogger Bank is an offshore windfarm site in the UK North Sea that will, once fully built, be the world's largest and most innovative. Here we break down the main elements and players in the project.*

By Bartolomej Tomic

Source: GE Renewable Energy

Located 130km off the Yorkshire Coast, the 3.6 GW offshore wind project will consist of three phases – each at 1.2GW, and will cover an area of 1675 km2, larger than Greater London.

The three phases were previously known as Creyke Beck A, Creyke Beck B and Teesside A.

In February 2020, the UK-based SSE and Norway's Equinor, which at the time owned the project at 50 percent stake each, decided to change the respective names to Dogger Bank A, B, and C, to recognize the wind-farm-site-to-be's connection to the ancient area Doggerland, which once connected the UK with the mainland Europe, and which was home to a Mesolithic community who lived around 12,000 years ago.

"The area was made up of hills, marshland, wooded valleys and swampy lagoons and was home to hunter-gathers. The end of the last ice age brought flooding to the area, followed by a catastrophic release of water from a glacier, removing what was left of this land. From this ancient area today remains Dogger Bank, a large sandbank in a shallow area of the North Sea between 125km and 290km off the North East coast of England," SSE and Equinor said early in 2020, announcing the name change.

Source: Doggerbank.com

THE UK'S RENEWABLE ENERGY AMBITIONS

The project is seen as a centerpiece of the UK government ambitious goal to reach 40GW of installed offshore wind capacity by and have every home in the UK powered by offshore wind by 2030. The three phases of the Dogger Bank Wind Farm, will deliver enough power for six million UK homes.

The Dogger Bank offshore wind development last year secured financing for the first two phases, which involved support from no less than 29 banks and three export credit agencies in what was dubbed the world largest offshore wind project financing, with $7.5 billion secured.

"Reaching financial close on the two first phases of Dogger Bank is a major milestone, demonstrating our commitment to profitable growth within offshore wind. The extensive interest from lenders underpins the attractiveness of UK offshore wind assets and confidence in SSE and Equinor. As the wind farm's future operator, we are proud to take this big step forward in delivering what will be the backbone of a growing wind hub in the North Sea," Pål Eitrheim, Equinor's executive vice president of New Energy Solutions, said at the time.

The financial close for Dogger Bank C is expected in late 2021.

The Dogger Bank project, for which The Crown Estate awarded development rights for fifty years in 2010, was granted consent as a Nationally Significant Infrastructure Project in 2015. A few years later, in 2019, the Dogger Bank then successfully secured 15-year contracts (CfDs) for 3.6GW of new offshore wind energy in the UK Government's auction for low carbon power in 2019. The strike price will be paid for every MWh generated by the wind farms during the contract.

The CfD terms, as shared by SSE are below:

- Dogger Bank A (1,200MW) with a strike price of £39.65/MWh (in 2012 prices, CPI-indexed) for delivery in 2023/24.
- Dogger Bank B and C (1,200MW each) with strike prices of £41.61/MWh (in 2012 prices, CPI-indexed) for delivery in 2024/25.

After the CfD contract ends, the projects will receive the market price for electricity. Each phase of the project is expected to generate around 6TWh of electricity annually.

SSE and Equinor in 2020 then sanctioned the development of the first two phases, awarding major contracts and subsequently welcoming a new partner, Italy's Eni, into the Dogger Bank A and B, where SSE now owns 40, Equinor owns 40 and Eni has 20 percent, for which it paid $750 million.

"For Eni, entering the offshore wind market in Northern Europe is a great opportunity to gain further skills in the sector thanks to the collaboration with two of the industry's leading companies, and to make a substantial contribution to the 2025 target of 5 GW of installed capacity from renewables, an intermediate step towards the more ambitious target of zero net direct and indirect greenhouse gas emissions in Europe by 2050," said Claudio Descalzi, Chief Executive Officer of Eni.

The third phase is still owned 50:50 by Equinor and SSE. SSE is lead operator for the development and construction phases of the Dogger Bank wind farm.

Source: GE Renewable Energy

HALIADE-X 13 MW FIGURES, as shared by GE Renewable Energy

- 13 MW capacity
- 220-meter rotor
- 248 meters high
- 107-meter long blades
- 38,000 m2 swept area
- One Haliade-X 13 MW can save up to 52,000 metric tons of CO2, which is the equivalent of the emissions generated by 11,000 vehicles in one year.
- One GE Haliade-X 13 MW spin could power a UK household for more than two days.

SIZE MATTERS

Apart from being the world's largest wind farm, securing world largest offshore wind project financing, being located in the world's largest offshore wind market – the UK, the Dogger Bank will feature GE's GE Haliade-X wind turbine, which will, once installed be the world's largest and most powerful wind turbines in operation.

For the first two phases, GE will deliver 190 Haliade-X 13MW offshore wind turbines, split evenly at 95 turbines for each of the two phases. These will be an enhanced version of GE's 12MW prototype unit which has been generating power in Rotterdam since November 2019.

The installation of these turbines will be the first time ever a 13MW Haliade-X is installed in the world. "One spin of the Haliade-X 13MW can generate enough electricity to power a UK household for more than two days," Equinor said in September 2020. For some color on where the offshore wind industry was starting off – bear in mind the 13MW capacity of a single Haliade-X turbine - the world's first offshore wind farm Vindeby in Denmark had a total capacity of 5MW, coming from eleven turbines.

Back to the Haliade-X giants. While having these goliaths installed for the first time is/will be a feat worth boasting about, the world's largest turbines are not there just for bragging rights.

Rystad Energy last year published an analysis that showed that the largest offshore wind turbines, while more expensive, reduce the overall cost of large-scale offshore wind farm development.

For the Dogger Bank Phase C, which has yet to be sanctioned, GE has also been selected as a preferred supplier, too. This phase, while expected to be 1.2 GW, the same as the first two, will have fewer wind turbine installed. Namely, GE will deliver an "uprated" version of the Haliade-X turbine type, with 14 MW capacity.

"Utilizing 14 MW turbines instead of 10 MW ones, the number of units required for a 1 GW project falls by 28 units, from 100 to 72. Moving to a 14 MW turbine from a 12 MW turbine still offers a reduction of nearly 11 units. Overall, the analysis shows that using the largest turbines for a new 1 GW wind farm offers cost savings of nearly $100 million versus installing the currently available 10 MW turbines," Rystad found.

GE Renewable Energy will establish its marshaling harbor activities at Able Seaton Port in Hartlepool, serving as the base for turbine service equipment, installation, and commissioning activities for Dogger Bank A and B.

The port will see the delivery of component parts for each of GE's Haliade-X 13MW wind, including the nacelle, three tower sections, and three 107m long blades, for pre-assembly on-site at Able Seaton prior to transport out to the North Sea for installation.

"This activity will lead to the creation of 120 skilled jobs at the port during construction," Equinor said in September 2020, announcing the contract with GE.

GE also has a five-year service & warranty agreement to provide operational support for the wind turbines. GE's Service team will be co-located with the Dogger Bank Operational and Maintenance team, based out of the Port of Tyne.

What is more, GE in March 2021, said its subsidiary LM Wind would open a new wind turbine blade manufacturing facility in Teesside in the North East of England, dedicated to the production of its 107-meter- long offshore wind turbine blades, a key component of GE's Haliade-X wind turbines.

GE Renewable Energy estimates that this new plant, set to open and start production in 2023, could create up to 750 direct renewable energy jobs and up to 1,500 indirect jobs in the area.

Dogger Bank Wind Farm Project Director, Steve Wilson, said the Dogger Bank Wind Farm was the anchor project for the blade facility announcement by GE.

"Dogger Bank Wind Farm is a world-leading development pushing the boundaries of offshore wind development and playing a key role in delivering the ambition to increase UK supply chain capacity and capability. Through our turbine supply order with GE, the Dogger Bank project is the catalyst for this important GE investment in Teesside, harnessing skills and expertise in the local area and delivering long-term benefits in the UK's offshore wind sector," Wilson said.

It is expected that a substantial number of Haliade-X blades for Dogger Bank Wind Farm will be among the first orders to

Source: Teesworks

be delivered from the new manufacturing plant. Blades produced at Teesworks will be installed from 2024 onwards with the final number of blades from the plant destined for Dogger Bank to be confirmed in due course.

The importance of Dogger Bank goes beyond just the ports and wind turbines. The project is important for offshore services suppliers, vessel owners, and shipyards in Asia, too, as the giant wind farm with its giant turbines requires giant vessels to build it.

This is a good opportunity to remember Chief Brody, from the 1975 movie Jaws, who, upon seeing a giant shark behind the Orca vessel, said: *"You're gonna need a bigger boat."*

VOLTAIRE – THE BIGGEST "BOAT"

Luxembourg-based offshore installation contractor Jan De Nul Group (JDN) in April 2019 ordered the largest jack-up installation vessel ever seen in the industry, on the back of the forecast that the available jack-up fleet wouldn't be able to handle the behemoth wind turbines of the – not so distant-future. It named it Voltaire, after the French writer, historian and philosopher.

The four-legged Voltaire, equipped with a DP2 system, is designed to transport, lift and install offshore wind turbines, transition pieces and foundations.

"For many current installation vessels involved in the construction of offshore wind farms, next generation turbines present new challenges due to growing sizes and installation heights, as well as ever-increasing foundation dimensions. These new larger turbines can be more than 270 meters high and are fitted with blades of 120 meters long.

"With a crane capacity of over 3,000 metric tons, an operating depth of approximately 80 meters and a payload of about 14,000 metric tons, Voltaire is specifically designed to help handle these challenges, JDN said at the time," announcing the order for the vessel which will be taller than the Eiffel tower.

For the Voltaire, the Dutch firm Huisman has been selected to design, construct and deliver "the biggest leg encircling crane ever installed on a wind turbine installation vessel."

When the Voltaire has its legs fully extended and the crane at full height, it will measure 325 meters tall – ***taller than the Eiffel Tower.***

Source: Jan De Nul

Source: Jan De Nul

Following the vessel order, Jan De Nul didn't have to wait long to secure the first contract. In October 2019, it was announced that the Voltaire would debut on, you guessed it, the Dogger Bank, with the firm contract signed in August 2020 for the Voltaire to transport and install the GE Haliade-X offshore wind turbines at Dogger Bank A and Dogger Bank B, with the work kicking off in 2023.

Interestingly, the vessel was ordered in April 2019, but the keel laying ceremony for the 169.3 meters long jack-up was held in China almost two years later, late in March 2021.

Offshore Engineer reached out to Jan De Nul for an explanation.

"Let's say that COVID-19 has been a true challenge the past year. A challenge which we manage. In any case, the project is currently on schedule," Heleen Schellinck, a Jan De Nul spokesperson said. "On schedule" means that the vessel is

still expected to be delivered in 2022, ahead its 2023 debut at the Dogger Bank. The vessel will install the wind turbines on monopile foundations, to be built by a joint venture between the Sif Group and Smulders.

Sif will be responsible for the fabrication and supply of 190 monopiles and primary steel for the transition pieces, as well as for the marshalling of all foundation components. Smulders will be responsible for the supply, fabrication and fit-out of the secondary steel for the transition pieces.

ALFA LIFT

Enter Offshore Heavy Transport. The Norwegian company specializes in, as its name suggests, offshore heavy transport. However, apart from just transport, the company will soon dive into the offshore installation work too, and will be responsible for the installation of the foundations on the Dogger Bank. (See complete story on OHT and Alfa Lift in our interview with Torgeir Ramstad, CEO, OHT, starting on page 36)

SOVS

Being far from shore means the wind farm will, once built, need to be serviced from large Service Operation Vessels, rather than by crew transfer vessels which are used to transport small crew of technicians to wind farms closer to shore.

SOVs, dubbed floating warehouses/hotels with walk-to-work turbine access are able to stay at the wind farm site for weeks, reducing transport and transfer time, and only come ashore to replenish supplies and equipment. Also, given that there's no need to transport technicians from shore every day, and that they can basically "walk-to-work" via a gangway, this means that they have more time out on the turbines. Also,

Source: North Star Renewables

Source: DEME

SOVs are equipped with a daughter craft used to move technicians round the wind farm to more remote turbines.

For the Dogger Bank, Aberdeen-based firm North Star Renewables in March 2021 secured contracts worth an estimated £270 million (~$375 million), to deliver three state-of-the-art service operation vessels (SOVs).

North Star will deliver the SOVs from summer 2023, with vessels chartered for a ten-year period, with an option for three one-year extensions.

The UK-based firm said the deal would create 130 new full-time UK-based jobs in crewing and shore-based roles for the lifetime of the contract.

In support of the contract, North Star said it would establish a new permanent presence at Port of Tyne, "delivering a local economic and supply chain boost to the coastal region."

One SOV will be used for scheduled maintenance at Dogger Bank A and B. The vessel is due to be delivered in January 2024 and will also serve Dogger Bank C when this phase of the wind farm is operational.

Two other SOVs will be delivered by North Star to be used for corrective maintenance, at Dogger Bank A and Dogger Bank B. Delivery of these vessels is scheduled for July 2023 and July 2024 respectively.

The vessels will be built by Norway's VARD at its shipyard in Vung Tau, Vietnam.

According to the shipbuilder, the hybrid vessels will be equipped with a diesel-electric propulsion system, highly efficient main propellers, and tunnel thrusters with permanent magnet electric motors in combination with SeaQ solutions supplied by Vard Electro in Norway.

CABLES

Belgium-based offshore installation services company DEME Offshore will deliver and install inter-array cables for the Dogger Bank A&B. The contract to deliver these cables connecting the turbines was described by Deme as a "substantial" one, meaning it's worth between 150 million and 300 million euros.

"The far-reaching scope includes the engineering, procurement, construction and installation of the subsea cables for the combined 2.4 GW wind farm. Deme Offshore will supply, install and protect 650 km of 66 kV inter-array cables and all related accessories," DEME Offshore said.

DEME will use its DP3 cable installation vessel 'Living Stone' to install the cables, which apart from its large cable capacity of 10,000 tonnes, features a "dual-lane" system one for laying the cable and one where the next cable can be simultaneously prepared and have the cable protection system (CPS) installed.

This, per Deme, reduces the time needed for preparing the cables, minimizes manual handling, increases the vessel's workability, and ultimately, improves production rates.

The inter-array cables will be built by Hellenic Cables at its plant in Corinth, Greece. As for the export cables, the Dogger Bank consortium awarded the contract worth 360 million euros to NKT.

The export cable system comprises the construction of around 4x175 km of 320 kV DC offshore export power cables

Source: Aibel

An artist impression of an offshore wind farm with an Aibel convertor platform.

and 4x32 km of 320 kV DC onshore export power cables as well as installation by the 2017-built cable-laying vessel NKT Victoria, for which NKT says is “the world’s most advanced cable-laying vessel.”

The power cables will be manufactured in Karlskrona, Sweden.

Among many firsts related to the Dogger Bank project, it is worth mentioning that the Dogger Bank will be High Voltage Direct Current (HVDC) connected wind farm in the UK due to its distance from shore.

For this, the Dogger Bank consortium have selected Aibel and Hitachi ABB Power Grids to deliver offshore platforms and associated transmission links for all three phases of the project, the third being subject to an FID.

Hitachi ABB Power Grids will install its compact high-voltage direct-current technology, called HVDC Light, for efficient transmission to the project’s onshore grid connections in the East Riding of Yorkshire for Dogger Bank A and B, and on Teesside for Dogger Bank C. Aibel will build the offshore converter platforms.

“An HVDC connection will ensure the renewable energy being transmitted over the long distances from the Dogger Bank offshore to the onshore grid connections in East Riding and Teesside, which will be achieved efficiently while minimizing losses,” Aibel and Hitachi ABB Power Grids explained.

Italian offshore services giant Saipem will be responsible for the installation of two offshore HVDC platforms for the first two phases. Saipem will use its Saipem 7000 crane vessel to install the platform consisting of a 2,900-tonne jacket and a 8,500-tonne topside.

Dogger Bank to supply 5% of UK electricity demand

Onshore works at the project began in 2020, while the offshore installation works at the Dogger Bank are expected to start in 2022.

First power is expected in summer 2023 for Dogger Bank A, and in and summer 2024 for Dogger Bank B and B, with commercial operations to follow around 6 months later. Turbine installation for Dogger Bank C is expected to begin in 2025, with the overall wind farm expected to be completed in 2026.

According to SSE, when fully complete in 2026, Dogger Bank Wind Farm will produce enough renewable electricity to supply 5% of UK demand and power up to six million homes each year.

SSE and Equinor in 2020 signed 15-year offtake Power Purchase Agreements (PPAs) for the first two phases of the Dogger Bank.

Separate PPAs for a total of 2.4GW across both Dogger Bank Wind Farm A and B have been concluded with external offtakers Ørsted (40% share) and Shell Energy Europe Limited (20% share), and with sponsor offtakers Danske Commodities (20% share) on behalf of Equinor, and SSE Energy Supply Limited (20% share) on behalf of SSE Renewables.

Following the completion of the construction, the operatorship over the Dogger Bank wind farm will transfer from SSE to Equinor. Equinor will then be lead operator of the wind farm for the duration of the wind farm’s operational phase of up to 35 years.

Worth noting, Equinor, known for years a Norway’s largest oil company, is working to transform itself into a broader energy company, with a goal to become “a global offshore wind major.” The company expects to increase its current installed capacity to 12-16 GW, around 30 times the current level, by 2035.

Source: OHT

OHT CEO Torgeir Ramstad

OHT was born to perform heavy lift in the offshore oil and gas business, and has evolved to position itself to lead in the booming offshore renewables sector, including a contract to work in the mammoth Dogger Bank offshore wind build out. ***Torgeir Ramstad, CEO, OHT,*** *discusses his company and its role in the growing offshore wind market.*

By Greg Trauthwein

When Torgeir Ramstad took the top post at OHT in 2015, the offshore oil and gas industry was just starting its historic nosedive. "When I joined the company, I saw great potential in developing the company into new industries," Ramstad said. "Oil and gas was in its nth downturn, we were looking at alternative industries and quickly came up with offshore wind, primarily because I came from Fred Olsen Windcarrier (as Managing Directory), which is active in turbine installation."

From there the mold was cast, and by 2020 OHT had more than 50% of its revenues coming from offshore wind deploying its existing fleet. As Ramstad and his team sized up the market and the opportunities, the mission turned to build its portfolio and potential in offshore renewable energy with the aim of exiting the oil and gas sector altogether by 2026, with one exception: sustainable oil and gas decommissioning.

"We will focus our intention on building business in offshore wind, primarily. We will build down our engagement in oil and gas in a deliberate way, and we will eventually decline opportunities in oil and gas if they don't suit our strategy, because we firmly believe there will be more than enough within offshore wind," said Ramstad.

THE VALUE PROPOSITION: TRANSPORT & INSTALL

The value proposition that OHT proposes is one shared universally: find a way to do "it" more efficiently. The key difference: "it" – in this regard – is seamlessly transporting mammoth pieces of equipment, thousands of miles in one of the most hostile environs on the planet and dropping it, as they say, on a dime in the bottom of the sea.

Enter Alfa Lift.

"We quite quickly came down to a conclusion that we would look at foundation installation primarily, as it is closer

“We have invested close to $600 million on speculation in Alfa Lift and jacket vessels and the organization. Now it’s the client’s turn to commit. We are more than willing to push the button for Alfa Lift 2 or more jack-up vessels, and we have options for three more jack-up vessels as well. But we’re not doing it on speculation.”

Source: OHT/Ulstein

The 216-meter long Alfa Lift vessel will feature a 3000-tonne crane and will be capable of carrying and installing up to 14 XL monopiles per voyage.

to the company’s heritage and expertise,” as well as complementary to its existing transportation fleets, said Ramstad.

While the existing OHT fleet would be an advantage, a newbuild was needed, a mammoth ship that could seamlessly pick up, transport and install the offshore wind foundations, all in one trip over long distances. “We have a unique concept in Alfa Lift, to install monopiles as a conveyor belt-type machine,” said Ramstad. “We can be faster and more efficient than our competitors; we’re not saying it, our clients tell us that we are the preferred choice in the segment.”

After an investment in design work and development with ‘key partners,’ OHT placed a shipbuilding order in 2018 with China Merchant Heavy Industries in Nantong, China, for Alfa Lift, which will be the world’s largest dedicated foundation installation vessel.

“This was done on speculation,” Ramstad noted, a calculated risk that paid off when 16 months after placing that shipbuilding contract, OHT signed the preferred supplier agreement for Dogger Bank, the world’s largest foundation and installation project for offshore wind. “That puts OHT firmly on the map in this industry,” he said.

“So this whole story was about thinking in terms of high volumes and repetitive tasks,” said Ramstad, with the ‘trick’ being to do it safely, efficiently, correctly, time and again. The traditional means to install the foundations entailed anchoring the ship on the seabed to stabilize the ship and maintain position. But with the pace of installation targeted to one day per monopile, this approach would have been too time-consuming. The solution: installing monopiles in dynamic positioning (DP) mode, something that had not (yet) been done in 2015” (and since then has only recently begun), an approach that saves time and money.

“The whole development of this concept started off with the controls and automation,” said Ramstad. “As I like to say, we took the Tesla approach. We didn't start with the car. We started with the software."

Central to the success of an operation of this scale in this environment is stability. While many of the challenges to monopile installation in DP mode mirror the challenges found in pipelaying, there is one very important difference: the size and weight of the unit being installed.

"The challenge is to keep the vessel stable enough to achieve very tight tolerances, in terms of verticality for the monopiles," said Ramstad. "You have to stabilize the monopile, which can be a hundred meters high and weigh maybe two and a half thousand tons. You're holding it around the center of gravity or even below it … It's unstable. So we deploy SpaceX algorithms to control it," the same way SpaceX are able to control the rocket's landing on a barge in the middle of the Atlantic Ocean."

Alfa Lift is scheduled to join the OHT fleet in early 2022, preparing for the start in Dogger Bank later that year. Meanwhile, in the middle of 2020, while COVID raged and business uncertainty abounded, OHT went from "not being so interested in offshore wind turbine installation" to ordering a Wind Turbine Installation Vessel (WTIV), again, on speculation with China Merchant Heavy Industries, a contract which entered force in November 2020 with a projected delivery in the middle of 2023.

"The end game for us would probably be to see at least two Alfa Lifts and two jacket vessels for the turbine side, accompanied by the transportation vessels that we currently have. And with this, we intend to become a leader in the offshore wind space for transport and installation services."

DOGGER BANK

As a newcomer in the installation business, OHT had to then convince one of the most demanding clients in the market that it, as an organization, would be able to step up in regards to capacity, competence, systems, and all that's required to be a proper contractor, that the concept of its fleet would work the way it's intended. And in regards to Dogger Bank, there will be little wiggle room for error, as it is a "big scale project, where you're looking at installing 190 monopiles and transition pieces in the first two phases over a relatively compact schedule," said Ramstad. "Alfa Lift efficiently transports and installs over medium distances, regardless of where you end up with your fabrication in Northern Europe. So, all the way down to Northern Spain, Alfa Lift can go to the fabricator, pick up the foundations, and go directly to the wind farm site and install. Whereas the competitors would rely on separate transportation, intermediate storage, reloading, and then going field to install."

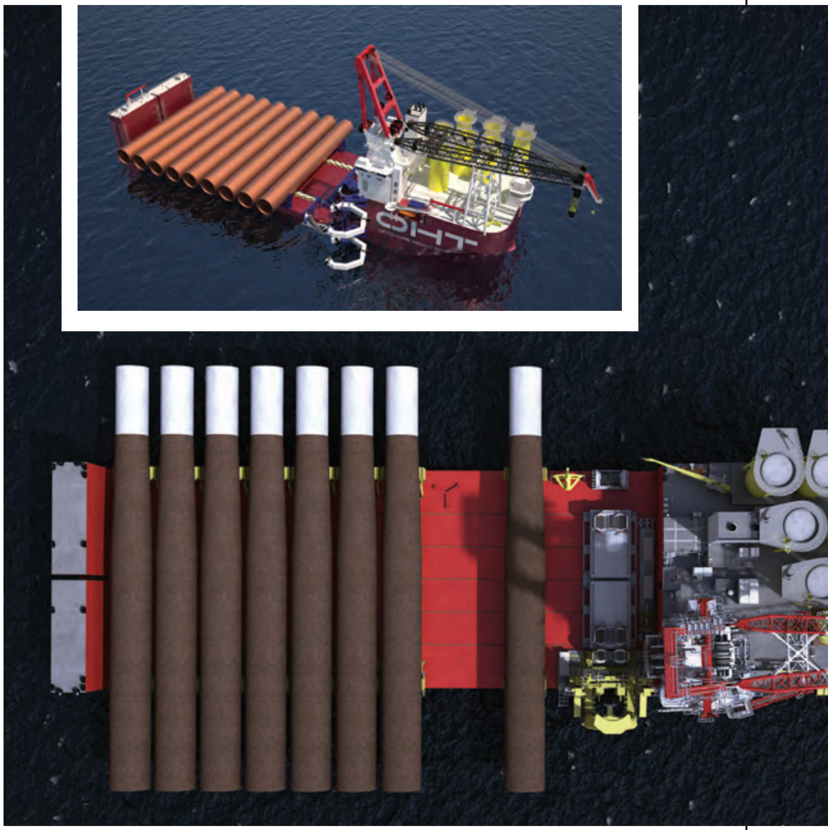
While Alfa Lift is a large and identifiable manifestation of the OHT proposition, Ramstad said it's not only about steel, cranes and ships. "That's just a small part of it," he said. "We are a contractor, and as such, you rely on trusting the people that you deal with, and you rely on being able to speak the same language, understand the challenges, and address them in the proper way. I believe that was an equally important aspect that was valid, and eventually led to that contract award (a contract awarded by Equinor, then upon the signing with OHT handed off to SSE, Equinor's partner, to execute the contract.)

INSIDE ALFA LIFT

As the offshore wind industry grows, 'feeding the beast' demands efficiency from foundation manufacture to final install. In this regard, Alfa Lift is both the beast and the buffet line, designed to cut down on trips from the field to the port.

"When we went to the ship designer Ulstein in Rotterdam, we didn't come with the normal standard metrics – this long, this wide, this deadweight (etc.)," said Ramstad. "We went and said, "Do you think it's possible to design a vessel that can install monopiles in one day? And that includes the positioning, the lowering of the monopiles, the piling, the transition piece installation, the bolting and grouting, and the sailing and the transiting and the loading time. So counting the time from [when] you leave port until you're back fully loaded and ready to leave again."

What resulted was a creative process to design a ship that is, in a word, big and strong, to streamline the handling of foundations on deck while minimizing transit time from port to field.



Source: Ulstein

"You also need a large stable platform to be more robust in relation to your harsh alignment out in the North Sea; the larger, the better," said Ramstad. "So, we started off with some iterations and it grew and grew and grew, because the first and the second iterations were too small, and eventually ended up at the sizes we are at now.

Next up was designing a cargo handling system to efficiently move and handle the massive piece of unique and valuable cargo … while buffeted by the notoriously rough North Sea.

"We said: 'In order to mechanize and automate the process of installation, which is actually a serial production or repetitive process, you need to handle things in parallel. You need to not do everything in sequence. You need to also get rid of the people who are exposed on the main deck doing manual operations," said Ramstad.

In the final concept they placed a crane upfront on the vessel to free up the space on the main deck, and created a mechanized deck transportation system to bring the foundation components up front towards the crane. Since the crane did not need to cover the entire main deck, it offers a shorter, more robust crane boom … and ultimately a cheaper crane, too.

"With this deck transportation system, we can then feed the crane in the upending position, bringing them from the horizontal to the vertical in an efficient way," said Ramstad. "And while installing one monopile, we prepare for the next. And then, of course, in between two monopiles, you do have transition piece, and we decided to carry the transition pieces on the SQ back. That's normally where you have a big hotel section on the vessel."

With the main deck being prime real estate for efficient foundation handling, the decision was taken to place the hotel portion of the ship underneath, allowing for much freedom in the placing of other valuable bits of equipment including the 900-ton piling hammer. "The piling hammer is a big beast," said Torstad, and that sits on the forecastle deck along with the transition pieces.

WHAT'S NEXT?

While the original Alfa Lift is yet to be delivered, thoughts have already turned to Alfa Lift 2, which is currently in basic design. "We have made certain modifications, essentially in relation to an even longer crane boom," said Ramstad. "This isn't because of heavier foundations; we are well-covered with what we have on Alfa Lift 1 in that respect. But, if the foundations grow higher or longer, for instance, we see jackets standing on the vessel's deck soon becoming the limiting factor, in terms of crane height or hook height." So the team is looking at a bigger crane with a longer crane boom.

"So, probably going from 3,000 tons to 5,000 tons," said Ramstad. And with a bigger crane comes a slightly longer ship to ensure stability during sailing and install. "For most people it would look identical. It's not that big a difference."

While OHT has invested much time and resources to race ahead in the offshore wind turbine installation game, Ramstad said the trigger for further investment is up to the clients in the form of a contractual commitment. "We have invested close to $600 million on speculation in Alfa Lift and jacket vessels and the organization. Now it's the client's turn to commit. We are more than willing to push the button for Alfa Lift 2 or more jack-up vessels, and we have options for three more jack-up vessels as well. But we're not doing it on speculation."

"Now clients need to commit to us before we push the button. And, I'm happy to note that several clients and are waking up to that different dynamic in the market, because what they see is this bottleneck from '24 onwards. More and more clients [are] coming to us, and probably to our competitors, to secure vessel capacity early. This is now close to early enough for having enough lead time to actually order and construct a vessel. Whereas before, the lead times for contracts were shorter than the time it takes to build a vessel. But now, it looks like we are approaching a crossing point or even longer lead times for contracts. And therefore, we can sign a commitment for a vessel, push the button with the shipbuilder, get the vessel delivered in time, and perform the project."

OHT is currently building the Alfa Lift, an Ulstein-designed offshore wind foundation installation vessel, and has secured a contract for work on Dogger Bank phases A&B. Being built by China Merchants Heavy Industry (CMHI) shipyard in Jiangsu, China, the 51,087-dwt Alfa Lift will transport the monopile foundations and transition pieces to the offshore site and install them in water depths up to 35m, using the vessel's 3,000-ton crane, mission equipment and a 10,000+ m^2' 'smart deck', capable of carrying and installing up to 14 XL monopiles per voyage and will be able to fully submerge the main deck to a depth of 14.66m. The foundations will be amongst the largest ever used for offshore wind and are expected to be installed at Dogger Bank A between 2022 and 2023. Specialist equipment suppliers for the vessel include the likes of Liebherr, MacGregor, MAN Energy Solutions, and Kongsberg Maritime.

Alfa Lift Dimensions

Length, o.a.	216.3 m	Propulsion thrusters	3 x 5,500 kW
Length, bpp	204.3 m	Retractable thruster	1 x 3,000 kW
Beam (molded)	56 m	Tunnel thrusters (fwd)	3 x 3,000 kW
Depth (main deck)	12.6 m	Positioning system	DP 2
Draft (design)	8 m	Class	DNV-GL
Draft (submerged max.)	27.6 m	Deck strength	30 t/m2
Service speed	13 knots	Complement	100 persons
Installed power	4 x 6,875 kW		

Wärtsilä's Compact Reliq Aims to Optimize BOG Reliquification

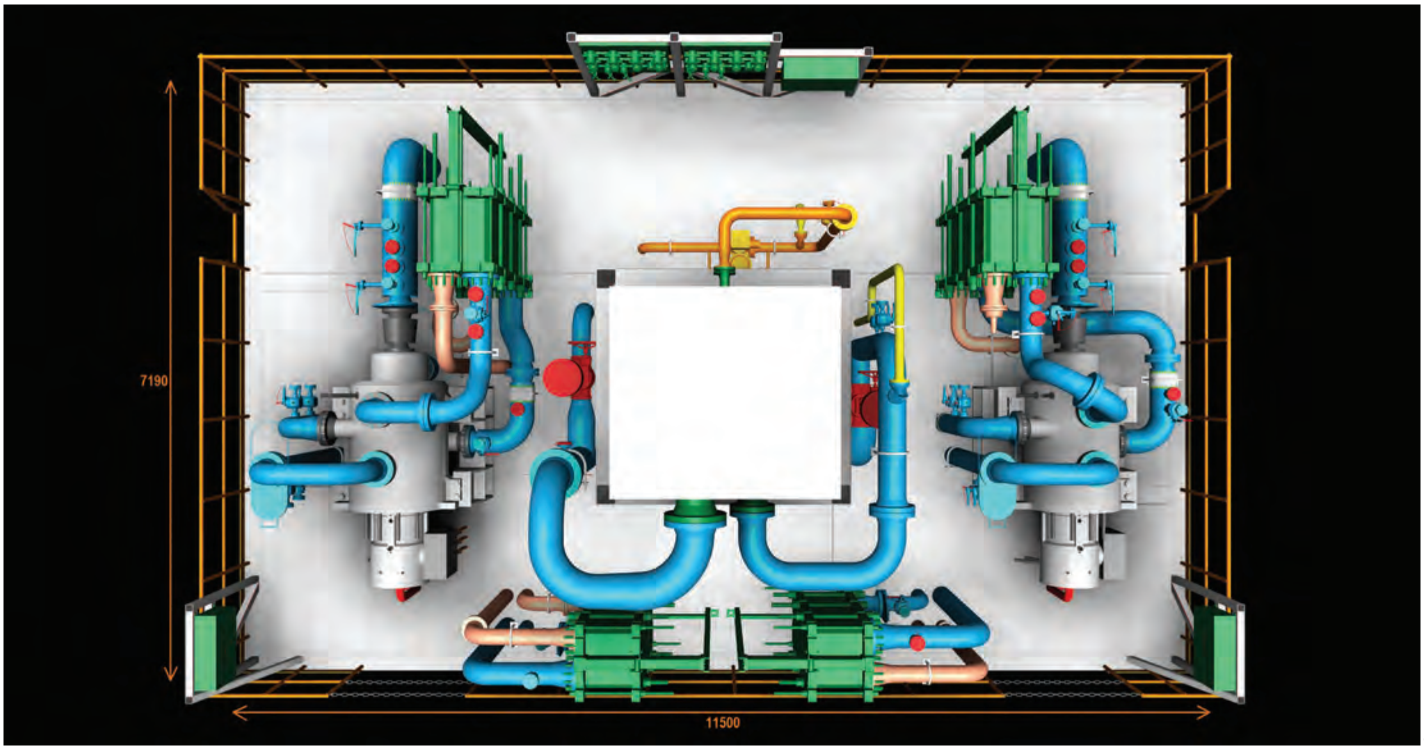
As the maritime and offshore industries steam toward decarbonization, the path to zero emissions will include many stepping stones. Wärtsilä's Compact Reliq is a step change in efficiently reliquefying boil off gas (BOG). Lasse Wichstrøm and Sylvain Fabreguettes explain.

By Greg Trauthwein

LNG carriers have, for years, utilized boil off gas (BOG) to help fuel the ship, even before 'decarbonization' and 'emission reduction' became lexicon in the maritime sector.

"Compact Reliq is not a brand-new product in the sense that reliquefaction plants have been around for some time," said Sylvian Fabrequettes, Product Line Manager LNGC Systems, Wärtsilä Gas Solutions. "Wärtsilä has been a pioneer, introducing the reliquefaction technology to the markets back in 2005."

But Compact Reliq is the latest evolution of LNG technology from Wärtsilä. "The Compact Reliq can help to improve the efficiency of the total chain and also the flexibility of the fuel, since we are able to handle the boil-off gas" to both fuel the ship's main propulsion and auxiliaries, as well as to reliquefy the gas for return to the cargo tanks, said Lasse Wichstrøm, Sales Manager, Wärtsilä Gas Solutions.



Source: Wärtsilä

Lasse Wichstrøm

Source: Wärtsilä

Sylvain Fabreguettes

"It's very simple," said Wichstrøm. "It is about controlling the boil-off gas and, and the pressure and temperature inside the LNG tank. So onboard an LNG carrier, the amount of boil-off gas is higher than the gas amount needed for the engines for main propulsion and auxiliary power. So what we are doing is that we are taking that excess boil-off gas and re liquefying it (back to the cargo tanks)."

Compact Reliq is based on the reversed nitrogen Brayton cycle refrigeration technology, a solution designed to reliquefy the boil-off gas (BOG) from gas carriers and LNG bunker vessels, according to Fabrequettes, and for keeping the cargo cool under all operating conditions. The process is a closed nitrogen cycle for extracting heat from the boil-off gas, and typically, the reliquefaction system is used to control the cargo tank pressure by liquefying boil-off gas. The new system has the capability to handle all boil-off gas (100% capacity) or only excessive boil-off gas not burned in the engines (partly liquefaction).

"It performs at about 850 kilograms per hour, in terms of BOG handling," said Fabrequettes. "We have a booster option available in several process configurations that will increase the capacity to almost 1500 kilograms per hour. Then we are going to the CRD model, which is a Compact Reliq double, which performs at about 1700 kilograms per hour. (With this too) we can adopt a booster option that to bring us to around 2000 to 2003 kilograms per hour. So it gives quite a good range."

The system received its first commercial order in late 2020, to be installed on a pair of new 170,000 cu. m. LNG ships (with an option for two more) being built for Knutsen OAS Shipping at Hyundai Heavy Industries in South Korea. Both will be installed with the CRD unit with a capacity 1.7 tons per hour.

"This is a great contract for us, showing that the market is ready to embrace this new Brayton nitrogen technology," said Fabrequettes. "we are working on several other opportunities with different shipyards, too."

In the case of the Knutsen OAS Shipping contract, the system will be instrumented for remote monitoring and online operational support as part of Wärtsilä's Operational Performance Improvement and Monitoring (OPERIM) program. The equipment is scheduled to be delivered to the yard commencing in February 2022, and the vessels are expected to begin commercial operations from late 2022.

NEWBUILD VS. RETROFIT

As its name suggests, the system is compact, designed to make it easy to retrofit on existing ships without extensive modifications, and the refrigeration process uses safe and easily obtainable commercial grade nitrogen. With the system's ability to efficiently control tank temperature and pressure, ships that traditionally have steamed at 20+ knots to help manage tank pressure are now able to slow down significantly, a double win for the bottom line and the environment.

"It is for both newbuild and retrofit," said Wichstrøm. "The module itself it's designed for easy installation, regardless if it's a new build or a retrofit. And we see a big potential in both these markets. (When you look at a five- to 10-year-old large scale LNG carrier), "they have a lot of life left and could be a lot more efficient going at maybe 12-13 knots then going at 20 knots, as they have to do today to keep the tank pressure under control."

The BOG reliquefaction system could be installed for vessels, offshore installations, or onshore facilities such as LNG terminals.

Watch the full interview here:
https://youtu.be/J5TV2R4kPHY

Simulation & Testing to Mitigate Challenges in Subsea Oil & Gas

By Bipin Kashid, Simulation Engineer & Mitch Eichler, Applications Engineer, Parker Hannifin Hydraulic Valve Division

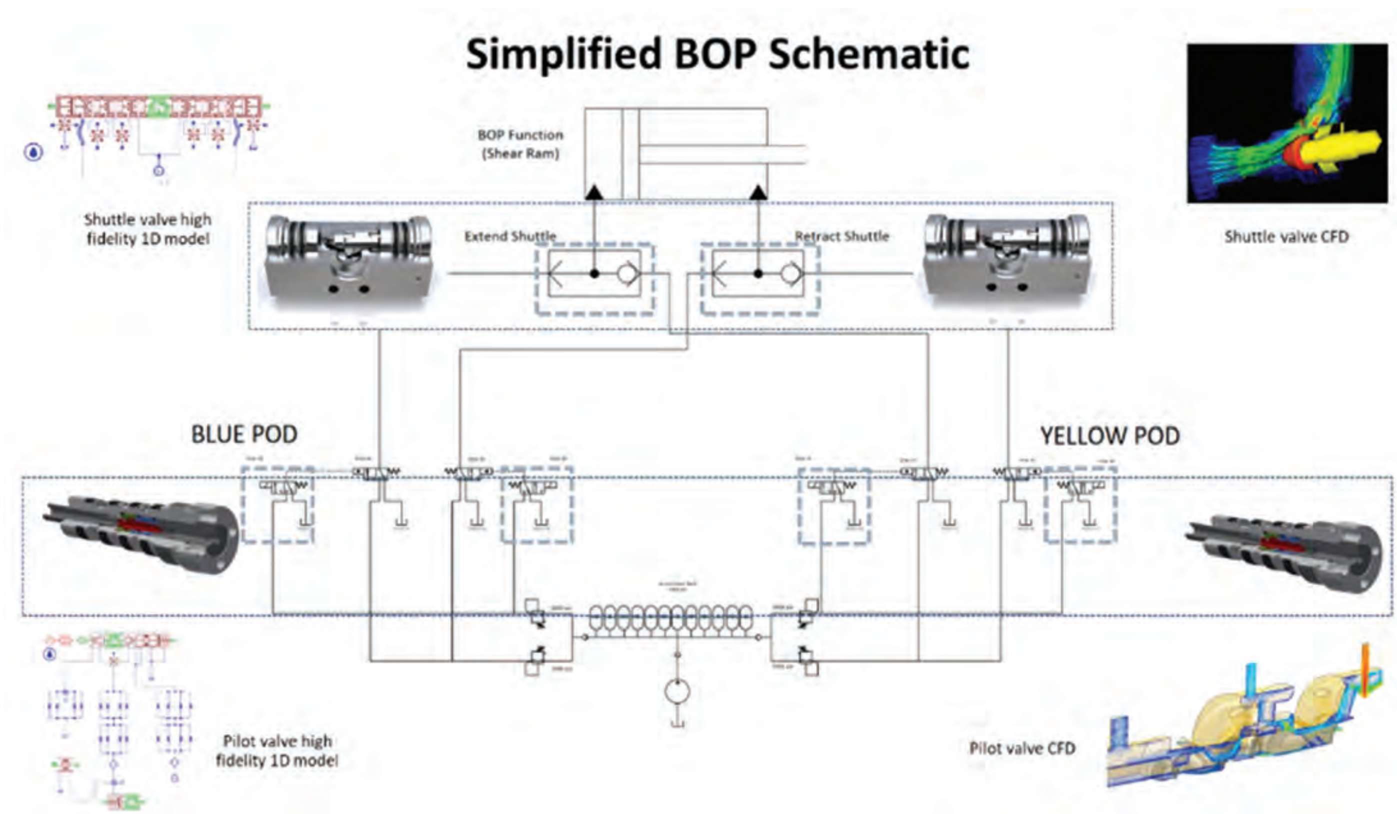
During the exploration phase of the offshore drilling cycle, pressure spikes of formation fluids in the well, known as "kicks" must be managed to prevent blowouts. Well control equipment, including choke and kill systems and blowout preventers act as the defense system for drilling contractors to prevent disaster. A blowout preventer, or BOP, is a vent-to-sea control system which expels fluid directly into the ocean. This BOP control fluid is often a 98/2-95/5 water and glycol mixture, effectively behaving as pure water does.

These systems are tested regularly to ensure quick and reliable operation. Valves are critical components to the hydraulic systems which often incorporate multiple different types of valves, including shuttle valves, pilot valves, pressure regulators, pressure relief valves, pressure intensifiers and flow control valves. Because most valves operate based on simple on-off control, if high-pressure fluid is rapidly expelled into the system it can create a high-shock and vibration operating environment that leads to valve wear in critical well management systems like the BOP.

There are several challenges and mitigating factors that should be addressed when designing systems for subsea applications. In order to ensure solutions and component selection will lead to reliable operation, simulation and testing technology should be incorporated into the design process.

Challenges & Mitigating Factors

Low-viscosity fluids used in subsea hydraulic systems provide minimal lubrication which can be aggressive on the internal components. This means that valves must be designed to stand up against rubbing wear. When designing a subsea



Source: Parker Hannifan

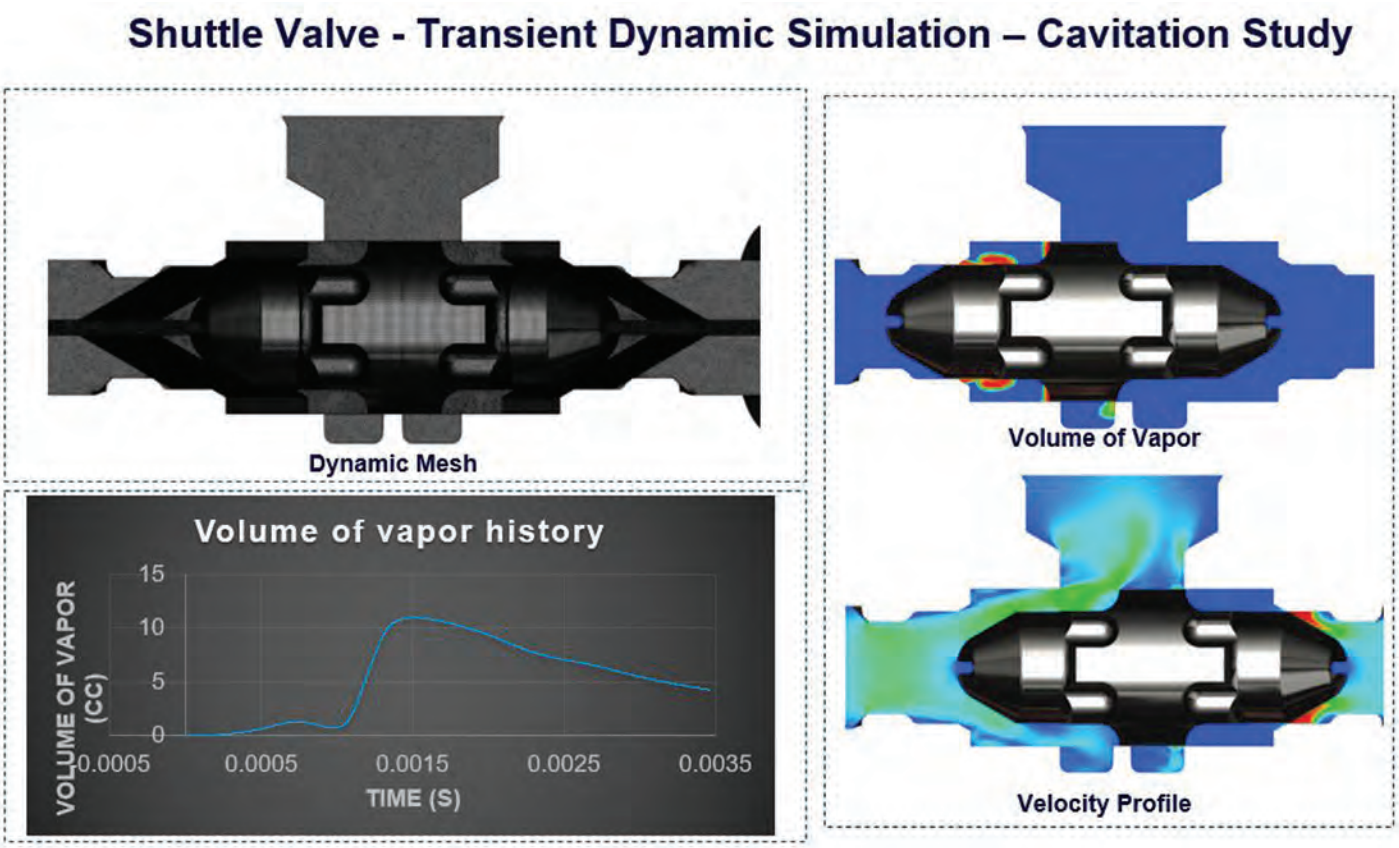
valve or system, consideration must be taken into account for the potential of material galling from low-viscosity fluids. Additionally, phenomena such as corrosion, cavitation and high-pressure surges all contribute to the valve design decisions.

• **MAINTENANCE:** Because this type of subsea equipment can operate miles below the surface of the ocean, equipment is not easily maintained. Therefore, it must be designed for maximum service life. Incorporating design features that act as a layer of defense against failure, such as a "last-chance" filter built into valves to help prevent contamination, are important. Additionally, for the subsea oil and gas industry, users are more interested in repairing components as opposed to replacing them, so serviceability of components must be considered.

• **SHOCK & VIBRATION:** The high-pressure and high-flow systems in subsea oil and gas applications create significantly more shock and vibration than what is seen in standard hydraulic systems, which are usually high-pressure and low-flow or low-pressure and high-flow. Shock and vibration in these systems can lead to premature failures including leaks, sticking, or in extreme cases loss of function. System designers need to manage the hydraulic flow paths to minimize shock in the system. One way to minimize this shock is to incorporate proportional pressure and flow control valves that will better manage the release of energy.

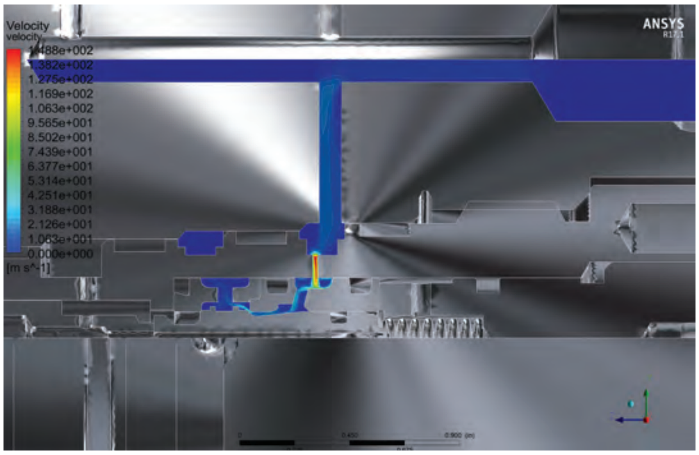
• **CORROSION:** The harsh operating conditions, coupled with the presence of seawater, especially when stagnant, can corrode and compromise the structure of the valve component. It is imperative to design valve components in subsea systems with high-corrosion and pitting resistance to avoid stress-cracking issues. As the industry changes, design engineers should stay current with industry standards, material properties and manufacturing methods in order to make the best component selection decisions.

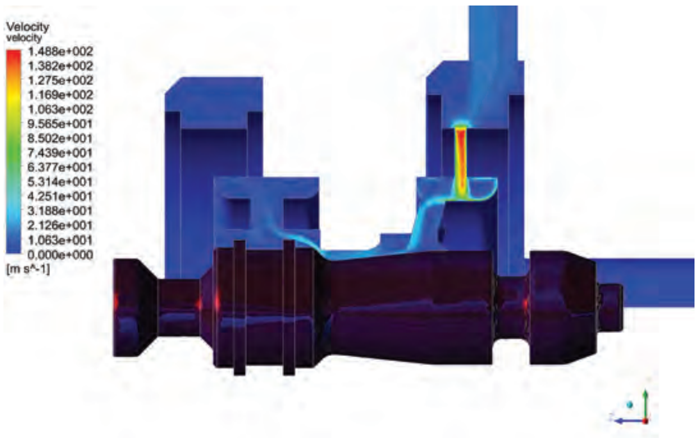
• **VENT-TO-SEA:** Vent-to-sea hydraulic systems require leak-tight internal sealing to contain the fixed volume of stored fluid in subsea accumulators. This means that typical hydraulic designs must be adapted to reduce or eliminate the internal leakage that is acceptable practice in closed-loop hydraulic systems. The systems must also have leak-tight external connections; this is required of all hydraulic systems, but especially so of those operating subsea. To accomplish this, engineers need to develop, or work with a developer of, resilient sealing technologies for both hard- and soft-seated designs. For external piping and connectors, subsea validated technologies like Parker's Dual Seal/Seal-Sub flanges and Phastite non-welded piping system are best used for safe and reliable connections between valves, accumulators, and cylinders and are preferred alternatives to unreliable tapered threads, pipe flanges, and socket welded interconnect piping.

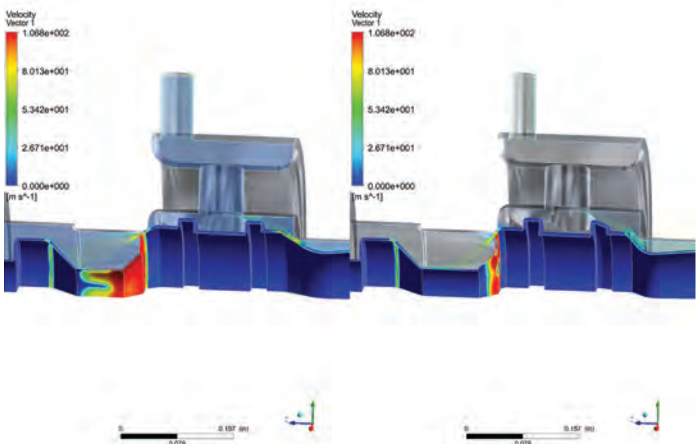


Source: Parker Hannifan

Pilot Valves







In subsea applications, if a BOP component fails, days can be lost retrieving, repairing and redeploying the BOP stack. When that happens outside of planned maintenance, it can cost hundreds of thousands or even millions of dollars in lost productivity, applying heavy economic pressure on the drilling contractor operating the rig and the operator funding the drilling activity.

Mitigate Challenges Through Simulation

Design engineers should take advantage of the tools that enable them to understand how a component will function in an application prior to installing it. The best way to begin testing a design or component is to run upfront multi-physics simulation studies on both the system and component level to identify and solve critical issues during the virtual prototyping phase, leveraging simulation-driven optimization. Testing virtually via simulation as much as possible prior to conducting application testing will save time and costs in system development. This will also provide more opportunities for the design engineering team to create solutions to the challenges of subsea applications.

Developing new simulation methodologies is important for this industry because it can be difficult to capture the complex physical phenomenon like transient pressure and flow conditions in BOP circuits. Design teams should develop custom analytical models based on extensive research and development that's backed by multi-physics simulations.

Optimization using 1D simulation & 3D CFD

Simulation can play a significant role in valve design and development for this industry and is heavily used in all stages of product development for all of the subsea technology that Parker offers, especially with shuttle valves and a variety of pilot valve designs. Using simulation tools early in the design process during the concept development and ideation phase is key in providing maximum value of the products.

Frequent and early simulation enables Parker to foresee and mitigate multiple design challenges during the concept development phase of several valve projects before any costly investments are made. Because Parker has designed multiple components or similar components in a given application circuit, it is possible to embed data from high-fidelity models into the system-level schematic. This provides an increased level of accuracy in the system because the system interaction is more properly captured than when boundary conditions are assumed for a component model.

To provide the oil and gas industry with the design assurance required for its most extreme applications, it is necessary to have simulation subject matter experts develop analytical models and further validate them with real-world tests. Various types of simulations across multiple domains of physics with varying complexities can be performed, including:

- 1D – Low- and high-fidelity component and system simulation
- 2D/3D – Transient dynamic CFD simulations
- 2D/3D – Fluid structure interaction (multi-phase physics: FEA and CFD)
- 2D/3D – Multi-phase fluid flow and water hammer CFD
- 3D – Non-linear implicit and explicit FEA

Extensive analysis with an intent of validation and correlation of the analytical models with test and field data led to the development of new simulation techniques and methods that Parker has used across a wide variety of projects. Additionally, direct engagement with both internal and external simulation software vendors, material scientists and manufacturing experts was critical to develop intellectual property and a strong simulation knowledge base that has been progressively developed and updated over the years. The simulation validation and test correlation process used to create better and more accurate predictions involved in-depth experiment designs and stochastic/sensitivity studies for variables including element types, turbulence models and contact models.

The ability to accurately model complex physical phenomena like multi-phase flow problems to examine microscopic wear and further validate these results with tests encouraged qualitative testing during the research and development phase. This synergy between simulation and test enables a group working in a thriving simulation ecosystem to model innovative concepts and build intellectual property.

With the right hardware, it is possible to conduct the complex analyses required to design hydraulic valves. However, if this is required of all users, this can become a large financial burden. By focusing on simplifying some of these tools, both design engineers and non-expert analysts will be able to use these tools to model even the most complicated interactions on their CAD terminals. This enables scalability without compromising on accuracy.

Building a simulation ecosystem within an organization will help to create a culture where simulation is trusted to both help new ideas fail fast and fail early, as well as assist with tuning or smaller adjustments near the end of a development cycle. Prototyping new and truly novel solutions is significantly less risky in an ecosystem where there is a high level of confidence in designs proven by simulation. Integration of quality tools like Design for Six Sigma can add an even deeper level of product reliability. Coupling both 1D and 3D simulations for high-fidelity modeling, also called co-simulation, is a best practice that design engineering teams should incorporate. When simulating for hydraulic systems, ensure that the entire hydraulic circuit is modeled rather than using simplified models from combined parameters in order to achieve high-fidelity results from simulation.

Additionally, simulation can aid in expanding further into market segments by optimizing and simplifying designs for better performance, reducing the number of parts, lowering costs and more. All of this can increase product reliability and customer confidence while reducing time to market.

Application Testing Validates Simulation Outcomes

In the testing environment, industry standards require supplementary information that outlines exactly how a specific test should be run. System designers should work with OEMs, system integrators and the end user to fully define testing requirements. Once requirements are in place, teams can construct research and development rigs that will closely mimic the application conditions. At this stage, engineers will want to minimize fluid connector changes such as changes to line sizes, flow directions or other functions that can serve to artificially remove energy from a system, creating an easier-than-intended test. They will also want to deploy the maximum energy in the testing environment by using higher flows and pressures than the application will actually require.

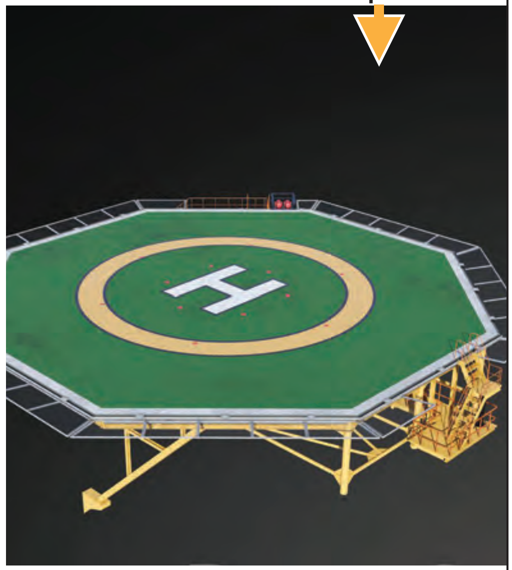
It is important to incorporate both common and unique hydraulic testing in development processes. By creating custom tests, teams can make sure to leave no stone unturned in the design process. It is also critical to conduct necessary testing for type approvals from certifying bodies. Depending on the specific application, these may include burst, fire, rated fatigue pressure, water hammer or cyclic fatigue, corrosion and bend testing. Validation through physical testing is the key to building confidence in simulation-based predictive models.

It has been said that “all the easy oil has already been gotten.” The offshore deep-water environment is challenging, and the technology requirements are only becoming more demanding as exploration warrants deeper water depths beyond 12,000 feet.

These more demanding subsea atmospheres require higher system pressures and increased design fidelity. In response, Parker is creating new models to intelligently and proactively advance the functionality of its products to help avoid unplanned downtime and bring better processes and efficiency to the market.

Transocean

Dropsafe



Wearable tech to boost drill floor safety

Offshore drilling contractor Transocean has recently deployed what it said was the offshore drilling industry's first safety system that integrates a wearable locating device with drill floor equipment and machine stoppage controls.

The system, called HaloGuard, combines a wearable alarm and a real-time location transmitter together with a machine vision system that is designed to track the position of personnel on the drill floor and key drill floor equipment while operating.

"When a crew member comes within a certain proximity of moving equipment, he or she is notified by an alarm through the wearable device. In the event the crew member remains in close proximity of the moving equipment, the system will stop the equipment from moving until the crew member returns to a safer, more distant position," Transocean explained.

By enabling machines with the technology to track, sense and, if needed, stop operations, HaloGuard provides an advanced layer of individual protection on the drill floor, the company said.

"We are extremely proud of our efforts to provide our crews with additional tools and resources to complement our industry-leading training and safety programs," said Transocean President and CEO Jeremy Thigpen. "This deployment once again showcases Transocean's ability to develop and advance innovation within offshore drilling. We believe HaloGuard[SM] will be a differentiating safety system that others will want to utilize within our industry and potentially within other industries as well."

Offshore Engineer reached out to Transocean, seeking more info on the system itself and what the main driver behind the development of the system was. Offshore Engineer also asked, following CEO Thigpen's comment on others wishing to use the system, if the company was willing to share it with competitors in the offshore drilling space and at what terms.

A Transocean spokesperson said the driver was the company's wish "to provide our offshore crews with additional safety tools and resources."

"....we and our suppliers would be open to commercial discussions with others interested in deploying the HaloGuard[SM] safety system in their respective businesses," the spokesperson added.

Transocean said its patented HaloGuard methodology and technology were developed with the assistance of Houston Mechatronics Inc. and Salunda Limited, and incorporate Salunda's patented CreWHawk real-time location technology.

The HaloGuard system is now operational on the Deepwater Conqueror drillship, which is working in the Gulf of Mexico. Transocean plans to deploy the technology on six additional rigs by the end of 2021.

Safety net

Dropsafe recently launched a helideck Perimeter Safety Net to protect offshore workers and equipment from falling, saving lives and reducing downtime

The system attaches to the perimeter frames of helidecks to protect personnel from falling and prevent loose objects from becoming dynamic Drops hazards.

"The new system developed by Dropsafe has been designed to offer a high-quality solution to the challenges posed by Drops on offshore helidecks. Drawing on extensive R&D and expertise tackling offshore Drops, it consists of 100% Japanese made 316 stainless steel wire and components," Dropsafe said.

According to the company, marine-grade stainless steel Dropsafe Perimeter Safety Net is designed for harsh offshore environments and can be fitted quickly and easily, as well as requiring minimal

Bosch Rexroth

Source: AdobeStock/Eugene

Henriksen Hooks

maintenance, which ultimately makes it a low-cost ownership proposition for helideck owners.

Subsea Valve Actuator certified for Safety Integrity Level 3

The new concept for Subsea Valve Actuators (SVA) from Bosch Rexroth has been certified by DNV GL for application in safety systems with up to Safety Integrity Level (SIL) 3 requirements.

The SVA is a self-contained actuator for opening and closing process valves in the deep sea at depths down to 3000 meters and deeper. The system consists of an electrically controlled drive with a hydrostatic transmission, which saves up to 75% of the energy required compared to a conventional electro-mechanical axis.

The patent-protected SVA is design to open and close process valves for oil and gas production or in CO2 storage systems in deep sea applications. A redundant design, for example of the safety valves and field-proven springs, ensures that the actuator can close the process valve safely even in case of power failure and without external energy supply. In addition, the actuator can also be operated mechanically from the outside using an underwater robot via an independent override interface.

Bosch Rexroth has integrated a continuous and automated monitoring of the system conditions, which significantly improves the diagnosis of the safety function.

Infectious Disease Mitigation Notation

A new notation and new guidance launched has been launched by the American Bureau of Shipping amid the COVID-19 pandemic with the aim to help marine and offshore operators reduce transmission of disease.

The ABS Guide for Mitigation of Infectious Disease Transmission On Board Marine and Offshore Assets details how the physical arrangement of a marine or offshore asset can act to mitigate transmission of infectious diseases, and, in an industry first, introduces a new notation indicating compliance with the standards.

Developed from a range of independent governmental and commercial guidance, including the U.S. Centers for Disease Control and Prevention (CDC), the guide addresses physical arrangement measures onboard.

The IDM-A (Infectious Disease Mitigation-Arrangements) notation is offered to vessels that meet the arrangement requirements addressing the configuration of spaces which can be used for the isolation and segregation of crew, passengers and onshore visitors, as well as the ventilation and interior surfaces of certain accommodation or working spaces.

Liferaft Hooks

Norway-based Henriksen Hooks launched full production of its new Liferaft Release Hook following completion of a prolonged testing program.

The new crane hook has been especially developed for launching inflated liferafts. It is permanently attached to the fall wire of a crane and clips into a steel lifting ring on the liferaft. It holds the liferaft safely while it is being hoisted out and lowered and releases automatically when the raft reaches the water and the load has come off the hook.

"First shown in 2017, the hook has attracted considerable interest from the marine and offshore markets but Henriksen has held it back until it completed a long and complex testing program," the company said recently announcing the launch.

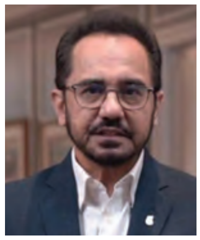
Versions of the hook are available for holding loads of 1,500 kg and 3,500 kg and feature a number of safety options that make them reliable and easy to operate in an emergency, the manufacturer said.


Miller


Hall


Koefoed


Geelen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Green


Gürtner


Lefton


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Maússe


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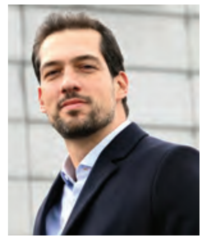
Mackenzie


Machado

Alexey Miller will remain at the helm of the Russian oil and gas giant Gazprom for another five years, as unanimously voted by the company's board.

Rick Hall, CEO of SOFEC, a company providing mooring systems for the international offshore oil and gas industry, decided to retire. **Brent Konstanzer** will take the role on April 1, 2021

Michael Koefoed took on the role of CFO in the Danish offshore vessel operator Maersk Supply Service, effective March 15, 2021.

Fugro's supervisory board nominated **Barbara Geelen** as a member of the board of management and CFO.

Wan Zulkiflee Wan Ariffin, a former CEO of Malaysian state energy firm Petronas, was elected to ExxonMobil's board in February.

Well-SENSE, appointed **Annabel Green** as its new CEO. Green join from Tendeka, where she was CTO.

Arne Gürtner, SVP, UK & Ireland Offshore at Equinor was in February named Co-chair of OGUK board.

The U.S. Bureau of Ocean Energy Management (BOEM) appointed **Amanda Lefton** as its new Director.

Norwegian oil and gas company OKEA selected **Svein J. Liknes** as the new CEO.

Aberdeen-based energy industry services company EnerMech has appointed **Celestino Maússe** to the newly created role of Mozambique country manage.

Former CEO of MHI Vestas Offshore Wind, **Jens Tommerup**, joined the board of the Danish renewable energy technology company Floating Power Plant.

Oilfield services company TechnipFMC appointed **Sophie Zurquiyah**, who serves as CEO of CGG, to its Board of Directors and Audit Committee.

Shell has announced the appointment of **Sir Andrew Mackenzie** as the new company Chair with effect from the conclusion of Shell's 2021 Annual General Meeting, scheduled for May 18, 2021.

Maersk Training UK (MTUK) has appointed **Leonardo Machado** as its new managing director.

Noreco appointed **John Hulme** as Chief Operating Officer (COO).

U.S. Representative **Deb Haaland** was confirmed as Secretary of the Interior.

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