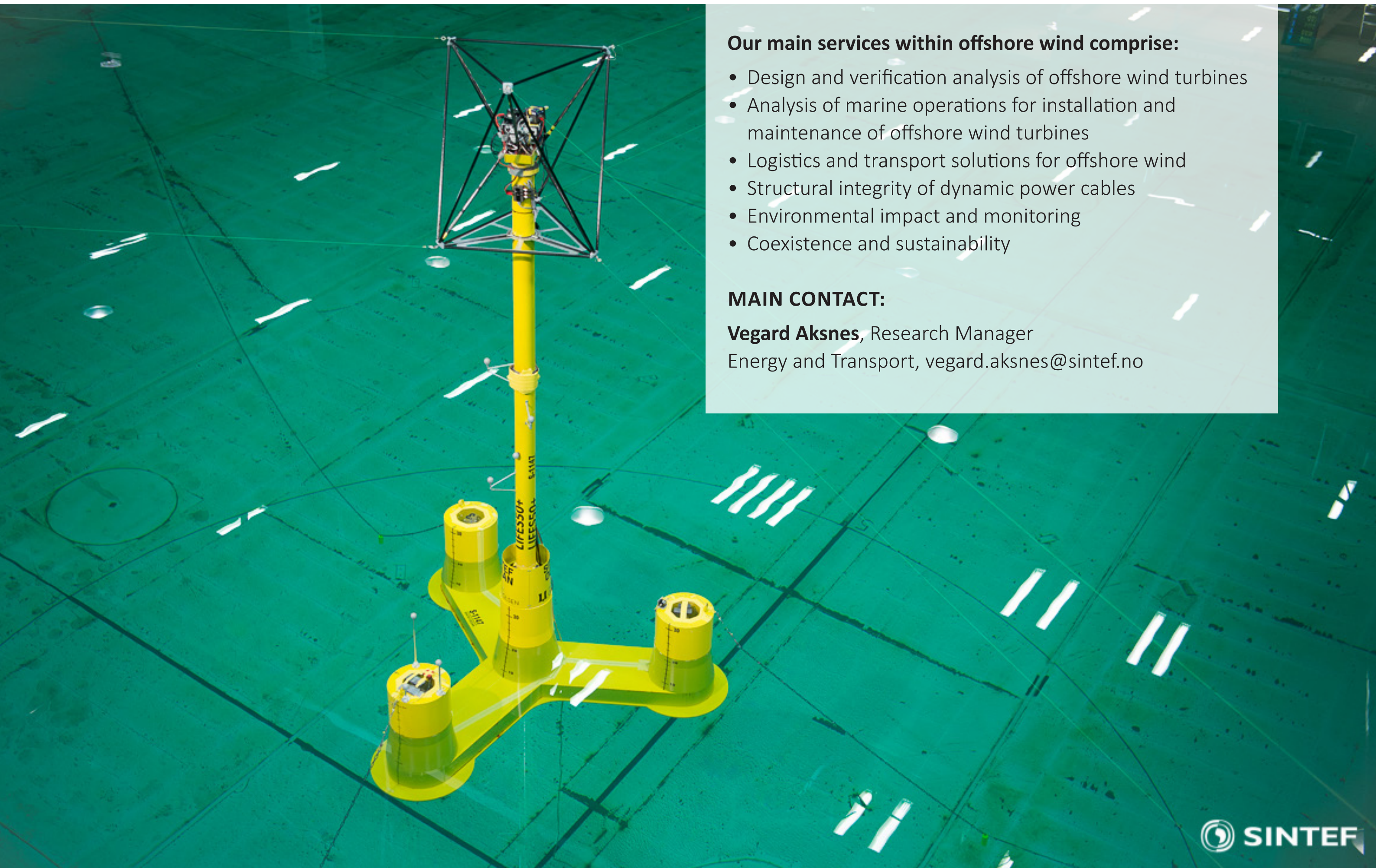
OFFSHORE WIND - SINTEF OCEAN

SINTEF Ocean helps ensure a more efficient and sustainable utilisation of ocean resources through technology development and research. We offer services to ocean related markets, such as offshore wind, offshore oil and gas, renewable ocean energy, aquaculture technology, marine pollution, fishery technology, new marine resources, maritime transport, and biomarine processing.

SINTEF Ocean operates world class laboratories, focusing on technology development for the ocean space. We combine our laboratory experience and our professional expertise in the development of numerical methods and software. We assist the industry with analyses and calculations, where professional expertise, experimental data and long experience from the offshore energy industry is crucial to succeed.

SINTEF Ocean takes an active part in the development of offshore wind technology through research, software development, model testing and new operating strategies.



Our main services within offshore wind comprise:

- Design and verification analysis of offshore wind turbines
- Analysis of marine operations for installation and maintenance of offshore wind turbines
- Logistics and transport solutions for offshore wind
- Structural integrity of dynamic power cables
- Environmental impact and monitoring
- Coexistence and sustainability

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Design and Verification Analysis of Offshore Wind Turbines

SINTEF has an important role in the development of concepts for offshore wind turbines. Since 2005, when the first model of Hywind Demo was tested in SINTEF Ocean's Ocean Basin, we have had offshore wind as a prioritised research area. We have constantly developed numerical and experimental methods for design and verification of offshore wind turbines.

SINTEF offers several services related to design and verification:

- Evaluation of fixed and floating concepts through experimental, numerical and theoretical studies.
- Design optimization.
- Analysis of hydrodynamic and aerodynamic loads, and structural response for fixed and floating foundations.
- Component analysis and testing through hydrodynamic model tests and specialist studies with CFD.
- Development and application of numerical methods and simulations tools.
- Development of experimental methods, such as Real Time Hybrid Model Testing – ReaTHM® — for combination of aerodynamic and hydrodynamic loads.
- Assessment of extreme loads and slamming.

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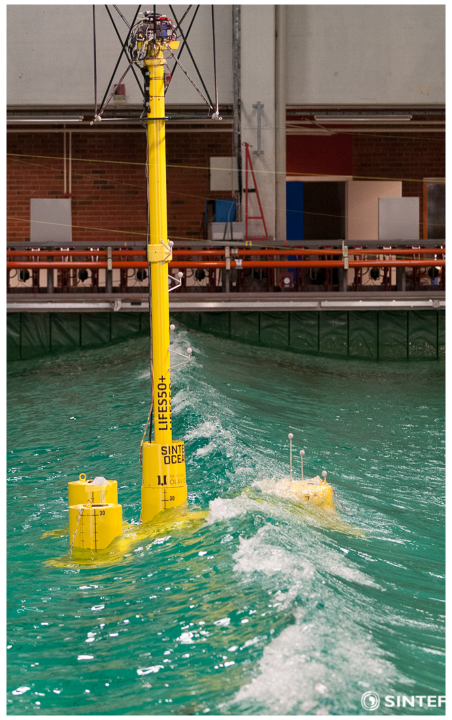

Logistics and Transport Solutions for Offshore Wind

SINTEF has long experience in developing optimisation models for maritime logistics related to offshore wind farms. We have also developed decision support tools to aid stakeholders to select and develop the most promising logistical resources.

Our tools are based on mathematical formulations of the decision problems and use complex and efficient analytical techniques from operations research to find optimal solutions according to the users' defined objective.

SINTEF Ocean has a proven track record in the following research areas:

- Advanced analysis of the logistic system for the installation and operation phases of offshore wind farm developments.
- Vessel fleet size and mix optimisation for installation and operation phases of offshore wind farm developments.
- Quantitative assessment of vessel designs and their performance in the overall logistic system.
- Optimised scheduling of O&M tasks and selection of resource requirements for O&M tasks execution.
- Optimised routing of vessels for maintenance tasks.

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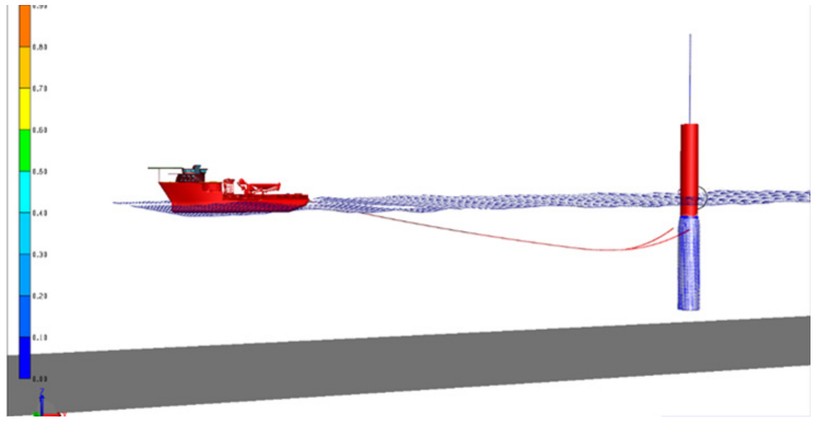

Analysis of Marine Operations for Installation and Maintenance of Offshore Wind Turbines

SINTEF provides solutions to analyse various marine operation scenarios for offshore wind applications. The solutions can be provided by model tests, numerical simulations or a combination of the two.

SINTEF has tools for numerical modelling of hydrodynamic response of slender marine structures and large volume floating structures. Standard coupling wires for towing and lifting, winches, cranes, fender/bumper/docking cone contact and ballast system can all be modelled. With upper limits of the allowed motion and tension specified, the limiting sea states of performing a particular operation can be identified. 3D visualization of the simulation is available.

Model tests of a wide range of marine operations, such as towing, up-pending and lifting operations, can be performed in the Ocean Basin.

Research fields:

- Installation methods for fixed and floating offshore wind turbines.
- Analysis and model testing of tow out.
- Repair and replacement methods for large components on offshore turbines.
- Transfer of personnel from vessels to offshore wind turbines (walk-to-work).

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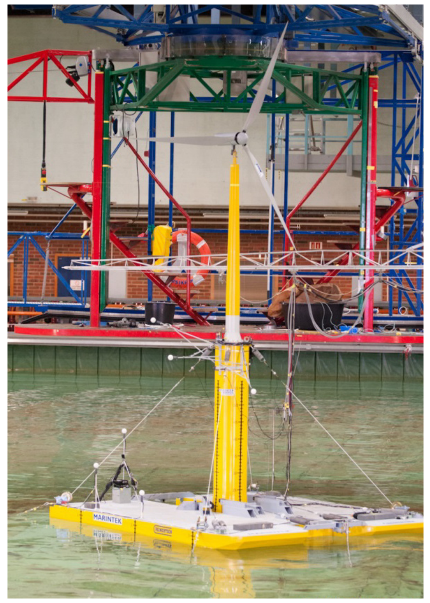

Structural Integrity of Dynamic Power Cables for Offshore Wind

SINTEF Ocean has a long track record of performing both structural analyses and testing to verify the integrity of subsea dynamic power cables. With our tailor-made software combined with decades of expertise on structural behaviour of slender marine structures, we provide deep insights on component level to describe the loads and responses within the floating offshore wind (FOW) dynamic power cables.

We also do research on ultimate- or fatigue capacity of other marine structures or components, often by a combination of advanced FEM analyses and structural testing.

Some of the main topics related to the FOW dynamic power cables are:

- Structural integrity analyses and full-scale verification testing.
- Dynamic testing of cables under combined compression and bending loads.
- Fatigue testing and structural analyses of components and marine structures.
- Torsion analysis and testing.
- Material testing, including SN data and friction factors.
- Vortex Induced Vibration (VIV) analyses in both frequency and time domains and testing.
- Flow induced motion analyses and testing, including Vortex Induced Motion (VIM) and galloping.
- Cable laying and on-bottom stability analysis considering 3D seabed terrain.

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Ocean Basin Laboratory

The Ocean Basin Laboratory is used for basic as well as applied research on marine structures and operations.

A total environmental simulation including wind, waves and current offers a unique possibility for testing of models in realistic conditions. With a depth of 10 metres and a water surface of 50x80 m, the Ocean Basin Laboratory is an excellent tool for investigation of existing or future challenges within marine technology.

Ocean basin laboratory data:

Size:	80x50x10 m
Max. current velocity:	0.25 m/s

Regular waves:

Maximum wave height:	0.9 m
Wave periods:	0.6 s and above

Irregular waves:

Maximum Hs:	0.5 m
Peak period:	0.7 s and above

The carriage system follows free running models with no constraints at speed up to 5 m/s, at any heading relative to the waves.

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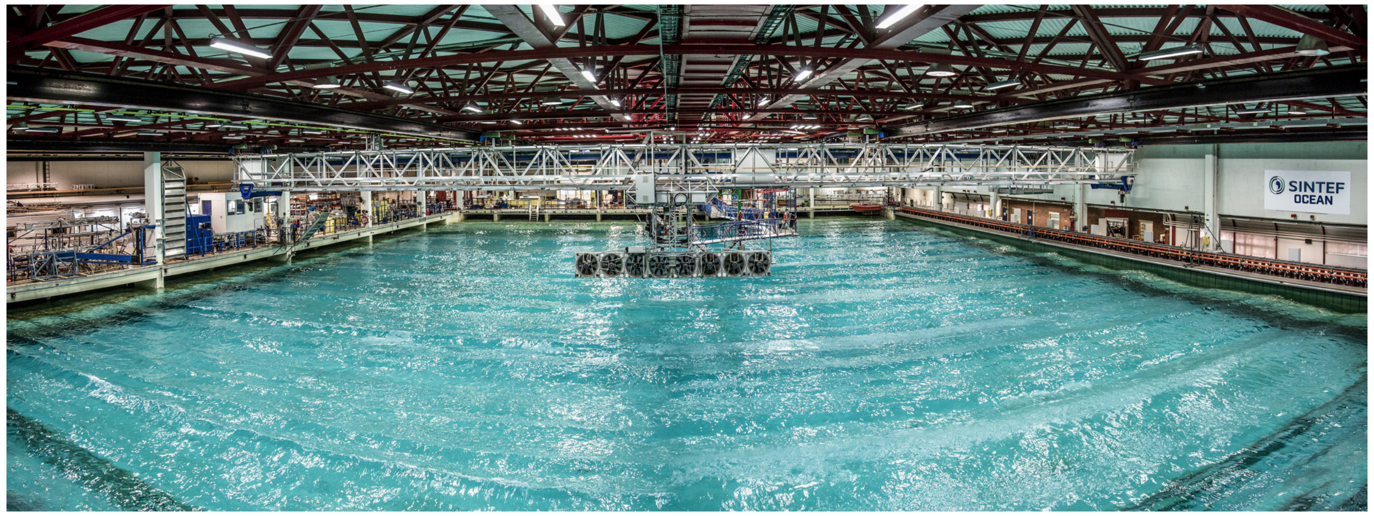

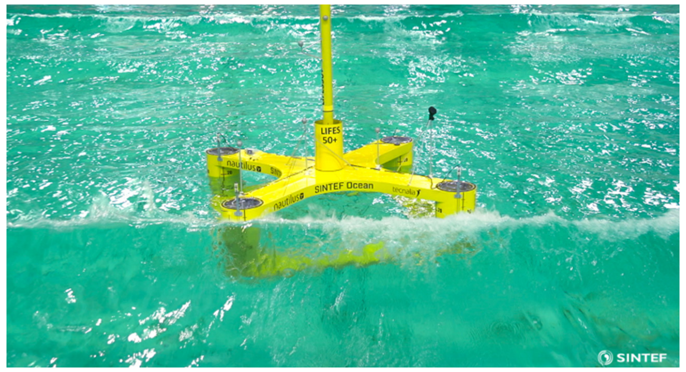

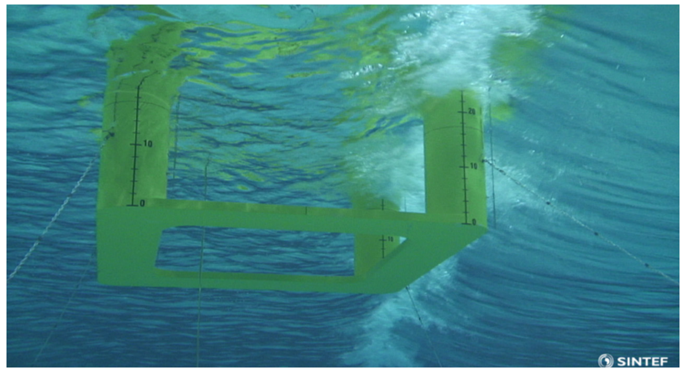

For more information and full description of all our laboratories, please visit **www.sintef.no/ocean-laboratories**

Ship Model Tanks

The main activity of the towing tanks is related to hydrodynamic performance of ships. This includes resistance, propulsion, seakeeping in head and following seas, and directional stability tests with free running models. The tanks are equipped with two carriages: One for towing up to 10 m/s for traditional calm water tests, and a second carriage for seakeeping tests and other tests performed with fixed or free-running models.

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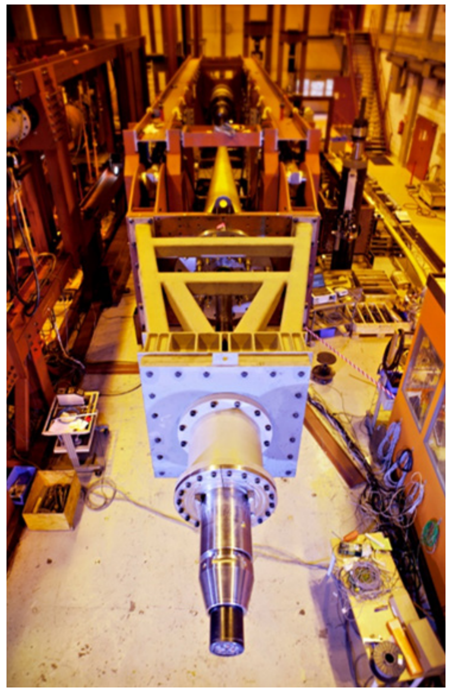

Marine Structures Laboratory

The main activities in the laboratory for marine structures are the testing of structures, structural components and materials. Typical problems involve fatigue testing, ultimate strength and collapse testing. Experimental work is often combined with analytical or numerical analysis. The laboratory is certified to ISO 9001.

The laboratory has permanent test frames for full scale testing of flexible risers, loading hoses, umbilicals and power cables. These frames can provide a combination of axial tension and bending loads, and can be used for qualification testing of power cables. A permanent test frame for combined axial and compression loading is particularly relevant for power cables. Mid-scale frames suitable for combined tension and curvature loading of separate conductors allows for more detailed studies of the cable components, as well as small scale frames to study for example single strands.

In addition to the permanent test frames, the laboratory has a range of load actuators and modular frame systems that can be combined to build unique set-ups.

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SIMA

Are you looking for in-place analysis or marine operations software that can do coupled analysis of any type of marine structure, including fixed and floating offshore wind turbines? SIMA can perform analysis, including the coupled effect of waves, wind and current for structural analysis or mooring analysis. For many floating structures, the combined effects of wind, current and waves must be taken into account. When this is to be applied to complex, multi-body systems, very efficient calculations are needed. SIMA computations are based on the well-known and highly efficient solvers, SIMO, RIFLEX and VIVANA.

SIMA is distributed by DNV and interacts seamlessly with the other modules of the Sesam package.

MODELLING CAPABILITIES

- Modeling of wind using 3D wind field (imported from TurbSim or IECWind), 2D wind or constant wind.
- Aerodynamic input
- Blade aerodynamic properties (including pre-bend and twist) for BEM method with dynamic inflow
- Dynamic stall based on lift curve
- Tower shadow option
- Up/downwind option
- Control system including pitch control for blades, torque control and power take-off. Internal control system with user-defined coefficients or completely user-defined control system may be applied.
- First and second order wave loads, current load, mooring system and wind drag forces on tower and nacelle may be included.
- Geotechnical models may be included as global springs in the finite element model.
- Generic nonlinear finite element solver for slender structures is included which may be applied to mooring lines, power cables, tower and blades.

INTEGRATED ANALYSIS

All the important physics are integrated in a single model which is solved in the time domain:

- Floater: hydrodynamic loads (1st and 2nd order potential wave forces, viscous drag).
- Mooring lines: hydrodynamic loads (generalized Morison load model), structural response, seabed contact.
- Tower: wind loads and structural response. Tower upwind effect on wind field by potential theory approach
- Blades: aerodynamic loads using BEM method (with dynamic inflow) on each element, structural response of blades
- Eigenfrequency solver is included
- Control system for blade pitch and electrical torque control algorithms

POST PROCESSING AND REPORTING

The SIMA workbench includes graphical tools for batch processing, complex workflows, post-processing and reporting of results. The workflow module allows the user to interact with external programs (such as python or irregular wind generators) when needed. Static, dynamic and eigenfrequency results are visualized in the 3D view. SIMA supports time domain analysis on a large scale. The licensing policy allows unlimited parallel runs on a single workstation.

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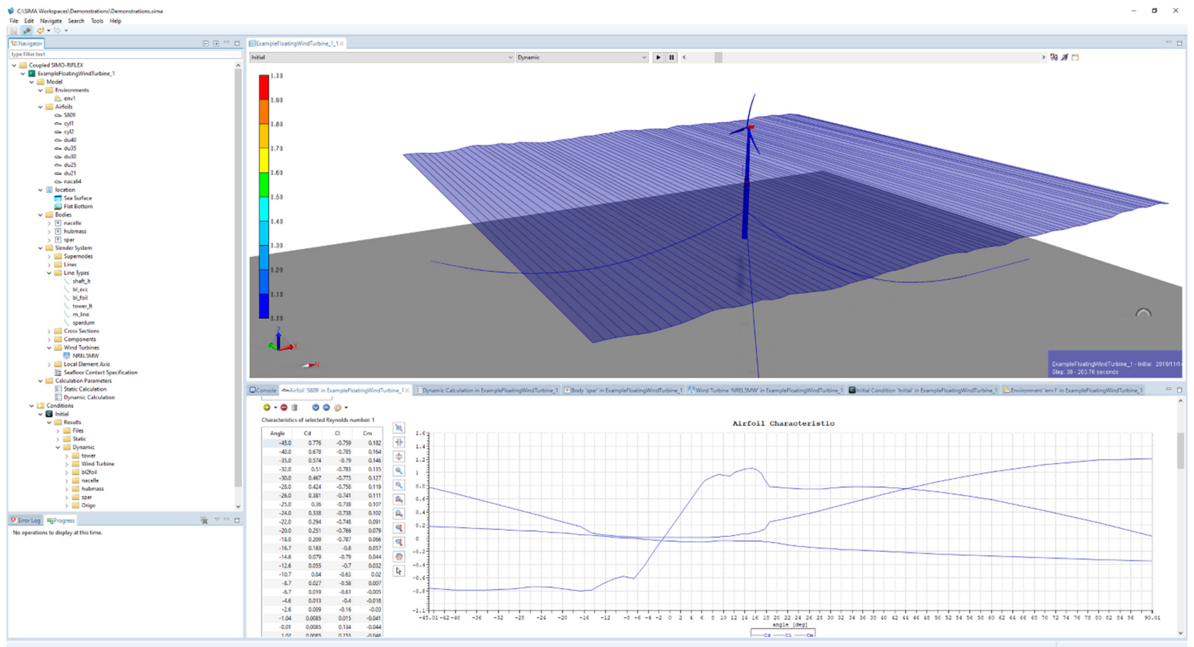

Real-Time Hybrid Model Testing

Real-Time Hybrid Model Testing* for floating offshore wind turbines was developed, and applied since 2015 to overcome:

- the Froude-Reynolds scaling incompatibility when model testing offshore wind turbines, and
- the uncertainty around the wind field generated in hydrodynamic facilities.

A physical substructure, consisting of a physical floater subject to waves and current is coupled to a numerical substructure used to simulate the wind turbine rotor loads. The simulated loads are applied at the tower top on the model by use of a cable-driven parallel robot. The use of a cable driven parallel robot enables us to apply the rotor loads in 5DOF (vertical loads have been documented to be unimportant for the tested concepts), with very short response time.

The main advantages of the method are

- a high level of control over the wind field and the rotor loads,
- high flexibility in the testing conditions allowing for testing of extreme cases, such as fault situations (blade seize), shutdown, wind gusts, change of wind direction,
- reduced cost since no physical rotor design is needed.

*ReaTHM® testing is a registrated trademark of SINTEF Ocean.

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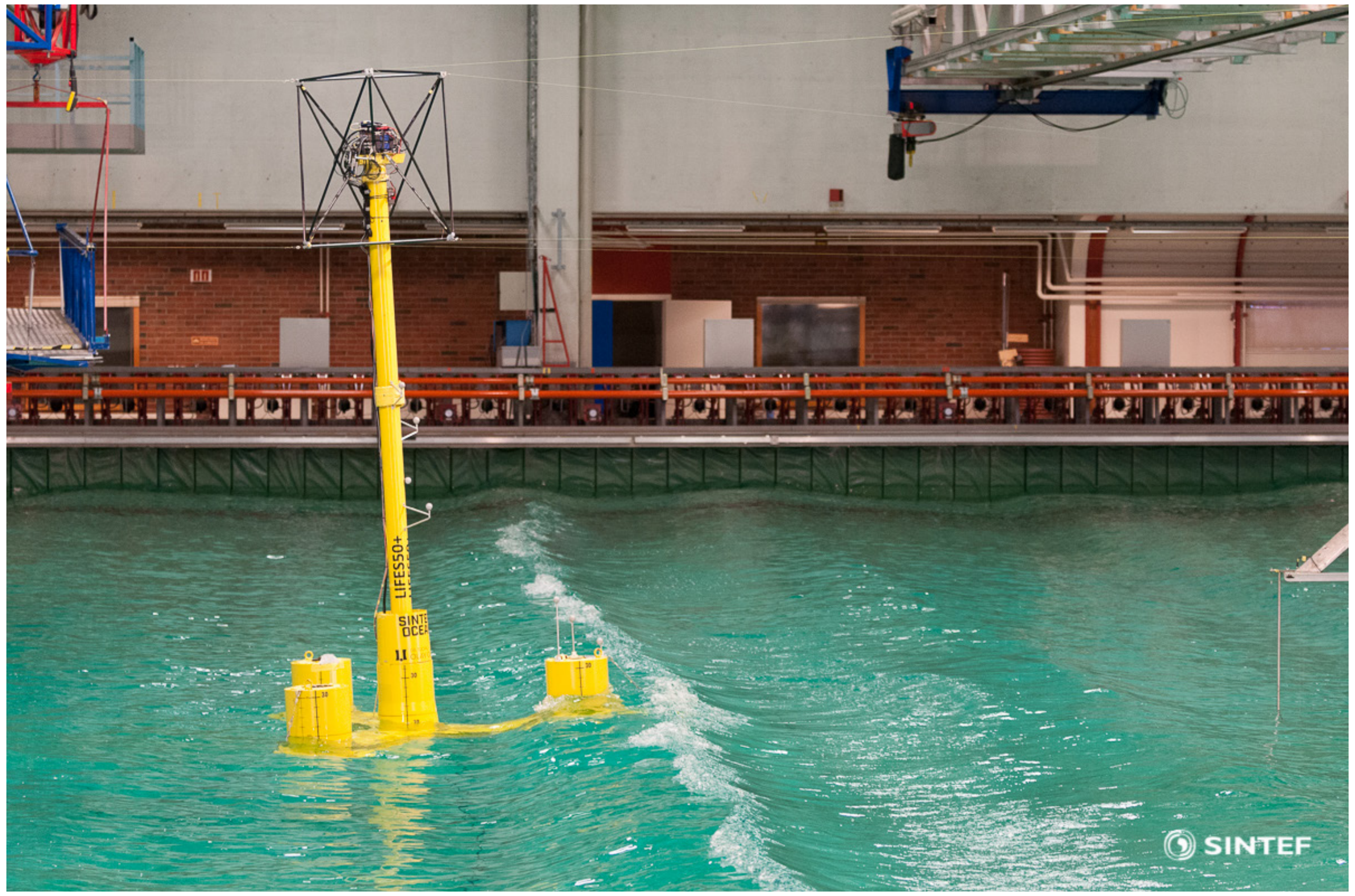

SIMLA

The SIMLA software system is a special-purpose tool for global nonlinear static and dynamic analysis of cables. The software is applicable for cable routing and assessment of seabed intervention work, cable laying analysis with RAO vessel motions, on-bottom roughness analysis, on-bottom stability analysis and for simulation of interaction between cables and fishing gear. SIMLA has a broad application range from simplified analysis during early-phase design to advanced nonlinear structural analysis using the finite element method.

Detailed seabed surface representation and advanced soil-structure interaction models are available. Complex irregular seabed topography based on DTM survey data can therefore be applied. High-performance contact models for bellmouth geometries, rollers, 3D bodies and cable-in-pipe systems are also implemented. The software offers a very robust and effective tailormade procedure for computing the cable static equilibrium configuration for arbitrary routes on 3D uneven seabed. In addition to tailormade procedures, the highly flexible modelling options permit a wide range of cable global response scenarios to be studied.

The software system includes a standalone tool specifically developed for assessment of cable routing and seabed intervention. This tool is very powerful during early phase design studies for identifying the most optimal cable route. Accurate estimates of the rock/gravel fill volumes and the excavation volumes are estimated efficiently. The tool allows for exporting high-quality images and videos of the cable system with analysis results, the seabed surface and user-imported geometry objects.

Capabilities:

- Optimization of cable route and seabed intervention
- On-bottom dynamic stability analysis of cables
- Effective and robust cable laying analysis methods
- Assessment of cable laying stability in route turns
- Simulation of fishing gear interaction loads
- Nonlinear bending models for cables
- Axial and torsion response models for cables

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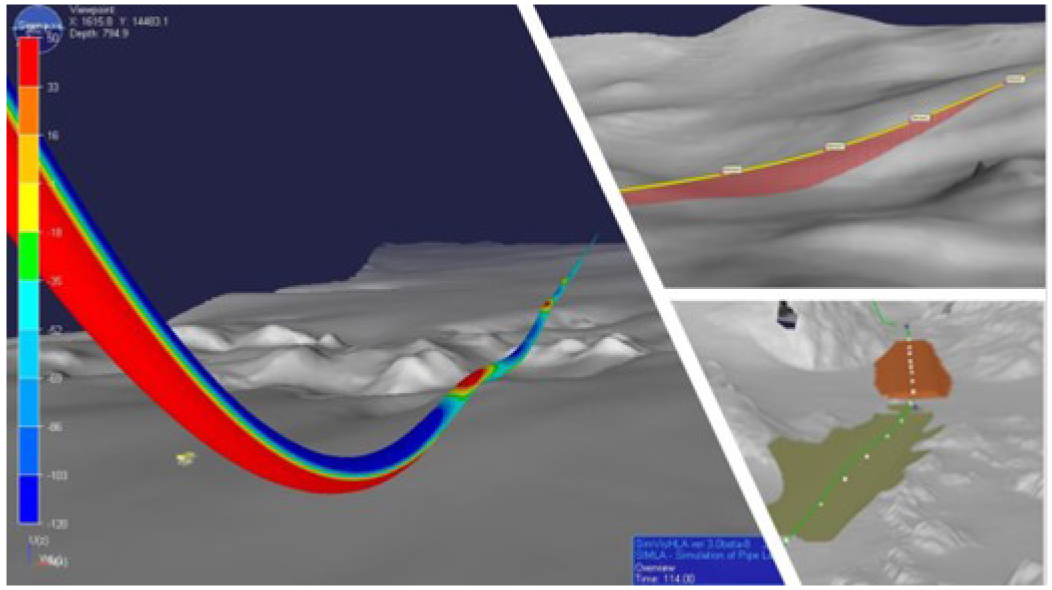
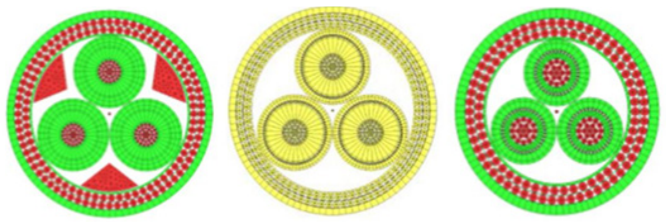


UFLEX

The UFLEX software system is a tool for local stress analyses for complex cable cross sections. Global mechanical properties for the cable can be established based on the cable design. In combination with global analysis of the dynamic behaviour, UFLEX provides the results that are required to determine the design life of a cable. Critical components within the cables are identified, and capacities for different load combinations can be defined.



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Torsion

Power cables, umbilicals and flexible pipes can display torsion-related behavior during handling. For example, when a flexible product is routed from an onshore turntable to an installation vessel, longitudinal markings may be observed to roll. Torsion builds up, until either the flexible product is damaged ("herniation buckling" is one of several local buckling modes that have been documented) or takes a helical shape which is difficult to manage. Often the damage is superficial and the consequences limited. On the other hand, sometimes expensive products are damaged, deliveries are significantly delayed, and installation of vessels remain on stand-by.

Since 2009, SINTEF has investigated multiple torsion-related failures which occurred during either production, loadout (to installation vessels), installation, or operation. This has given us a unique insight into the complexity of torsion: A glossary of all the terms needed to describe torsion-related concepts, just to make it possible to discuss a mishap, a failure or an improved design, takes several pages. The mathematics needed to model the relevant processes includes advanced concepts (rotations in 3D, material vs. spatial derivatives, etc.). From 2018 to 2022, SINTEF has carried out the Torsion JIP, which delivered a 200 pages "Torsion Handbook", detailing the physics and mathematics involved, and providing guidelines for the prevention of torsion problems. The project also delivered simple software for the analysis of the effect of route geometry on torsion.

SINTEF is currently developing a torsion test rig, to specialized products' torque capacity and other "load parameters". The Torsion KPN (planned 2023-2027) will develop a specialized finite element tool, which, with the above mentioned load parameters will provide detailed simulation of torsion loads in all phases of operations. This will provide our customers with the ability to design better handling systems, verify operations beforehand, and train personnel. The torsion test rig will also be used to validate the torsion capacity criteria provided in the Torsion Handbook.

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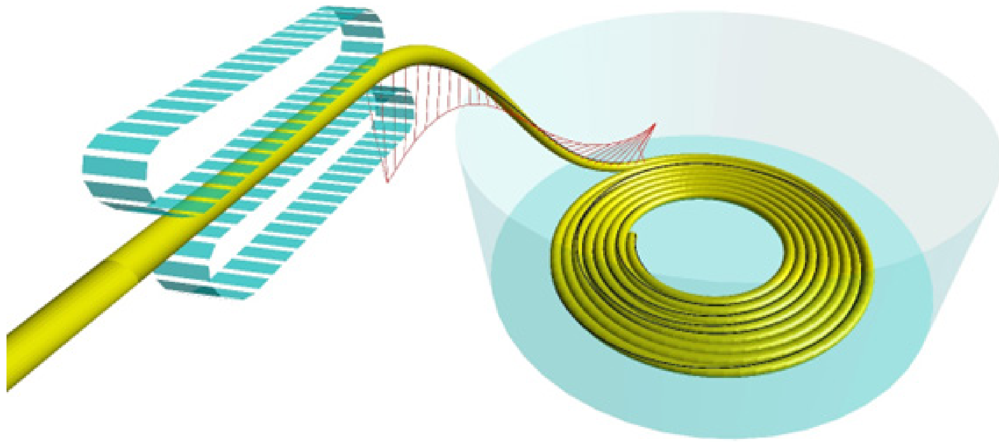

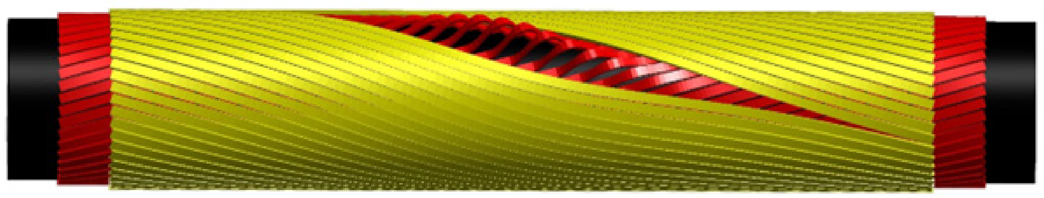

DIWA: Wind simulation in a farm

Wind turbines, both floaters and bottom fixed, are normally placed in large farms. The wind in farms consists of both the ambient turbulent wind and wake created by upstream turbines. The wake consists of a deficit, with reduced wind speed, and an increased turbulence. For the fixed wind turbines, it has been the increase in the low frequency turbulence that has been the most important. However, the floating wind turbines has much higher eigenperiods, and thus the large scale turbulence are more important. The meandering of the wake, that is caused by the large scale turbulence, will have an impact on the response of the floating wind turbines

DIWA generates new wind boxes, based on either Mann turbulence boxes or TurbSim turbulence boxes, which contains the wakes from upstream wind turbines. It uses dynamic wake meandering (DWM) theory, as recommended by the IEC standard. The main aim of the program is to provide the user with a wind box for aero-servo-hydro-elastic simulation of the wind turbine, but it can also generate visualization of the wind through the wind farm and estimate the power and thrust.

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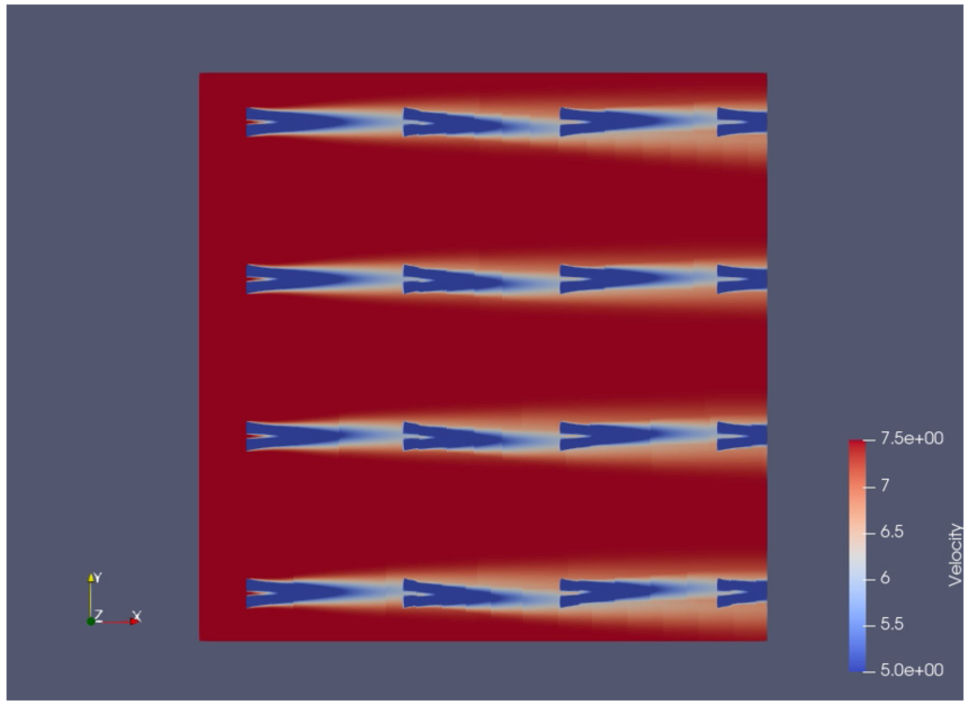

Installation logistics tool

The installation process has shown to be challenging and in many cases more cost- intensive than what believed necessary. Even though production costs have had significant cost reductions as the industry has matured there is still a large improvement potential when it comes to the installation logistics. While there exist a relatively large number of different decision support systems (DSS) for O&M, there is a lack of advanced decision support tools for the installation phase. Hence, through a series of projects we have developed (in close cooperation with the industry) an advanced innovative DSS with the goal of bringing down the handling and logistics costs of large components for the installation phase.

The installation logistics tool is a combined simulation and optimisation-based planning tool that optimise the subpart of the LCOE related to the installation phase. The DSS especially focuses on the choice of vessels and corresponding capabilities (lifting, speed, transportation capacity, accommodation, fuel consumption, weather limitations), activity schedule (depending on weather condition and resource availability), assembly strategy (onshore, offshore, at port), and ports and infrastructure capabilities. An optimisation-based decision support module uses advanced analytical techniques from operations research in order to automatically search for the best configuration of logistical resources

Numerical simulation and model testing of gangway systems

Several windfarms are being developed and there is an increasing need for advanced simulators supporting design and development of wind farm support vessels. Both as a tool to evaluate operational safety limits, and as a design tool for evaluating design parameters. SINTEF Ocean has both numerical simulators and experimental test facilities to evaluate wind farm support vessels. Our vessel simulator (VeSim) is capable of numerically evaluate position keeping capabilities as well as gangway operating limits. Thrusters are modelled with our propulsive library incorporating loss effects from thruster-thruster, thruster-hull and ventilation losses. The operability of the gangway can also be evaluated.

SINTEF's Ocean basin can be used for experimental validation of wind farm support vessels, both in terms of position keeping capabilities, vessel responses and gangway operational limits. The dynamic positioning (DP) system can either be our in-house DP in VeSim or from a commercial DP vendor.

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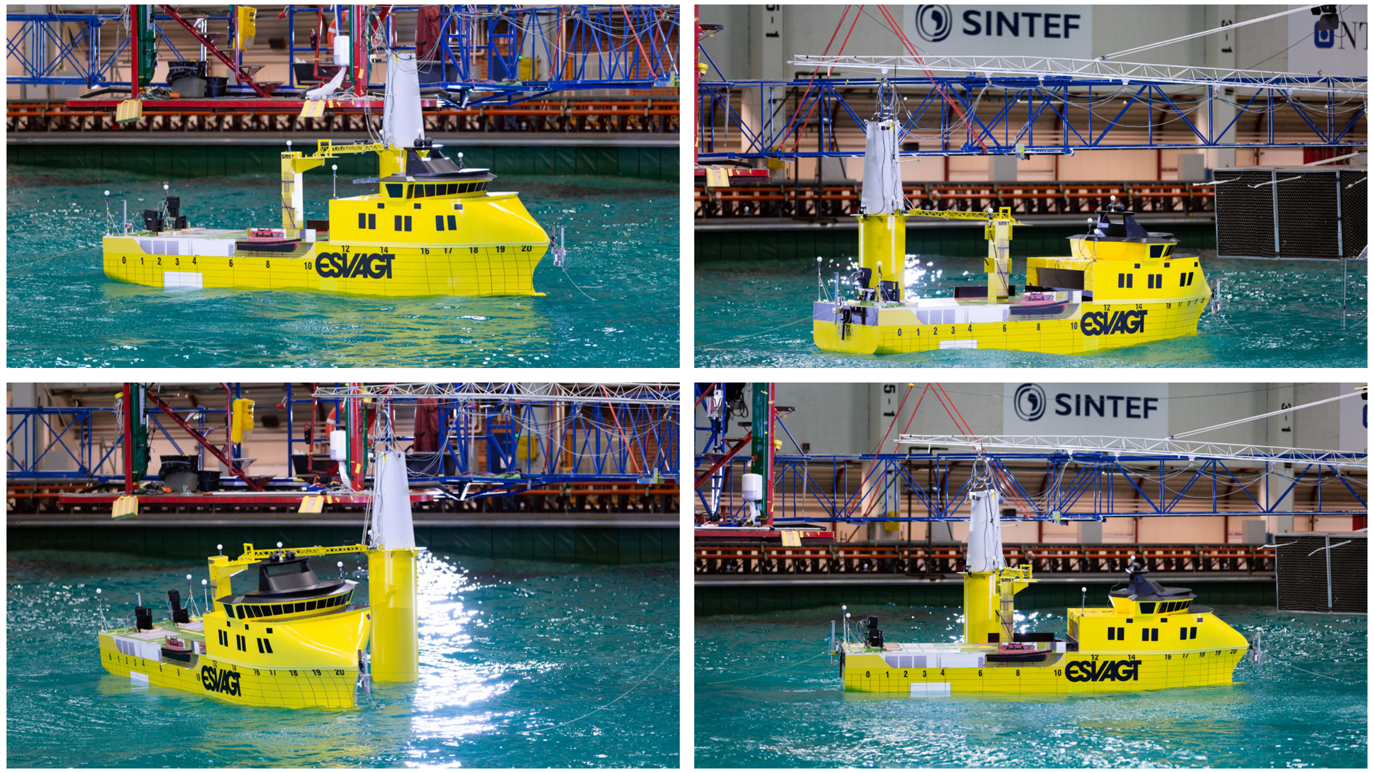

and activity schedule for transport and installation of offshore wind farms. Thereafter the simulation module enables a visualisation of the risk profile of the installation plans as well as the expected time and cost for the optimised installation strategy.

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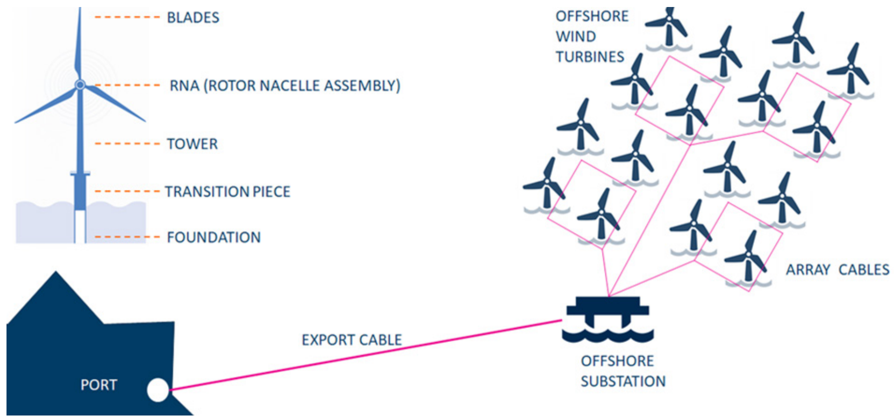

Numerical Wave Simulators

Most numerical tools for the design and analysis of offshore structures are based on wave simulations. Depending on applications, the quality of the analyses strongly relies on the accuracy of the generated wave data. Due to the nonlinear characteristics of the equations describing the propagation of waves at the water surface, no closed form mathematical solution exists to model wave properties in a general way. Simplified and fast models, such as linear or second-order wave theory, assume low steepness, and consequently fail at reproducing steep wave events, which are often the primary ones of interest for design purposes.

At SINTEF Ocean, we are developing capabilities to couple our numerical analysis tools to high accuracy numerical wave models that can efficiently generate 3-hour realisations of steep sea-states defined in terms of a wave spectrum. Two Numerical Wave Simulators (NWS) are currently being developed at SINTEF Ocean. Both are one-phase potential solvers that provide surface elevation and wave kinematics in the whole computational domain at any simulation time. Depending on the targeted application, the most suitable code is selected in terms of efficiency and capabilities. In cooperation with NTNU, much focus is put on validation to ensure the accuracy of the numerical models, even in the challenging cases of steep and breaking waves.

Applications for an NWS

- Digital twins of experimental wave basins to review laboratory designs and explore their range of capabilities.
- Identification of dangerous wave events along with their probabilities of occurrence for a given structure prior to model testing.
- Investigation of statistical properties of steep waves.
- Generation of three-hour nonlinear wave realisations for numerical analysis tools.

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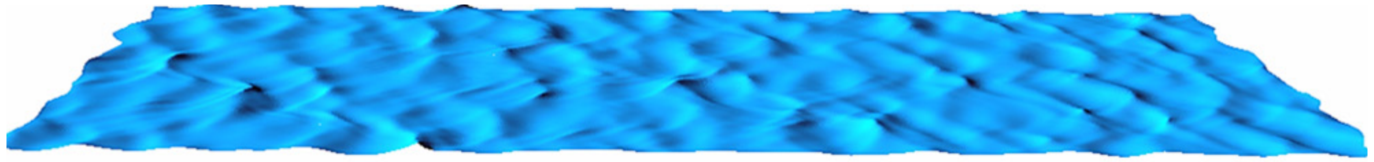
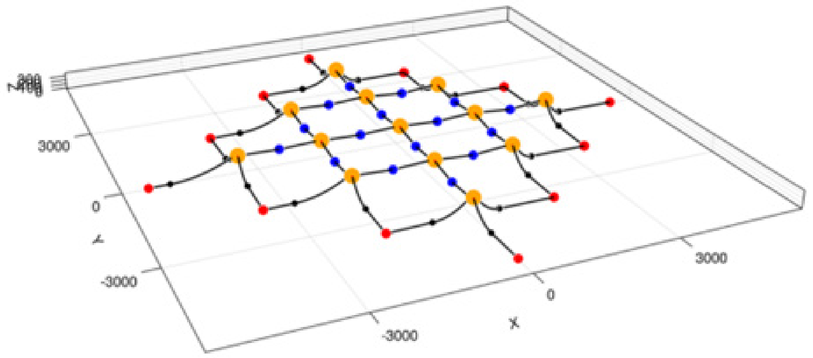


Floating wind parks with shared mooring system

Several novel concepts of floating wind parks have emerged in which wind turbines are not moored individually, but instead share mooring lines and anchors, as shown to the right. The aim of such park layouts is to minimize mooring costs, mitigate supply-chain challenges, minimize impact on the seafloor due to anchors, and possibly mitigate extreme loads in the mooring system.



SINTEF Ocean drives forward the research on such lattice-like marine structures, and offers services related to:

- Preliminary modeling and optimization of shared mooring systems. In particular, SINTEF develops and maintains OptimISt™, a finite-element-constrained optimization tool for interconnected structures.
- Systematic study of failure conditions (loss of one or several lines)
- Modal wave and wind loads analyses, and extreme value statistics of key quantities for the wind park, such as relative and absolute offset between turbines, tensions in the shared and anchored lines, etc.
- Complete dynamic analysis of floating wind parks using SIMA

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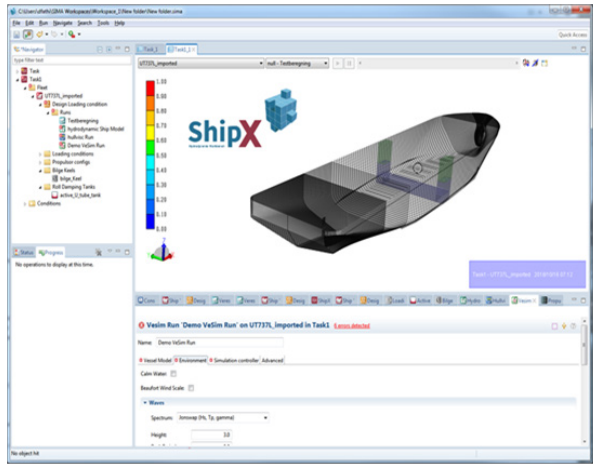
ShipX



For more than 15 years we have developed a hydrodynamic workbench called ShipX. ShipX incorporates a multitude of hydrodynamic tools enabling the user to perform many different types of calculations based on the same vessel input. The basic idea behind ShipX is to make a platform that integrates all kinds of hydrodynamic analysis into an integrated design tool. By removing the need for file format conversions and re-entering of input for each new program, systematic design studies using highly advanced hydrodynamic analysis tools is fully possible.

In addition to the basic functions built into ShipX, like hull geometry manipulation and database operations, advanced functions are added as "Plug-Ins". The basic functions built into ShipX makes it fast and easy to create new "Plug-Ins". Currently, plug-ins for seakeeping calculations (VERES program package), animation of ship motions, simulation of manoeuvring and station keeping capabilities as well as calm water performance prediction and calculation of speed loss in waves are all available as "Plug-Ins". In addition, the new report generator at SINTEF for analysis of performance tests is developed as a ShipX Plug-In.

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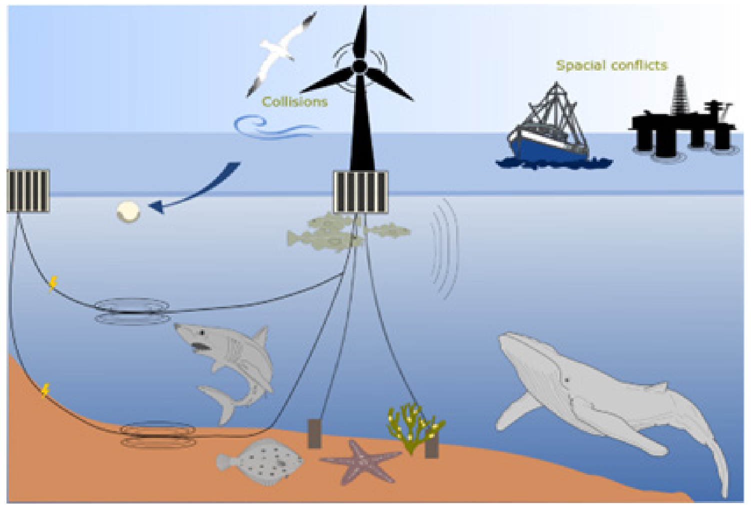
Potential physical and chemical impacts of offshore wind farms on the marine environment

SINTEF Ocean has for decades worked with chemical and particle pollutants in the marine environment, including advanced chemical and particle analyses, ecotoxicity testing and environmental risk assessments (ERA). During planning and development of offshore wind farms (OWF), concerns about the potential environmental impacts of chemical and particle releases, as well as physical impacts (noise, electromagnetic fields), have been raised.



Chemicals of relevance for OWFs include lubricants, coatings (paints, polymers and additives) and antifouling agents, in addition to particle erosion from rotors and subsea structures. In order to use environmental models to perform ERA, there is a need to identify chemicals leaching from OWF, understand their fate and behaviour in the environment as well as their toxicological significance.

Electromagnetic field from submarine power cables used offshore may impact marine species that use the Earth's geomagnetic field for orientation and migration. SINTEF Ocean is developing an experimental system enabling exposure of marine organisms to EMF in a controlled manner. The primary focus is to use video analysis to assess the effects of EMF on swimming and feeding behaviour on a range of marine species, with the ultimate goal of establishing effect thresholds for EMF enabling an evaluation of the potential for EMF to be an environmental risk driver for offshore wind installations.

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WINDMOOR: Advanced Wave and Wind Turbine Mooring System Design

In order to grow from its present nascent stage – several demonstration projects and one small commercial farm – the floating wind turbine (FWT) industry needs further cost reductions and design improvements, especially related to the hull and mooring system.

The WINDMOOR project is a research and competence-building project (KPN), financed by participating industry and the Research Council of Norway through the ENERGIX programme. The SINTEF-led project aims to better understand the forces from wind, waves and current – all of them being significant drivers for the hull and mooring system design – as well as assessing novel mooring systems for wind farms in shallow and deep water. To enable more efficient design of FWT farms, the project will address several limitations of today's global aero-hydro-servo-elastic analysis tools:

- Synthetic fibre rope mooring system components require adapted material models and analysis methods. Relevant material models have been implemented, but their consequences for design have not yet been studied, and a systematic investigation of design drivers for the mooring system at different water depths is proposed.
- The prediction of low-frequency hydrodynamics responses due to waves and currents, especially for semi-submersible type FWTs, using state-of-the-art tools, is not satisfactory. Alternative load and wave kinematic models, including application of computational fluid dynamics, will be studied and validated against new experimental tests. The new experimental tests will include quantification of the repeatability of low-frequency responses, systematic investigations of the effect of changing the platform pitch angle, and simultaneous inclusion of realistic aerodynamic loads.
- The incoming wind field applied to a turbine is usually described based on spectral parameters for neutral atmospheric conditions, and only a single turbine is typically considered. The present project will address the consequences of accounting for atmospheric stability and dynamic wake meandering effects.
- Simplified simulation methods which can account for shared mooring components in a farm configuration will be developed.

This 4-year project started in 2019 and partners include SINTEF, NTNU, Equinor, Inocean, MacGregor and APL Norway.

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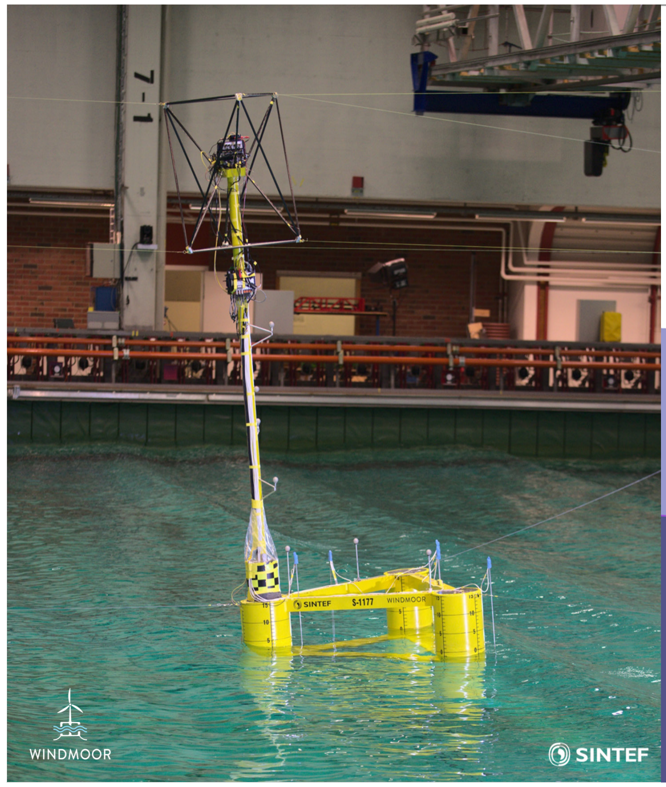

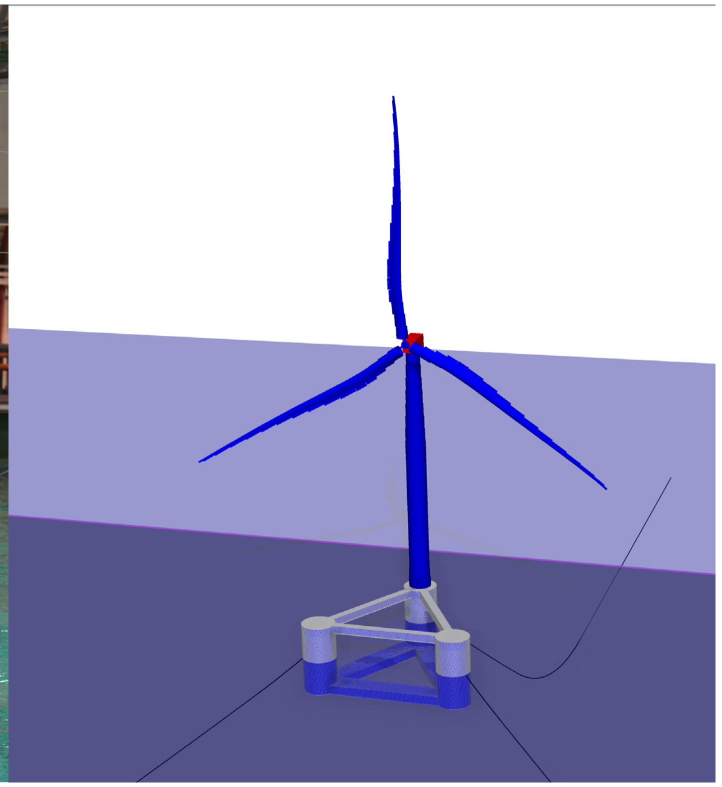

WAS-XL: Wave Loads and Soil Support for Extra Large Monopiles

Economies of scale are pushing for larger (6-12MW) offshore wind turbines (OWT), which require larger support structures. For shallow and intermediate water depths, large-diameter monopile foundations are considered most promising with respect to the levelised cost of energy. However, the eigenfrequencies decrease – getting closer to the primary wave frequencies – as structure size increases. This makes the structure more susceptible to nonlinear wave loading, for which more accurate and validated analysis methods are needed. Also, the wave load history on the monopile has an impact on the soil response, which current design practices do not address properly.

The project addresses uncertainties related to nonlinear wave loads and responses of large-diameter wind turbines with a focus on integrated engineering analysis including soil responses. The work combines numerical and experimental methods. The combination of expertise in hydrodynamics and geotechnical engineering permits detailed study of non-linear phenomena and application of new models to long-term structural response modelling.

The project aims to produce and disseminate results of academic and practical importance:

- New model scale data for validation of nonlinear hydrodynamic wave kinematics and loads on monopiles in steep waves.
- Advances in numerical and empirical engineering methods for including nonlinear wave loads in the design of offshore wind turbines.
- Improved and verified design tools for integrated analyses.
- Recommended practice on the use of monopile soil models accounting for irregularity in cyclic load histories and partial drainage in the soil.
- Recommendations to design practice and standards.

This 4-year project started in 2017 and partners include SINTEF, NGI, NTNU, Equinor, Vattenfall, Innogy, EDF and Multiconsult.

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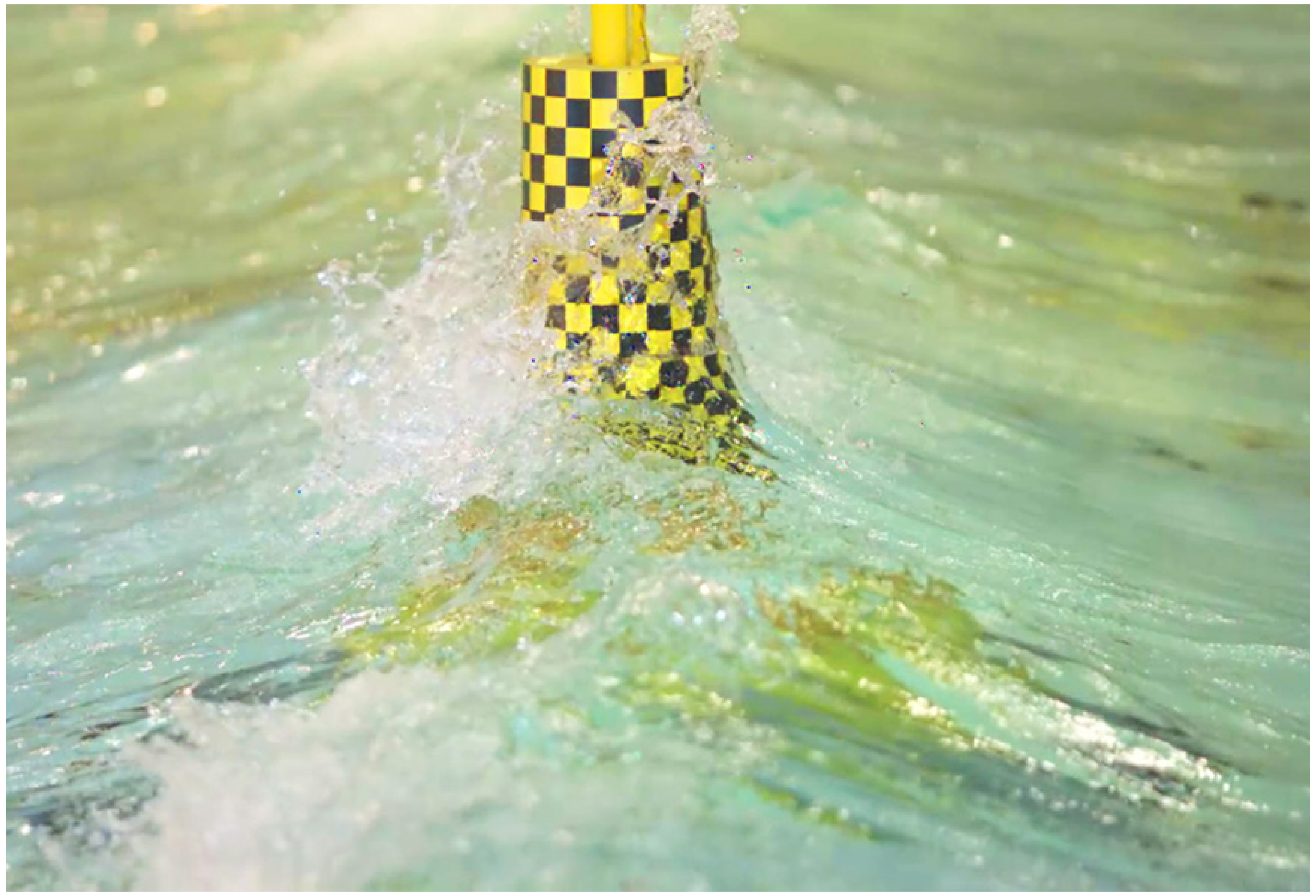
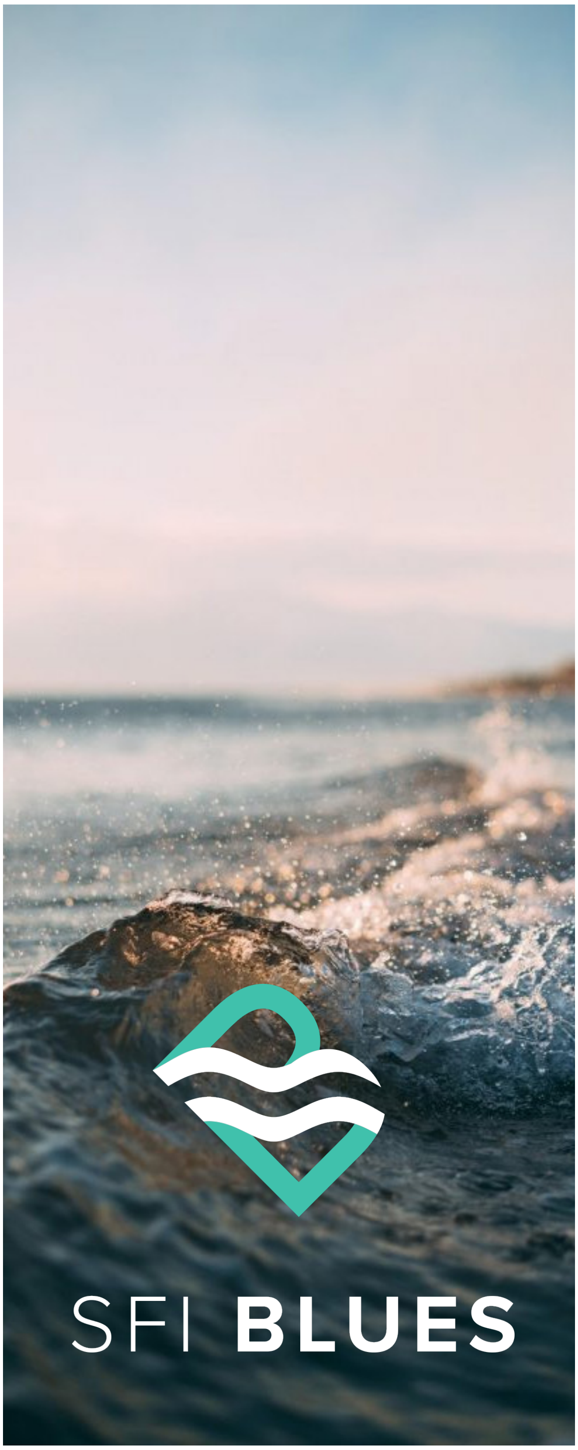


Long term research centres

SINTEF Ocean hosts SFI BLUES and is a key partner in FME Northwind. These are long-term research centres involving research institutes and industry partners.

SFI BLUES (2021-2028) is a centre for research-based innovation enabling Norwegian industry to create new types of floating structures for renewable energy, aquaculture and coastal infrastructure www.sfiblues.no.

FME Northwind (Norwegian Research Centre on Wind Energy 2021-2028) brings forward outstanding research and innovation to reduce the cost of wind energy, facilitate its sustainable development, create jobs and grow exports. www.northwindresearch.no



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