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REVIEW

Operation and maintenance of offshore wind farms: cost and benefit analysis

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Figure 1. Lillgrund offshore wind farm. Source: hochtief.com

It is important to be able to analyse the consequences of new concepts and strategies for the operation and maintenance of offshore wind farms. NOWITECH (Norwegian Research Centre for Offshore Wind Technology) has developed a framework and structure for a life cycle cost and benefit model for offshore wind farms with special emphasis on operation and maintenance, and work on developing a prototype has begun.

NOWIcob is the name of a model currently under development, which aims to calculate the life-cycle costs of an offshore wind farm. The primary focus of the model is on analysing operation and maintenance (O&M) activities. The whole life-cycle is taken into account in the development process in order to enable all the effects of new concepts to be analysed.

The NOWIcob model

NOWIcob is divided into two parts: a database and a simulation/optimisation model. The general structure of the model is illustrated in Figure 2 (see page 2).

The database contains all the information needed to simulate the lifetime of an offshore wind farm. Part of this information comprises data on weather and failure statistics, maintenance activities and general technical data. The other part contains technical specifications, i.e. type of wind turbines, their access solutions, number and types of vessels etc.

The simulation/optimization model is divided into a number of modules. This division has been made for several reasons:

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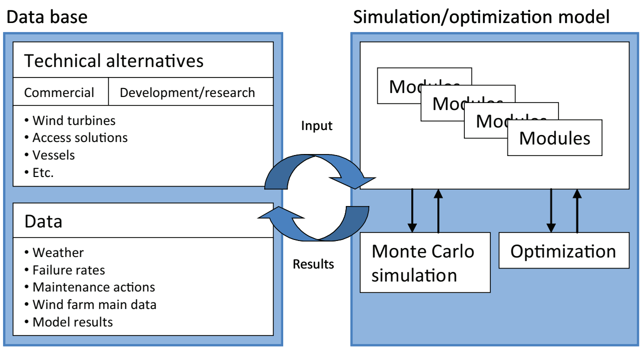

Figure 2. General structure of the NOWIcob model

- Simple to maintain an overview of the model
- Easier to implement
- Modules can be improved or changed without having to redesign the whole model
- Facilitates communication between experts

Uncertainty in input data will be considered by a Monte Carlo simulation approach in which weather states and failure events, for example, will be drawn from their respective probability distributions. Some decisions of importance for maintenance strategy and logistic operations are planned to be optimized in the model by means of heuristic search algorithms.

Operation and maintenance activities

In the NOWIcob model, special emphasis is placed on O&M activities. The objective of these activities is to provide lifetime support for the wind farm in order to reduce downtime and increase the power production and thus the revenues of the wind farm.

The O&M part of the NOWIcob model is split into two modules: one for the maintenance tasks, and one for operations and logistics. This separates the maintenance tasks from general operations and logistics activities. In the maintenance module a maintenance strategy is chosen and maintenance tasks are generated; these are subsequently input to the operations module, where the time required to perform the task and the costs are calculated. However, the modules are strongly interlinked, as an optimal maintenance strategy depends on optimal scheduling and performance of operations and logistics activities, and vice versa.

The objective of the maintenance module is to create the maintenance tasks that need to be completed. These tasks are of two main types:

1. Preventive maintenance: tasks carried out to avoid component failures and thus reduce system downtime
2. Corrective maintenance: tasks carried out due to unforeseen failures of the system or its components

The maintenance tasks are allocated time windows during which they should be performed. The main challenge is dealing with corrective maintenance tasks, since by definition, the need to perform such tasks cannot be anticipated. Various strategies may be employed, the simplest one being to repair all failures as soon as possible. Another strategy can be to group unplanned activities together with planned activities and thus reduce the costs of mobilisation and accessing the wind farm. Such strategies can be implemented in the maintenance module and the effects tested by the NOWIcob model.

The objective of the operations and logistics module is to calculate costs and time required to complete maintenance tasks. The tasks to be completed are input from the maintenance module. The time needed to perform each task is then calculated from the following components:

- Logistic time: Time to mobilize resources (personnel, equipment, spare parts, transportation)
- Assembly onshore: Time used to preassembly components onshore
- Weather time: Time to wait for suitable weather conditions (weather window) to perform the offshore operations
- Travel time: Time used to travel to the wind farm
- Operation offshore: Time needed offshore to complete the maintenance task

Applications of the NOWIcob model

The NOWIcob model aims to be a tool that can be used by researchers and wind-farm developers and operators. It can be used as a tool to simulate the total lifetime of an offshore wind farm. The main application is the analysis of different O&M strategies, although decisions with regards to the design of the wind farm can also be examined.

Some examples of decisions on O&M strategies that can be analysed are:

- Location of maintenance base
- Location of maintenance personnel
- Scheduling of maintenance tasks
- Location of warehouses with resources
- Inventory strategy for spare parts
- Vessel fleet size and mix and ownership
- Number of maintenance teams

In general, the NOWIcob model analyses the effects of a given infrastructure and strategy for operation and maintenance. Testing several options and combinations gives decision-makers information regarding which choices can be expected to perform best. Due to the large number of options and combinations, further work on NOWIcob aims to incorporate search algorithms so that the model can provide users with optimal or near-optimal decisions on strategies for O&M activities.

WINDOPT - Optimisation of floating support structure for deepwater wind turbines

›› Research scientist Petter Andreas Berthelsen
›› Senior principal research engineer Ivar Fylling

Floating wind turbines are exposed to wave-induced motions that intensify the dynamic interactions between the support structure and the wind turbine. Conceptual design processes will have to take such interactions into account and limit the wave-induced response in order to provide acceptable operating conditions for the turbine, and this needs to be done as cheaply as possible. MARINTEK has taken this into consideration and extended the mooring optimization tool MOOROPT to also include the optimisation of a floating wind turbine support structure.

Program description

WINDOPT is a program for conceptual optimization of floating wind turbine support structures of the spar-buoy type, including mooring system and power cable. Optimisation in this context is equivalent to minimizing costs while satisfying functional and safety-related design requirements. The program is an extension of the mooring- and riser optimisation tool MOOROPT. It utilizes efficient design tools for the analysis of mooring system forces and vessel motions, and combines this with a gradient method for solving non-linear optimization problems with arbitrary constraints. WINDOPT consists of the following three tools:

NLPQL – An efficient non-linear optimisation code

MIMOSA – A standard mooring analysis program used for the static and dynamic response analyses of moored floating structures

WAMOF3 – A hydrodynamic analysis tool for calculating hydrodynamic coefficients of slender structures

Test cases show that the strategy used by WINDOPT is capable of improving the spar buoy design, mooring system and power cable, even when design starting points are unfeasible.

Cost function

The cost function to be minimized is the total material cost of the spar buoy, mooring lines and power cable. The spar buoy is modelled as a set of cylindrical sections with different mass and cost properties, and each section with uniform

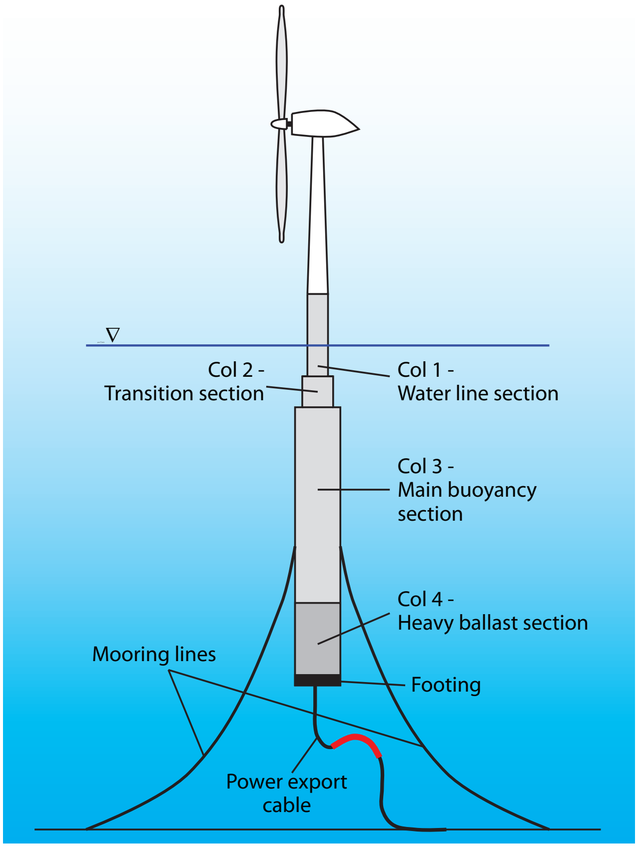

Figure 1. Wind turbine on a floating support structure. Idealization of spar buoy geometry.

mass distribution along its length. The cost is assumed to be proportional to the material mass. The mass of the individual parts of the buoy is scaled accordance to their sizes.

Design constraints

Typical design requirements (constraints) considered are: Vessel motion, tower inclination, tower top acceleration, cable tension and radius of curvature, mooring-line load limitations and minimum fatigue life, minimum horizontal line pre-tension, and maximum offset.

Different values of the constraints can be specified for individual cases that represent different operational and survival conditions.

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Energy from ocean tidal currents

Numerical simulation of tidal current turbine installation

›› Research manager Yusong Cao

In 2009 and 2010, MARINTEK's Houston office successfully performed a feasibility study of installation methods for a tidal turbine electricity generator for Clean Current Power System Incorporated (a Canadian company) and ALSTOM Hydro (a French company), the developers of the turbine. The study involved numerical simulations of the installation utilizing SIMO as the main software package.

Tidal turbine use tidal currents to generate electricity. The subject device in this study is a gravity-based unit that will be installed on the seabed at Minas Passage in the Bay of Fundy, Nova Scotia, Canada (Figures 1 and 2). The main objectives of the study were to determine the capacities of the major components of the installation (mooring cables,

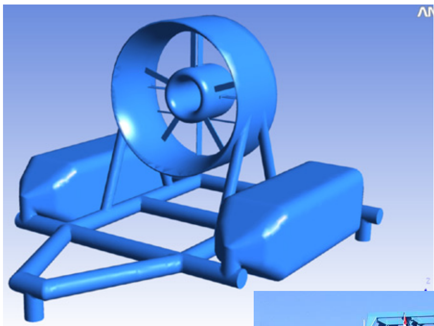

Figure 1. CAD model of the turbine. (Courtesy of Clean Current)

Figure 2. Ready for installation. (Courtesy of Clean Current)

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Design variables

Optimisation variables include the height and diameter of each cylinder section, the diameter of its damper plate (footing) and the vertical positions of the mooring-line fairleads. For the mooring lines and power cable, they include line variables such as line direction, pre-tension and distance to anchor, and segment variables such as segment length and diameter (mooring line) or submerged weight (cable). Buoy and clump weights can also be included in the optimization.

Acknowledgements

This work was performed as part of the NOWITECH programme, which is co-funded by the Research Council of Norway, leading industrial companies and research organisations. WINDOPT has been presented at the EWEA2011 [1] and OMAE2011 [2] international conferences.

[1] Berthelsen, P.A., Fylling, I.J., "Optimization of floating support structures for deep water wind turbines", EWEA2011, Brussels, March 14-17 2011.

[2] Fylling, I.J, Berthelsen, P.A., "WINDOPT – An optimization tool for floating support structures for deep water wind turbines", OMAE2011, Rotterdam, June 19-24 2011.

Examples

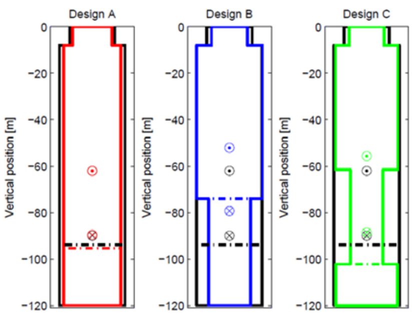

Figure 2. Examples of three different optimized designs of the spar buoy shape.

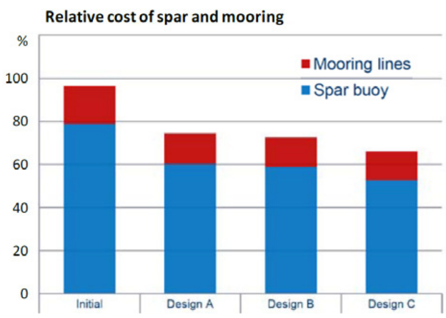

Figure 3. Examples of relative cost of spar buoy and mooring lines.

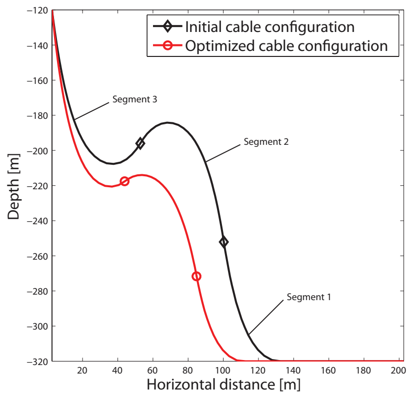

Figure 4. Example of optimization of power cable configuration.

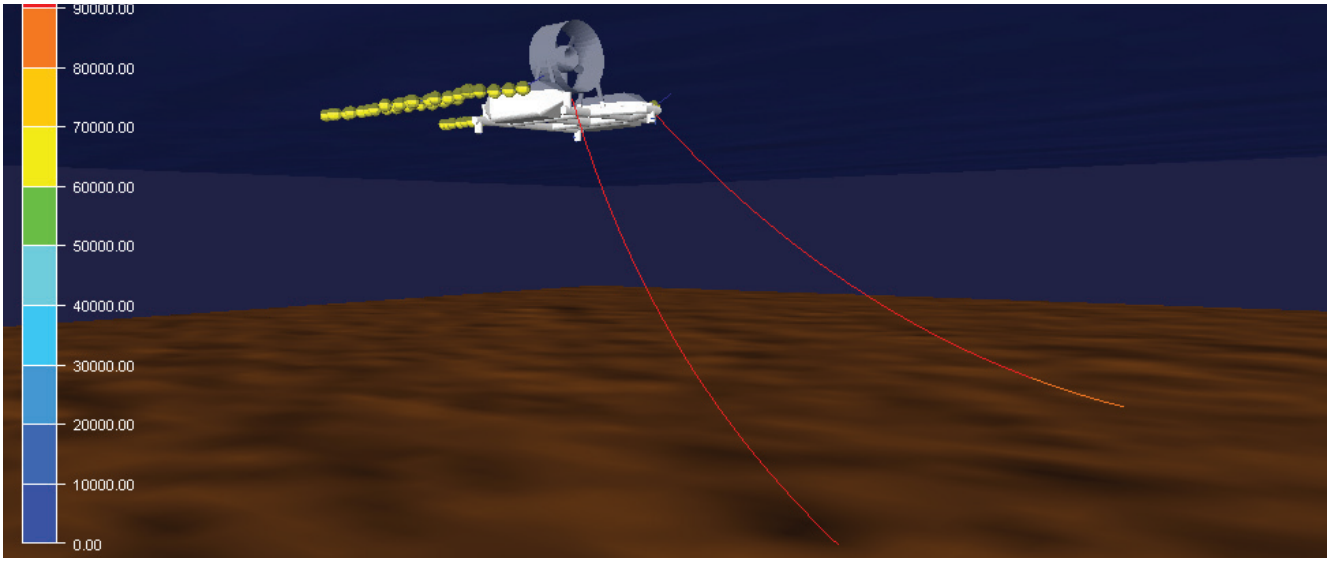

Fig.ure 3. SIMO model of the system, unit on the surface (MARINTEK).

buoyancy lines, ballast pump capacity, etc.), and develop a deployment procedure for safe installation under a wide range of wind, current and wave conditions. The simulation-based approach using SIMO involved an iterative search for a feasible solution for safe deployment of the unit on the seabed in three stages:

- Surface effects: the unit passing through the water surface, from a partially submerged (floating) condition until fully submerged
- Transient effects: the unit descending to the seabed
- Seabed effects: the unit landing on the seabed.

The study also investigated the feasibility of recovering the unit from the sea floor to the surface.

One of the installation methods uses two mooring lines, and four buoyancy lines each consisting of linked spherical buoys to help to keep the unit stable during the installation, especially during stages 2 and 3 when the unit is fully submerged and the two pontoons can no longer provide hydrostatic restoring forces and moments, as shown in Figures 3 and 4 of the SIMO model of the system. Ballast and de-ballast procedures have been developed to sink and retrieve the unit.
A new challenge facing in the numerical simulations for this project was that the total hydrodynamic load on the unit (wave load; inertial load due to the motion of the unit, i.e. added mass and wave damping effects; and viscous drag) changes with the depth of submergence. The usual SIMO hydrodynamic models were not able to model this depth-dependent hydrodynamic load.

Several new modeling techniques were developed to solve this problem:

- A series of WAMIT model were built for different depths of submergence of the unit (when the unit is partially submerged and fully submerged but is relatively close to the water surface). The wave diffraction/radiation problem was solved for the different unit depth. A database of the hydrodynamic wave load coefficients was built. The hydrodynamic wave load at instantaneous unit depth was interpolated from the database during the numerical simulations.
- Similarly, A CFD model was built and the drag coefficients (in 6 DOFs) were obtained from the CFD calculations for different unit depths (the CFD modeling and calculations were performed by Clean Current). The CFD results were used to build a database for the viscous load. The viscous load on the unit at the instantaneous depth was interpolated from this database.
- SIMO's EXTERNAL FORCE feature (which allows the user-defined load during the simulation to be employed) was used. A Fortran subroutine was written to communicate with SIMO, calculate the wave and viscous loads based on the information on the unit's position received from SIMO, and feed the loads back to SIMO to be applied to the unit in the simulations.

The new techniques have proven to be very effective, and have allowed the project to be completed successfully.

Peter Sandvik from MARINTEK Norway helped with the basic SIMO modeling in the early stages of the project and provided valuable advice throughout it.

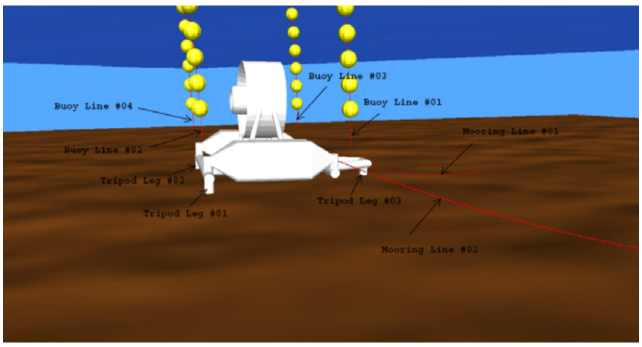

Figure 4. SIMO model of the system, unit landing on the seabed (MARINTEK).

Development of analysis tools for offshore wind turbines

›› Research scientist Petter A. Berthelsen ›› Senior research scientist Harald Ormberg
›› Senior scientist Elizabeth Passano ›› Research scientist Mateusz Graczyk

Offshore wind technology is a growing research area at MARINTEK. Significant effort is being put into developing our competence and ability to model and analyse offshore wind turbines. One important activity is the development and improvement of design and analysis tools for both bottom-fixed (piled) and floating wind turbines. These include NIRWANA for bottom-fixed offshore turbines and SIMO/RIFLEX for floating turbines.

Floating offshore wind turbines

SIMO is a non-linear time-domain simulation program which has been developed by MARINTEK for the computation of rigid-body motion and loads of vessels and other structures involved in marine operations. The software includes comprehensive hydrodynamic force models such as linear and quadratic potential forces, slender-body force models based on Morison's equation, coupling-line forces, and specified control forces.

RIFLEX is a non-linear analysis program for slender marine structures. The software is based on a finite element (FE) formulation that can handle unlimited displacements and rotations of slender structures. RIFLEX can be combined with SIMO, allowing a fully coupled analysis to be performed, in which one or more rigid-body floating structures are integrated with a dynamic model of the mooring and riser systems. This method has been verified by comparisons with model test and is widely used for analyses of floating structures in the offshore petroleum sector.

SIMO and RIFLEX have recently been extended with new functions for dynamic analysis of floating offshore wind turbines. The new features include:

- Aerodynamic forces on rotor blades based on blade element momentum theory (BEM), including empirical tip loss and dynamic stall corrections and upwind-tower shadow effects
- Control system for blade pitch angle and electrical torque for power extraction
- Various wind field descriptions, ranging from simple steady uniform wind to fluctuating turbulent wind, with or without shear profile

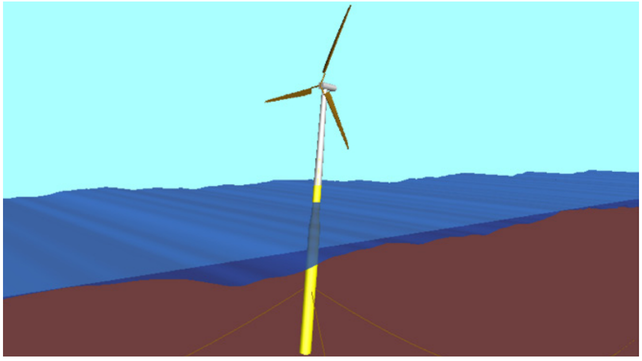

Figure 1. Visualization of a floating wind turbine simulation model.

The simulation tool has the ability to include all important parts of the system in the finite element model, thus offering fully aero- and hydro-elastic coupling. The system response is calculated by non-linear time-domain analysis. This approach ensures dynamic equilibrium within each time step and provides a proper time domain interaction between the blade dynamics, mooring dynamics and tower motions.

The full model includes blade deflection, elastic deflection of tower structure, and dynamic cable and mooring line responses. As an alternative to this detailed model, parts of the system can be simplified using rigid connections instead of elastic beam elements: e.g. to allow elastic deflections of the tower and rotor blades to be neglected. A simple PI-control algorithm for pitch and torque control has been implemented in the software. Alternatively, external user-defined

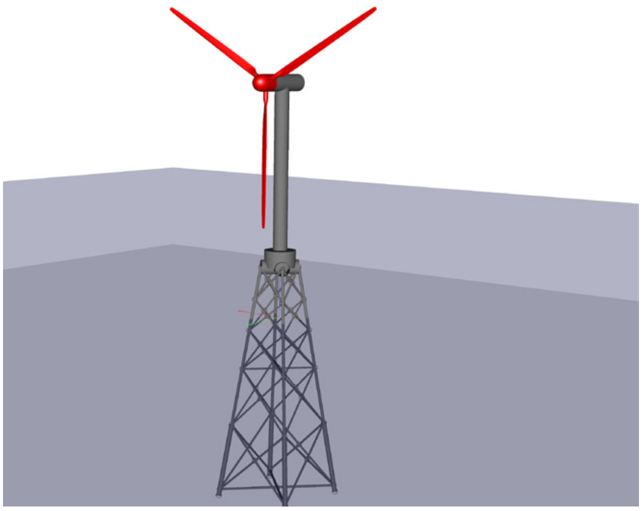

Figure 2. Simulation model of a Jacket type offshore wind turbine.

control algorithms can also be applied via a plug-in interface.

The intended uses of the software are:

- Conceptual studies
- Design verification of final system; extreme response and fatigue damage
- Dynamic interaction of proposed blade/turbine and floating support structure designs
- Adaptation of control/power take-off algorithms to floating support structure behaviour

Bottom-fixed offshore wind turbines

The finite element analysis program NIRWANA developed by MARINTEK has been widely used in consulting and research projects related to oil and gas industry and marine technology.

The program has been designed specifically for structural dynamic analysis of jacket (space frame) structures. Its functions include modelling non-linear wave loading, i.e. forces to exact wave elevation and drag loads, and non-linear soil-structure interaction. Structural geometry and material properties are linear and the response is solved in the time domain.

The tool has been thoroughly validated through numerous analyses of oil and gas jacket platforms and by comparison with field measurements and scale-model test results. NIRWANA is currently undergoing further development to facilitate analysis of bottom-fixed wind turbines.

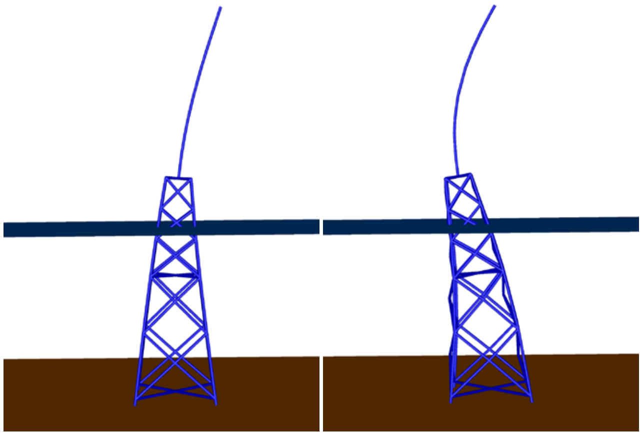

Figure 3. Modal analysis of the substructure global response.

Stepwise implementation of wind forces

The first step towards enabling the dynamic analysis of bottom-fixed wind turbines was to introduce the rotor thrust force in the model. The program was therefore modified to allow the import of force time history at an arbitrary node in the model. The externally calculated rotor thrust forces are thus applied at the top node of the tower. SIMO may be used to calculate the thrust force on the rotor by applying blade element momentum (BEM) theory.

However, this decoupled approach has obvious limitations with regard to possible dynamic interactions between the individual components of the system. Implementation of the

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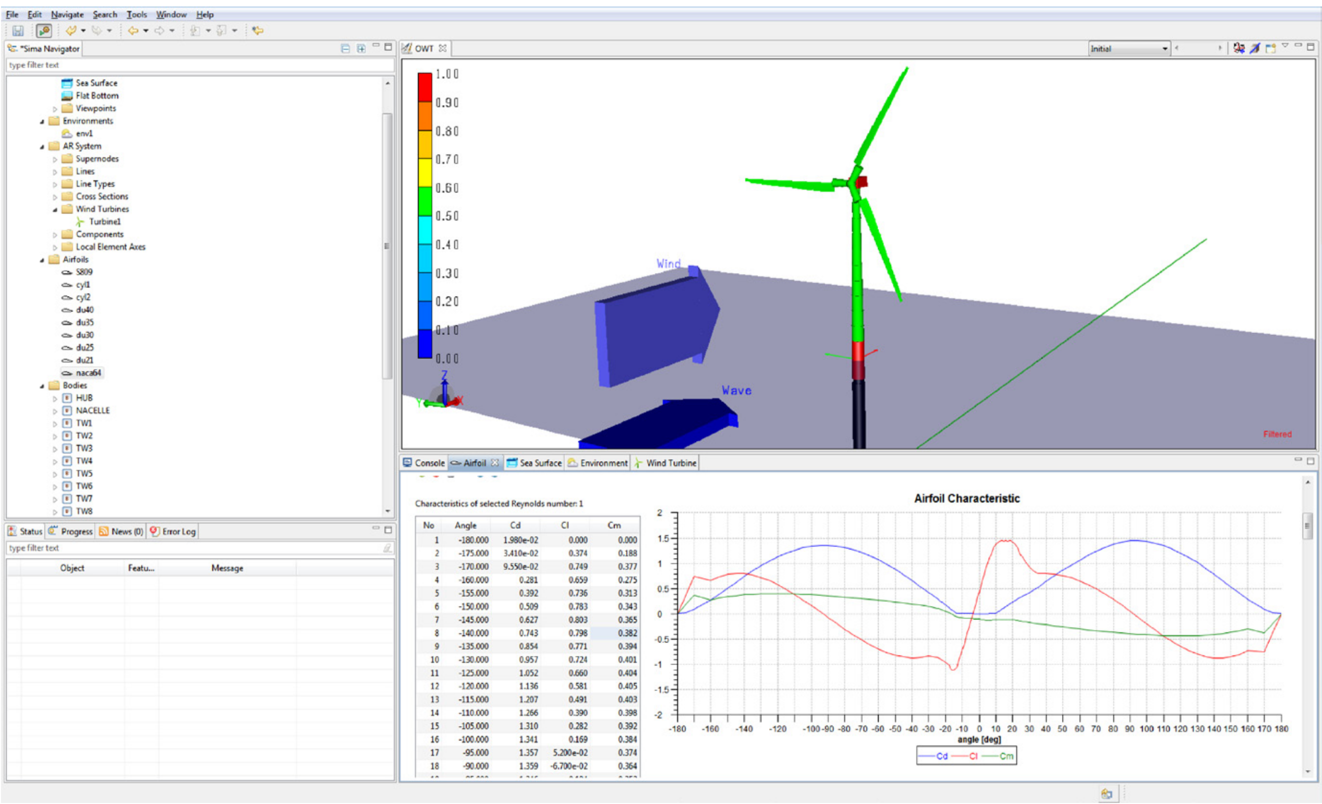

Figure 4. Screenshot of the SIMA modelling environment.

Advanced model testing techniques

›› Research scientist Jan Visscher
›› Senior research scientist Chittiappa Muthanna

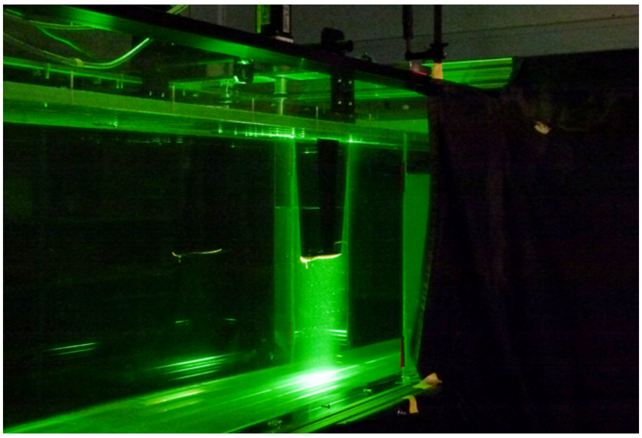

Figure 1. Tidal turbine model mounted inside the CWT lab. The flow is from left to right. A vertical plane is illuminated from below.

Optical flow measurement techniques such as Laser Doppler Anemometry (LDA) and Particle Image Velocimetry (PIV) allow non-intrusive measurements to be made at high spatial and temporal resolutions. The Circulating Water Tunnel (CWT) is tailor-made for these techniques, as well as for distinct flow visualization, and was reviewed in MARINTEK Review no. 1-2011. The CWT facility is jointly operated by MARINTEK and NTNU (the Norwegian University of Science and Technology). Several studies of basic hydrodynamic phenomena have been performed here, as well as tests of realistic turbine models. →

Development of ..., cont. from page 7

wind turbine in NIRWANA is therefore the next step of the development, in which the rotor and blades are represented by a rotating rigid body. The aerodynamic loads on the blades are calculated at each time step using the BEM theory, including the effects of varying blade pitch. The resulting loads are applied to the connection point on the tower. This enables the response of simultaneous wave loads on the support structure and aerodynamic loads on the wind turbine to be calculated in a single program.

In addition to the finite element model of the jacket and tower, the blade geometry, foil load coefficients, blade and torque control parameters and wind will be input to the program.

Second-order wave kinematics

The wave kinematics formulations already implemented in NIRWANA include regular and irregular linear waves with optional empirical corrections to the instantaneous wave height such as Wheeler modifications and Stokes fifth-order regular waves.

The second-order wave model is expected to become the standard for load calculation in the offshore industry. This formulation includes interactions between wave components and may yield more accurate results than linear waves. This model is currently under development in NIRWANA and will include the wave kinematics in deep water and in finite water depth, for regular and irregular long-crested waves.

Implementation of foundation model

At present, the foundation models implemented in NIRWANA include linear and non-linear springs in six degrees of freedom. Alternative formulations for structure-seabed interaction, e.g. dynamic p-y curves, will be reviewed. The ability of these formulations to accurately relate pile deflections to the non-linear soil reactions will be evaluated. The chosen models will then be adapted and implemented in NIRWANA.

Development of SIMA, an integrated user interface tool supporting MARINTEK's software

SIMA is an integrated modeling and simulation environment for MARINTEK's software programs. This graphical user interface (GUI) has been developed in a Joint Industry Project in collaboration with Statoil. The purpose of this environment is to make the task of setting up a simulation model of a dynamic system easier and faster. Its functions also include performing simulations, and analysing and reporting the results. The program provides a common interface for the analysis software modules, and it presents visualizations of the simulation model as it is being prepared.

The program currently provides an interface for SIMO, RIFLEX (including SIMO/RIFLEX coupled analysis) and NIRWANA. This covers a wide range of applications, including the modeling and analysis of both floating and bottom-fixed wind turbines.

The near wake around rotating tidal turbine blades

A realistic model of a two-bladed tidal turbine rotor has been mounted on a neutral nacelle shaft that is a scaled-down version of a type frequently used in open-water tests in the Towing Tank. The flow around the individual blades was measured by synchronizing the PIV acquisition with the rotor revolution rate. Within a single run, the blade thus appeared to be in a fixed angular position relative to the measurement plane, in which all three velocity components were registered. The whole volumetric structure of the wake could be reconstructed from multiple runs at different angular blade positions. The results show the strength and location of the velocity defect, the tip vortices and the intensity distribution of the induced turbulence. This work was carried out as a master's thesis project at NTNU, with the support of MARINTEK.

Scaling effects on the flow around foils

In hydrodynamic model testing, the choice of the scaling factor is often a compromise between the size of the facility and close matching of the characteristic numbers such as Reynolds, Froude or Stokes. Improved understanding and quantification of scaling effects on foils and rotor blades can improve the outcomes of model tests at efficient sizes. For the current study, a standard wing geometry was manufactured in several sizes and measured at identical Reynolds numbers through variations in the inflow velocity.

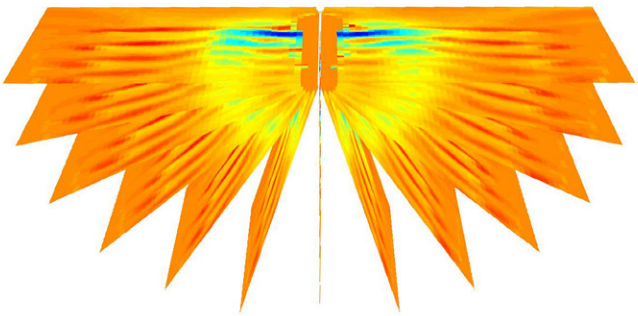

Figure 2. Visualization of the 13 different angular positions of the rotor relative to the PIV plane.

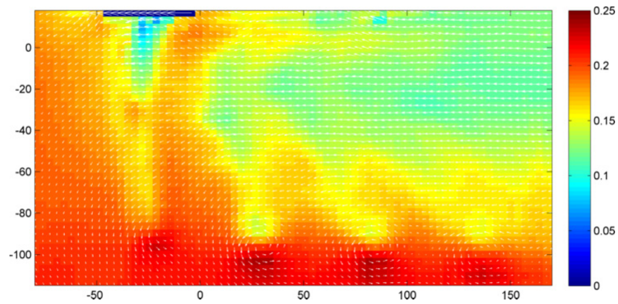

Figure 3. An example result of the time-averaged velocity magnitude reveals the defect downstream of the blade.

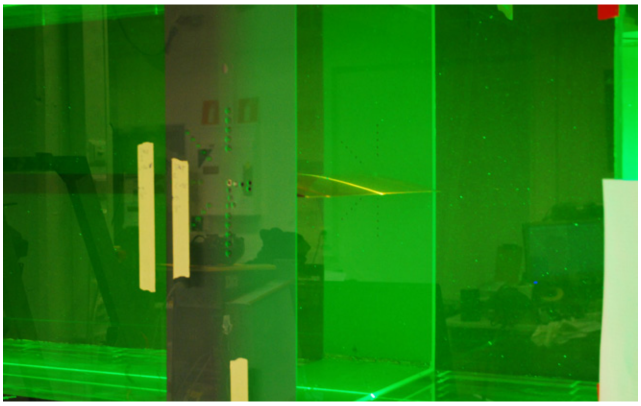

Figure 4. A wing model mounted wall-to-wall. The measurement plane is vertically orientated in mid-span position.

Vortex shedding of stepped-diameter cylinders

Many varieties of cylindrical structures are found in the marine engineering world. Cylinders with a stepped change in diameter can occur in spar buoy-type concepts or floating wind energy converters. When such structures are subjected to an inflow, like ocean currents, the well-known vortex shedding phenomenon occurs, with different characteristic frequencies depending on the local diameter. The complex vortex interactions in the transition regions are capable of significantly altering the design loads regarding vortex-induced vibrations (VIV) and can efficiently be studied by PIV at model scales. The ongoing investigation in the CWT employs a range of diameter ratio and Reynolds numbers.

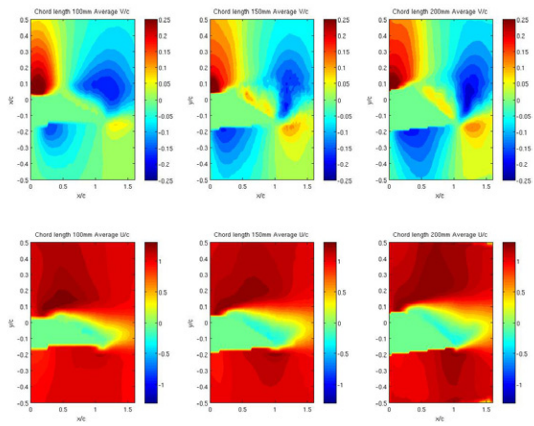

Figure 5. Results of the horizontal and vertical velocity component from three different model scales.

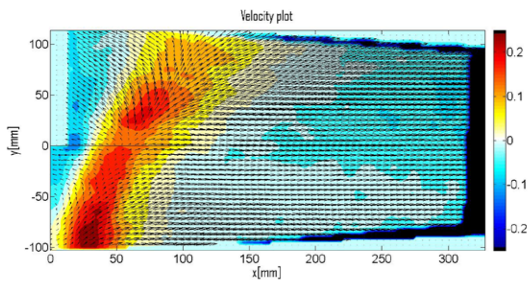

Figure 6. Time-averaged velocity field in the wake, revealing a spanwise flow from the smaller diameter end (below y=0) to the larger diameter end (above y=0).

Statkraft tests tidal turbine in extreme combinations of current and waves

›› Research scientist Kjetil Berget

Statkraft, a European leader in renewable energy, is focusing significantly on sources of ocean energy, including tidal power. A new tidal turbine design has been developed in close cooperation with NTNU, the Norwegian University of Science and Technology. Tidal turbines are already operating in challenging environments with wide variations in current speed and direction and harsh sea states, which have led to structural failure of some tidal turbines in different parts of the world.

More knowledge of dynamic loadings and insight into the hydrodynamic behaviour of tidal turbines is essential if their operation is to be stable and long-lasting. Experimental data

Figure 1. MARINTEK model of the Statkraft tidal turbine is admired by colleagues from NTNU.

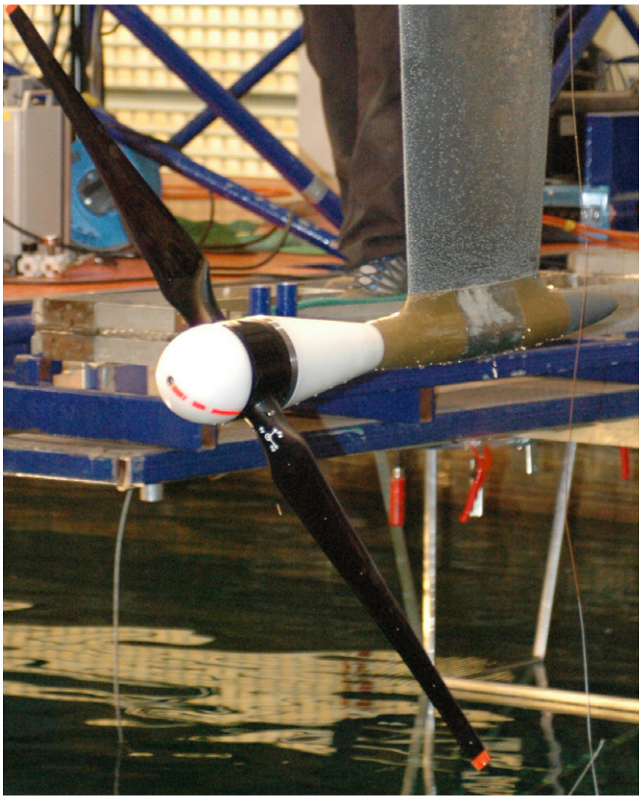
Figure 2.

on these effects has been available, particularly on a sufficiently large scale to permit the detailed study of dynamic load components in combined current and wave conditions.

MARINTEK has applied its cutting-edge know-how of the dynamics of ship propulsors in seaways to develop specialised instrumentation and rigs for testing tidal turbines in waves. These include a unique blade dynamometer developed in-house to measure loadings on a single blade of a turbine operating in waves. A high sampling frequency and wireless data transmission were used when measuring blade forces.

Significant variations in blade loadings were found in a single revolution of the turbine when operating in waves. For the first time, these measurements provide exceptional data to the international scientific community, potentially leading to better understanding and eventually more reliable and stable designs. The test results also provide a unique opportunity to validate and tune numerical methods and tools for the analysis of hydrodynamic behaviour of tidal turbines.

Model testing of wave-power plants

›› Senior research scientist Karl Erik Kaasen

In the quest for viable ways of producing sustainable energy many have turned towards ocean waves, and quite a number of ideas and concepts and have emerged in order to exploit this incessant source of energy. Although the energy abundant, enlisting it in our service involves challenges.

What appears to be the least problem is finding a method for converting the waves' mechanical energy to electrical energy. The biggest obstacle is robustness: will the power plant survive a hurricane, or be shattered, sunk or washed ashore? Then there is endurance: will the plant live through millions of load cycles from the waves without some part failing? And if a robust and durable design can be made, what will the manufacturing cost be?

Designing a wave power plant is indeed a multidisciplinary task that involves hydrodynamics, mechanics, structural engineering, materials technology, hydraulics, pneumatics, electrical engineering, power electronics, control engineering and more. While much can be achieved by advanced calculations and computer simulations, in most cases we will want to test a physical scale model in a test basin.

There are at least two motives for model testing. One is to verify the calculations and computer simulations. This will in general involve extensive instrumentation for measuring motions, forces and power extraction. The other is phenomenological: does the device behave as foreseen, or perhaps very differently due to some overlooked effect or quirk of nature. For these aspects, the use of video recording during the model tests is indispensible.

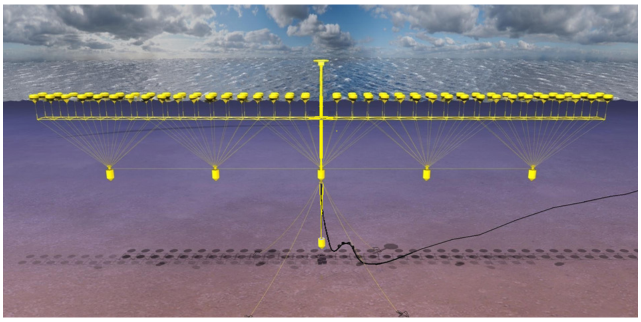
Figure 1. Wave-power plant concept. (Illustration: Pontoon Power AS)

MARINTEK has carried out many model tests of novel devices for wave energy conversion. The most recent is the system of the company Pontoon Power AS. The concept, Pontoon Power Converter (Fig. 1), represents wave power production on a rather grand scale. A large number of floats are connected to a common horizontal truss frame. Hanging from the frame by a system of cables are five heavy weights that together with the frame balance the total buoyancy of the floats. The whole plant is held in position by a slack mooring system. Each float is connected to a pump. As the floats move in the waves, they pump water through pipes to a hydraulic turbine in the engine room in the central tower. To survive in a storm, the entire plant is lowered to a safe depth by ballasting the floats.

The model tests at MARINTEK were performed with a representative section of the power plant (Fig. 2) in regular as well as spectral seas of varying magnitude. The orientation of the model relative to the waves was also varied, and the submerged survival mode was tested with storm waves.

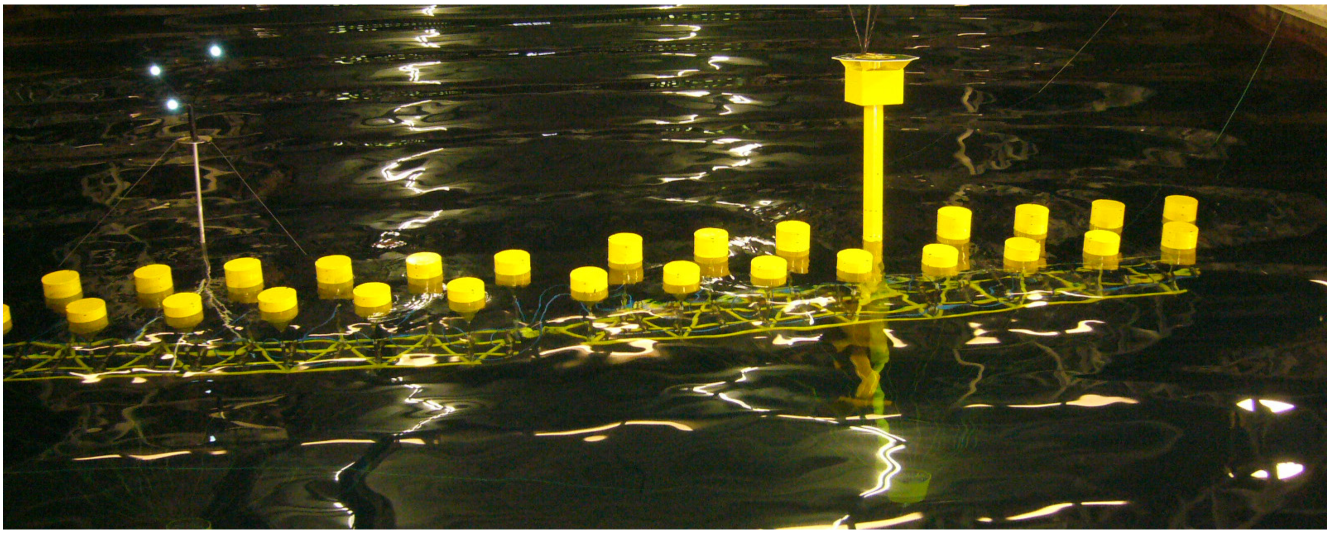
Figure 2. Test at MARINTEK. (Photo: Pontoon Power AS)

Condition- and performance based maintenance and operating logistics of offshore wind-farms

›› Research manager Anders Valland

MARINTEK is involved in research on condition and performance monitoring of offshore wind-turbines; their instrumentation, data-analysis and operating logistics. Collaboration with industry, research institutes and test facilities has put MARINTEK in a unique position to exploit its long experience in the maritime and offshore industries in improving the operation and maintenance of offshore wind-turbines.

Published fault statistics on wind-turbines all over Europe show that electronics and electrical systems suffer from high failure rates. Such components have short repair times, which helps to reduce the down-time resulting from faults in these systems. Components with an unfavourable combination of high failure rates and long repair times include gear-boxes, rotating systems and rotor blades, all of which currently lack satisfactory monitoring systems. A challenge to profitable operation of offshore wind farms lies in minimizing the need for interventions on the turbines. This can be achieved through different means such as improved design, remote monitoring and operation, remote inspection and intervention using robotics.

Photo: Shutterstock

MARINTEK is a member of NOWITECH (Norwegian Research Centre for Offshore Wind Technology), one of eight Norwegian research centres for environmentally friendly technology, which aims to develop good solutions for remote monitoring of offshore wind turbines by means of dedicated condition-monitoring instrumentation. Large offshore wind-farms of several hundred turbines will make significant demands on planning, prioritising and implementing maintenance programmes. Operating logistics and fleet planning for support vessels, spare parts and personnel are important areas that require more research to allow the envelopes of opportunity in base and field structures and choice of technical solutions to be described.

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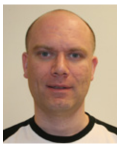

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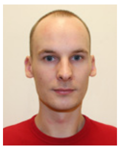

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