Report 2021

Task 30

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Offshore Code Comparison Collaboration, Continuation, with Correlation and uncertainty (OC6)

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The present extension of IEA Wind Task 30, named the Offshore Code Comparison Collaboration, Continued, with Correlation and unCertainty (OC6), was initiated in 2019.

The goal of OC6 is to validate engineering-level offshore wind modelling tools that consider the simultaneous loading from wind and waves, as well as the interaction with the structural dynamics of the system and its control algorithms (aero-hydro-servo-elastic tools). In addition, the OC6 project includes higher-fidelity models (such as computational fluid dynamics models - CFD) to better understand the underlying physics. A three-way validation is performed where both the engineering-level modelling tools and higher-fidelity tools are compared to measurement data. The results will help inform the improvement of engineering-level models and/or guide the development of future test campaigns.

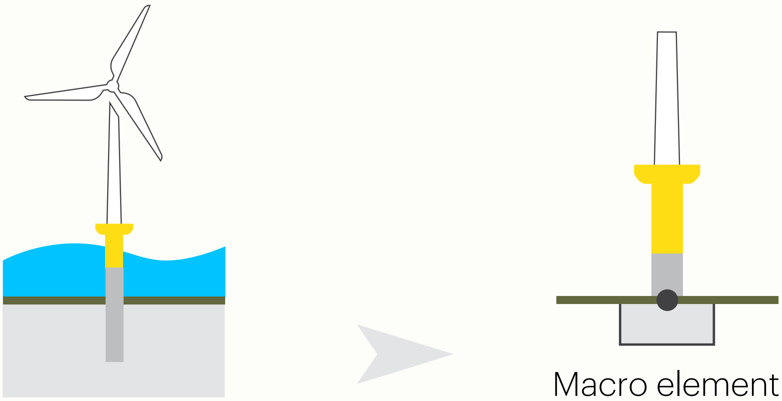

Figure 1. Illustration of an offshore wind turbine (left) and macro-element approach for soil-structure interaction (right)

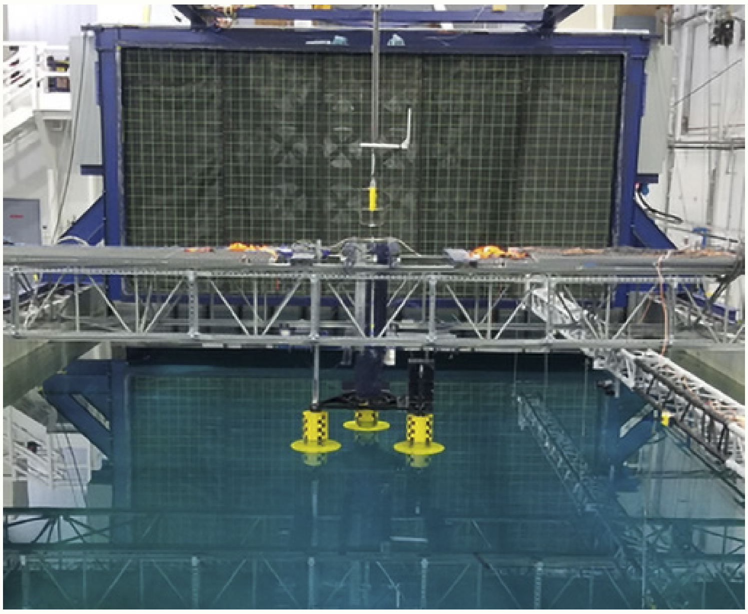

Figure 2. View towards the wavemaker in the W2 wave basin at the University of Maine showing a new component-level test for OC6 Phase Ib. Photo reproduced with permission from Matthew Fowler, 1/50-scale DeepCwind semi-submersible component wave testing [1]; published by the University of Maine, 2021.

In 2021, the remainder of activities for Phase I, focused on validating the slow-motion hydrodynamic response of a floating wind semisubmersible, was accomplished. This work included higher-fidelity simulations, which took much longer to complete than the engineering modelling work, and a new experimental campaign (labelled OC6 Phase Ib) that helped to validate these models [1]. Phase II of the project was also completed, which was focused on the implementation and verification of an advanced soil-structure interaction (SSI) model for offshore wind system design and analysis. Participants integrated an advanced macro-element capability to coupled aero-hydro-servo-elastic offshore wind turbine modelling tools and verified the implementation by comparing simulation results across the modelling tools, for an example, monopile design. The simulation results were also compared to more traditional SSI modelling approaches.

Introduction

The OC3 (Offshore Code Com-

Table 1. Countries Participating in Task 30

	COUNTRY	INSTITUTION(S)
1	**China**	Chinese General Certification, Dalian University of Technology, Shanghai Investigation, Design & Research Inst., Shanghai Electric Group Company Limited, Xinjiang Goldwind Sci & Tech Co.,Ltd., Ming Yang Smart Energy Group., Ltd., CSIC Haizhuang Windpower Co., Ltd.
2	**Denmark**	Technical University of Denmark (DTU)
3	**France**	EDF, IFPEN, PRINCIPIA, Vulcain, Bureau Veritas, DORIS Engineering, Aix-Marseille University
4	**Germany**	Rostock University, Stuttgart University, Fraunhofer IWES, University of Duisburg-Essen, Ramboll, Hamburg University of Technology
5	**Japan**	ClassNK, Univ. of Tokyo, Nippon Kaiji Kyokai
6	**Korea**	University of Ulsan
7	**Netherlands**	MARIN, TU Delft, ECN.TNO, TU Eindhoven, Wyndtek
8	**Norway**	Norwegian University of Science and Technology, 4Subsea, SINTEF Ocean, IFE, Norwegian Geotechnical Institute, Simis AS
9	**Spain**	TECNALIA, CENER, SIEMENS Industry Software, IH Cantabria, UPC-Barcelona, SAITEC Offshore, Core-Marine, SENER, eureka!, Universitat Politècnica de Catalunya
10	**U.K.**	DNV, Orcina, University of Exeter, Queen's University, Newcastle University, University of Strathclyde, University of Plymouth, Manchester Metropolitan University
11	**U.S.**	NREL, ABS, Sandia, Bureau Veritas, University of Michigan, Principle Power, University of Massachusetts, Convergent Science, SIEMENS Industry Software, Front Energies, Technip Energies

parison Collaboration) – OC6 projects were created under the Wind framework of the International Energy Agency (IEA) to address the need to verify and validate the load predictions of coupled modelling tools for offshore wind design. These projects have proven to be vital to the companies developing and improving the numerical modelling tools used to design offshore wind systems, as well as designers, certifiers, and research institutes that apply these tools for design, research, and instruction (see Table 1 for current OC6 members).

Within the previous OC3-OC5 projects, differences were observed between the modelling approaches and the measured data, and often the reason for the differences was not well understood. The focus of the OC6 project is to develop more focused validation projects to better understand some of these observed differences and to address other modelling/validation aspects that were outside the scope of the previous OC projects. The focus of these studies is physical phenomena that have demonstrated a large impact on accurately modelling the global response behaviour of offshore wind systems and will be investigated through measurement data obtained across multiple test campaigns. In addition, the OC6 project will employ higher-fidelity models (such as computational fluid dynamics models) to better understand the underlying physics of the phenomena. This will constitute a three-way validation where both the engineering-level modelling tools and higher-fidelity tools will be compared to measurement data. The results will help inform the improvement of engineering-level models and/or guide the development of future validation campaigns.

Progress and Achievements

The OC6 project consists of four phases, focused on four different phenomena critical to the accurate modelling of offshore wind systems. In 2021, activities for Phase I and II were completed, and work was initiated on Phase III.

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The focus of OC6 Phase I was to examine the underprediction of the response (loads/motion) of a floating semisubmersible at its surge and pitch natural frequencies. OC6 conducts a three-way validation where these measurements are compared to simulation results from both engineering-level tools that are commonly used to design offshore wind systems and higher-fidelity, computational-fluid-dynamics (CFD) models that better resolve the physics of the system. Significant work was needed for the CFD simulations, and so the OC6 Phase I project was divided into two subgroups focused on the two fidelities of modelling tools. The work for the CFD group was just concluded in 2021, including simulations of the semisubmersible in bichromatic waves [2] and its free-decay motion [5]. The bichromatic wave cases came from a new validation campaign, called OC6 Phase Ib, that focused on looking at the hydrodynamic loading across the structure in a more detailed way ([1][2][3][4]). This new experiment was conducted at the University of Maine's W2 wave basin, and the measurements have been made available to the public [6].

Also, in 2021, Phase II of the OC6 project was completed, which was focused on the implementation and verification of an advanced soil-structure interaction (SSI) model for offshore wind system design and analysis [7]. The soil-structure interaction model comes from the REDWIN project and uses an elasto-plastic, macro-element model with kinematic hardening, which captures the stiffness and damping characteristics of offshore wind foundations more accurately than more traditional and simplified soil-structure interaction modelling approaches. To verify the integration of the new REDWIN SSI capability, participants in OC6 Phase II modelled a monopile offshore wind system examined in the WAS-XL (Wave loads And Soil support for eXtra Large monopiles) project; ran a series of simulations, including wind and wave loading; and compared the resulting system loads across different modelling tools. The macro-element approach resulted in smaller overall loading in the system due to both shifts in the system frequencies and increased energy dissipation compared to more traditional modelling approaches.

Highlight

The REDWIN macro-element approach differs from traditional methods in including plasticity and hysteretic damping. It requires more elaborate inputs (e.g., stiffness matrix and load-displacement curves at the seabed) to characterise the SSI. Still, the resulting estimates for the support structure loads at the first and second bending modes are smaller than other modelling approaches. Figure 3 shows this decreased load estimated for the WAS-XL monopile's fore-aft bending moments at the seabed. This decrease in loading values would mean a lower fatigue estimate using the REDWIN model than traditional SSI modelling approaches. Although no validation was done here to assess the accuracy of the REDWIN capability, this validation was achieved within the REDWIN project.

All major coupled aero-servo-hydro-elastic modelling tools across the industry incorporated this new modelling approach within the OC6 project, and all predicted very similar results (as shown in Figure 3). This verifies the accurate implementation of the REDWIN capability in these

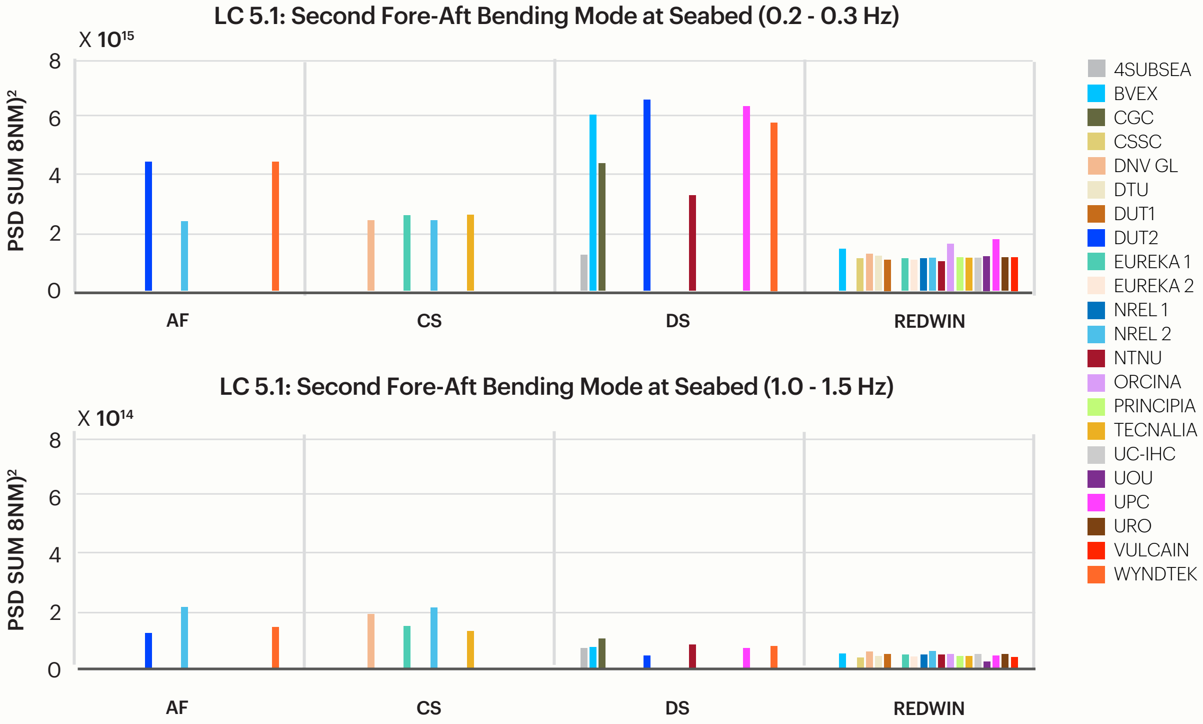

Figure 2. Example results of the Power spectral density (PSD) sums of the fore-aft bending moment of an offshore wind monopile at the seabed, showing a decreased load prediction when using the new REDWIN modelling approach compared to AF = Apparent Fixity, CS = Coupled Springs, DS = Distributed Springs

tools, making them ready for use in the design of future OWT systems. The impact is that load estimations for fixed-bottom offshore wind designs should be more accurate, decreasing uncertainty in the design and allowing for less conservative and thus more cost-effective offshore wind designs.

Outcomes and Significance

In the concluding work of OC6 Phase I, we found that CFD tools provide more accurate estimations of the hydrodynamic loading on semisubmersibles than engineering-level modelling tools. The CFD models were successfully validated across many conditions, and focused on the motion characteristics in the water and under wave loading. With the high computational cost, it will be difficult to use only CFD tools in the design process for offshore wind systems. Instead, they are being used to improve the accuracy of the modelling approaches for the lower-fidelity engineering models and are also being used to tune the hydrodynamic coefficients for the engineering models.

In OC6 Phase II, we have successfully integrated the REDWIN modelling approach for soil/pile interaction into industry offshore wind design modelling tools. These models are used to design the foundation of offshore wind systems, which provide significant contributions to the overall loading in the entire system. This more advanced approach provides a more accurate estimation of the damping and resulting loading in the structure, which will allow for a lower fatigue estimate. This improved accuracy will mean that offshore wind system designs could remove some conservancy.

Next Steps

In 2022, Phase III of the OC6 project will be concluded, and Phase IV initiated. Phase III is focused on validating the accuracy of aerodynamic load predictions for a floating offshore wind turbine as it experiences large surge and pitch motions, as would occur during normal operation. The dataset investigated comes from the UNAFLOW project, as well as some new testing performed at Politecnico di Milano's wind tunnel, which involves moving a wind turbine in prescribed oscillatory motions using a robotic excitation system. Phase IV of OC6 will examine the accuracy of hydrodynamic modelling approaches for a novel floating wind system, the Stiesdal Tetraspar.

References

[1] Robertson, A, and Wang. L. (2021). *OC6 Phase Ib: Floating Wind Component Experiment for Difference-Frequency Hydrodynamic Load Validation* Energies 14, no. 19: 6417. https://www.mdpi.com/1996-1073/14/19/6417

[2] Wang, L, Robertson, A, et al. (2021). *Investigation of Nonlinear Difference-Frequency Wave Excitation on a Semisubmersible Offshore-Wind Platform with Bichromatic-Wave CFD*

Simulations. Proceedings of the ASME 2021 3rd International Offshore Wind Technical Conference. ASME 2021 https://doi.org/10.1115/IOWTC2021-3537

[3] Wang, L.; Robertson, A.; et al. (2021).
OC6 Phase Ib: Validation of the CFD predictions of difference-frequency wave excitation on a FOWT semisubmersible. Ocean Engineering, Vol. 241. https://doi.org/10.1016/j.oceaneng.2021.110026

[4] Wang, L., Robertson, A, et al. (2021).
Uncertainty Assessment of CFD Investigation of the Nonlinear Difference-Frequency Wave Loads on a Semisubmersible FOWT Platform. Sustainability 13(1): 64.

[5] Wang, Lu; Robertson A.; et al. (2021).
OC6 Phase Ia: CFD Simulations of the Free-Decay Motion of the DeepCwind Semisubmersible Energies 15, no. 1: 389.
https://www.mdpi.com/1996-1073/15/1/389

[6] https://a2e.energy.gov/ds/oc6/oc6.phase1b

[7] Bergua, R; Robertson, A; Jonkman, J; et al. (2021).
OC6 Phase II: Integration and verification of a new soil–structure interaction model for offshore wind design Wind Energy, 2021; 1- 18. doi:10.1002/we.2698.

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