Report 2023
Task 30

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Offshore Code Comparison Collaboration, Continued with Correlation and unCertainty (OC6)

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IEA Wind Task 30 (OC6) began in 2019 with the aim of validating offshore wind modelling tools.

These tools are designed to handle the complex dynamics of wind and wave loads, and their interactions with wind turbine structures and control systems, known as aero-hydro-servo-elastic tools. OC6 also integrated higher-fidelity models like computational fluid dynamics (CFD) to deepen the understanding of the physics involved. The project involved a three-way validation of both engineering-level and higher-fidelity models against actual measurement data with the goal of aiding the development of these engineering models and planning future tests.

In 2023, OC6 concluded its fourth

and final phase, which focused on structural stresses and overall performance of a state-of-the-art floating offshore wind turbine design using a 3.6 MW turbine mounted on the Stiesdal TetraSpar platform. This phase involved 16 different software tools, and results were compared with scale model test data from the University of Maine. The project was particularly successful in predicting wind loads and structural bending at the turbine tower's base. Due to cable interferences from instrumentation, it was a challenge to accurately model the mooring system's forward-facing forces. However, strong correlations between simulated and actual tensions along the keel line suggest we can effectively predict internal stresses in floating turbine structures.

Introduction

The OC3-4-5-6 projects were created under the IEA Wind TCP framework to verify and validate the load predictions of coupled modelling tools for offshore wind design. These projects have been vital to the companies developing and improving the numerical modelling tools used to design offshore wind systems. Additionally, for designers, certifiers, and research institutes who apply these tools for design, research, and instruction (see Table 1 for current OC6 members).

During the previous OC3-5 projects, differences were found between the modelling approaches and the measured data. Often, the reason for the discrepancies was not well understood. The OC6 project was therefore developed to conduct more focused validation projects to understand these observed differences and to address other modelling/validation aspects that were outside the scope of the previous OC projects. The studies focused on physical phenomena that impacted the ability to accurately model the global response behaviour of offshore wind systems. These were investigated through measurement data obtained through multiple test campaigns. In addition, the OC6 project employed higher-fidelity models (such as CFD models) to better understand the underlying physics of the phenomena. This constitutes a three-way validation where both the engineering-level modelling tools and higher-fidelity tools are compared to measurement data. The results were used to help inform the improvement of engineering-level models, and/or guide the development of future validation campaigns.

Table 1. Countries Participating in Task 2023.

	COUNTRY	INSTITUTION(S)
1	**China**	Dalian University of Technology, Shanghai Electric, China General Certification Center, Shanghai Jiao Tong University, Nanjing University
2	**Denmark**	Technical University of Denmark
3	**France**	Bureau Veritas, Électricité de France, Principia, IFP Energies Nouvelles
4	**Germany**	Hamburg University of Technology, University of Stuttgart, Technical University of Berlin
5	**Ireland**	Gavin & Doherty Geosolutions, W&UG, Wood Group
6	**Italy**	Politecnico di Milano, University of Florence
7	**Netherlands**	Maritime Research Institute Netherlands, Netherlands Organisation for Applied Scientific Research (TNO)
8	**Norway**	Institute for Energy Technology, Norwegian University of Science and Technology
9	**Spain**	Tecnalia, Universitat Politècnica de Catalunya, Eureka!, CENER, Siemens, University of Cantabria, IDOM, Saitec
10	**U.K.**	Orcina, DNV, Queens University Belfast, University of Plymouth, University of Strathclyde, Manchester Metropolitan University, Newcastle University
11	**U.S.**	National Renewable Energy Laboratory, Shell, Convergent Science, Tufts, Front Energies, Technip, Sandia National Labs, University of Massachusetts Amherst

Progress and Achievements

In 2023, the OC6 project published an additional paper related to its Phase III work focused on the wake behaviour of floating wind systems [1], and concluded its final phase, Phase IV. This phase focused on validating the dynamic responses—including aerodynamics, hydrodynamics, and structural dynamics—of the Stiesdal TetraSpar floating wind design, modelled at a 1:43 scale under combined wind and wave loads. The design's innovative features, such as connected thin members and a hanging keel, enabled thorough testing of advanced hydrodynamic and internal load modelling capabilities using both engineering and high-fidelity models. The findings were detailed in a comprehensive journal article submitted to Wind Energy Science [2]. Additionally, a Definition Document was published to assist participants in model construction and to offer a benchmark for further research using the available data and modelling results [3].

The completion of OC6 instigated a series of strategic planning meetings to identify remaining challenges in offshore wind design. These sessions, held at the National Offshore Wind R+D Consortium meeting in Boston in December 2022, and through various online meetings in early 2023, involved industry stakeholders sharing insights on critical design and analysis needs. Additional internal discussions at NREL led to the creation of a phenomenon and identification ranking table, which was reviewed by OC6 participants and industry experts. These collaborative efforts resulted in a new Task proposal, which was presented at the IEA Wind ExCo meeting in the Autumn of 2023, where Task 56, the OC7 project, was approved. The results of OC6 show the success of the initiative to contribute to the development of wind technology and promote its further development through preparation for future projects.

Highlight(s)

Phase IV of the OC6 project focused on testing and validating a 3.6 MW horizontal-axis wind turbine mounted on the TetraSpar floating support structure. The project included an international group of participants and 16 different software tools. The Phase compared numerical simulations to experimental data from a 1:43 scale model test conducted by the University of Maine, covering wind, wave, and combined conditions. The findings showed that comparisons between Morison equation and

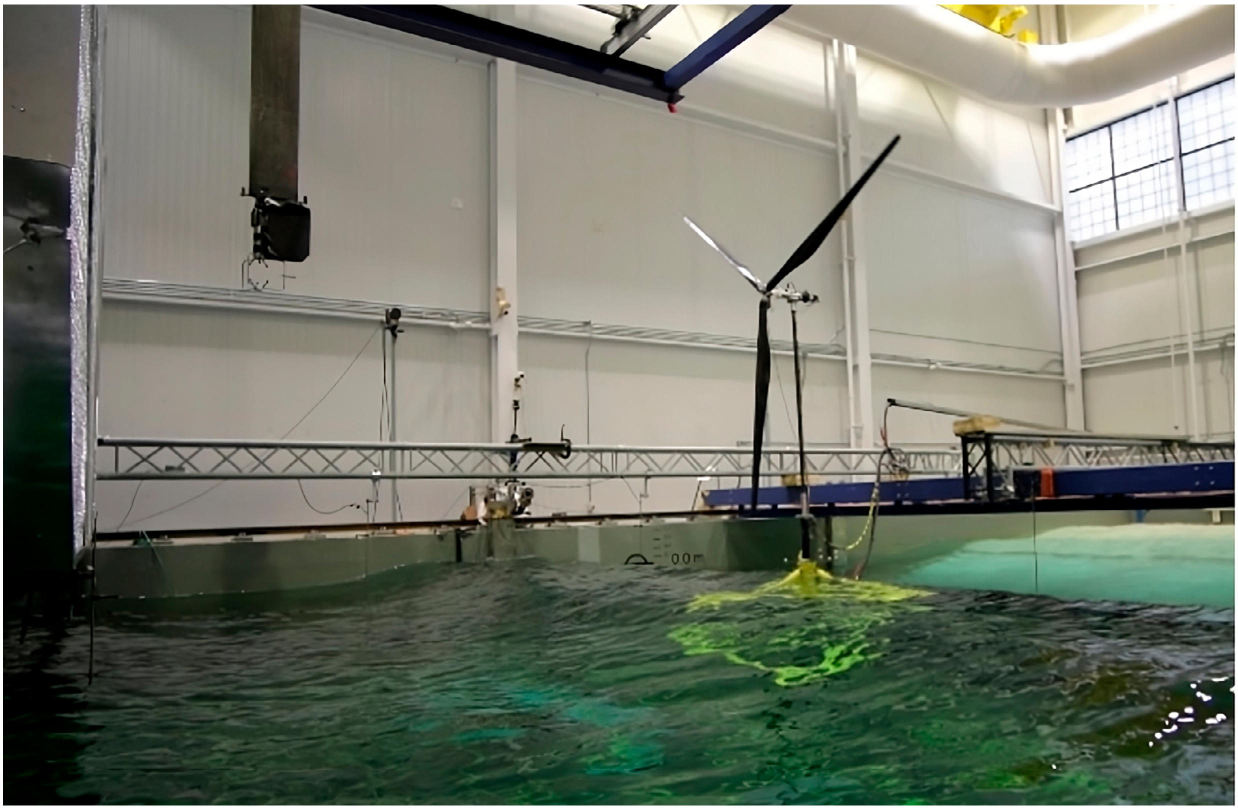

Figure 1. TetraSpar 1:43 scaled model during testing at the University of Maine.
Photo Credit: Matt Fowler, University of Maine.

potential flow methods in hydrodynamic modelling had no significant differences for the slender TetraSpar design. This provided reliable performance results across typical analytical approaches (see Figure 2). For combined wind and wave conditions, variations in the equilibrium position of the hull affected mooring line responses, which made it a challenge to accurately simulate dynamic loading. Nonetheless, the numerical models closely matched experimental results in assessing keel line tensions, which highlights their effectiveness in predicting internal loads for floating wind support structures.

This phase of the OC6 project not only validated the coupled dynamic response of the TetraSpar design but also revealed the complexities and potential of floating wind technology. Furthermore, to enhance the predictive accuracy of floating wind models, it is important to consider sensor impacts and varying equilibrium positions in dynamic simulations.

Outcomes and Significance

OC6 Phase IV was a collaborative effort involving 17 academic and industrial partners from 10 different countries to validate numerical models against experimental data for a 3.6 MW horizontal-axis wind turbine on the TetraSpar floating support structure. This Phase demonstrated the strong relationship between numerical models and experimental observations, particularly in the tension of keel lines, which has contributed to predicting and understanding member-level loads in floating wind structures.

This phase's findings underscore the potential for advanced numerical models to effectively simulate complex interactions in floating wind systems, which will pave the way for more accurate and reliable design tools. As with previous phases, the detailed modelling information, simulation results, and experimental data from Phase IV have been made publicly available through the U.S. Department of Energy's Data Archive and Portal. The availability of these resources aims to promote further research and development to grow the overall body of knowledge that will ultimately lead to optimised designs for floating wind systems.

Next Steps

The OC6 project concluded its four phases in 2023, and has laid the framework for its successor, the Offshore Code Comparison Collaboration 7 (OC7) project, by the IEA Wind TCP as Task 56. Running from FY24 to FY27, OC7 aims to enhance modelling tools for offshore wind design, especially floating structures. It will address three key challenges: developing best practices for hydrodynamic modelling of innovative designs, incorporating structural flexibility in design frameworks, and enhancing predictive accuracy for turbine performance and loading in floating wind farms. OC7 will bring together over 100 global industry leaders to collaboratively advance these areas.

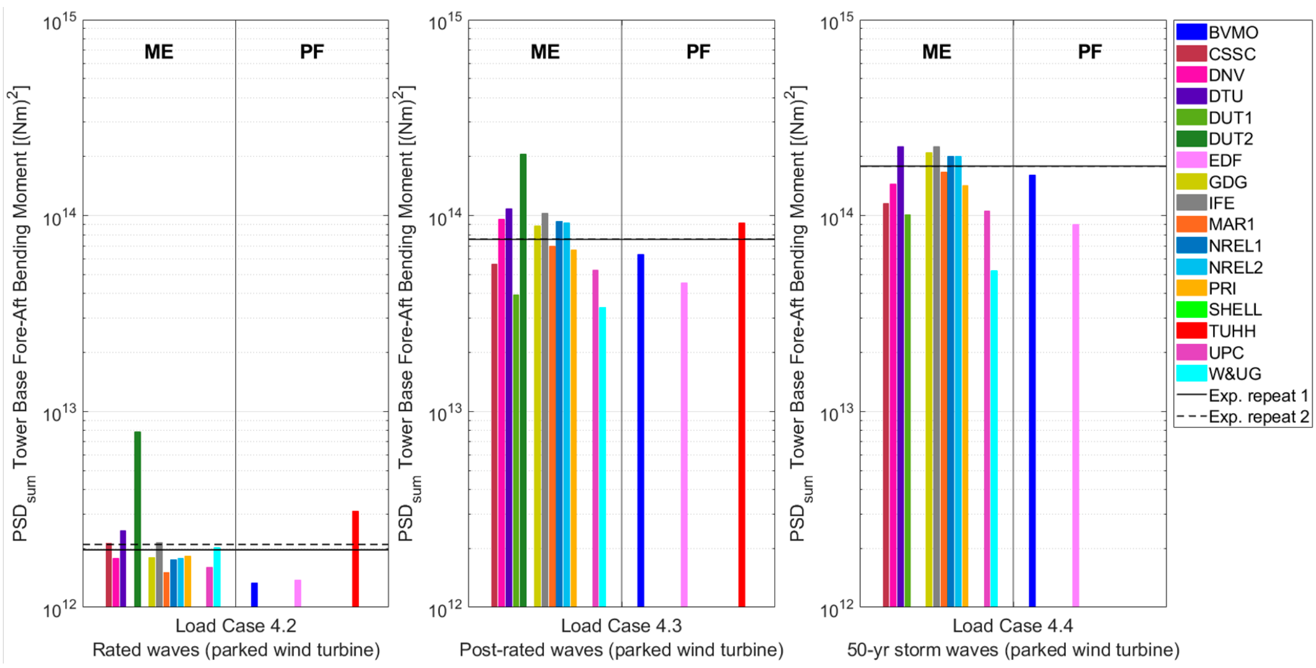

Figure 2. Power spectral density (PSD) sum of the fore-aft tower base bending moment for the wave-only conditions in Load Cases 4.2, 4.3, and 4.4. Outputs sorted according to the hydrodynamic theory: Morison equation (ME) and potential flow (PF) with augmented viscous drag. Vertical axis in logarithmic scale.

References

[1] Cioni, S. et al. (2023) 'On the characteristics of the wake of a wind turbine undergoing large motions caused by a floating structure: an insight based on experiments and multi-fidelity simulations from the OC6 project Phase III', Wind Energy Science, 8(11), pp. 1659–1691. https://doi.org/10.5194/wes-8-1659-2023

[2] Bergua, R., W. Wiley, A. Robertson, J. Jonkman, C. Brun, J.-P. Pineau, Q. Qian, et al. 2023. "OC6 Project Phase IV: Validation of Numerical Models for Novel Floating Offshore Wind Support Structures." Wind Energy Science Discussions 2023: 1–36. https://doi.org/10.5194/wes-2023-103

[3] Wiley, W., Bergua, R., et al. (2023) Definition of the Stiesdal Offshore TetraSpar Floating Wind System for OC6 Phase IV. National Renewable Energy Laboratory (NREL), Golden, CO (United States).

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