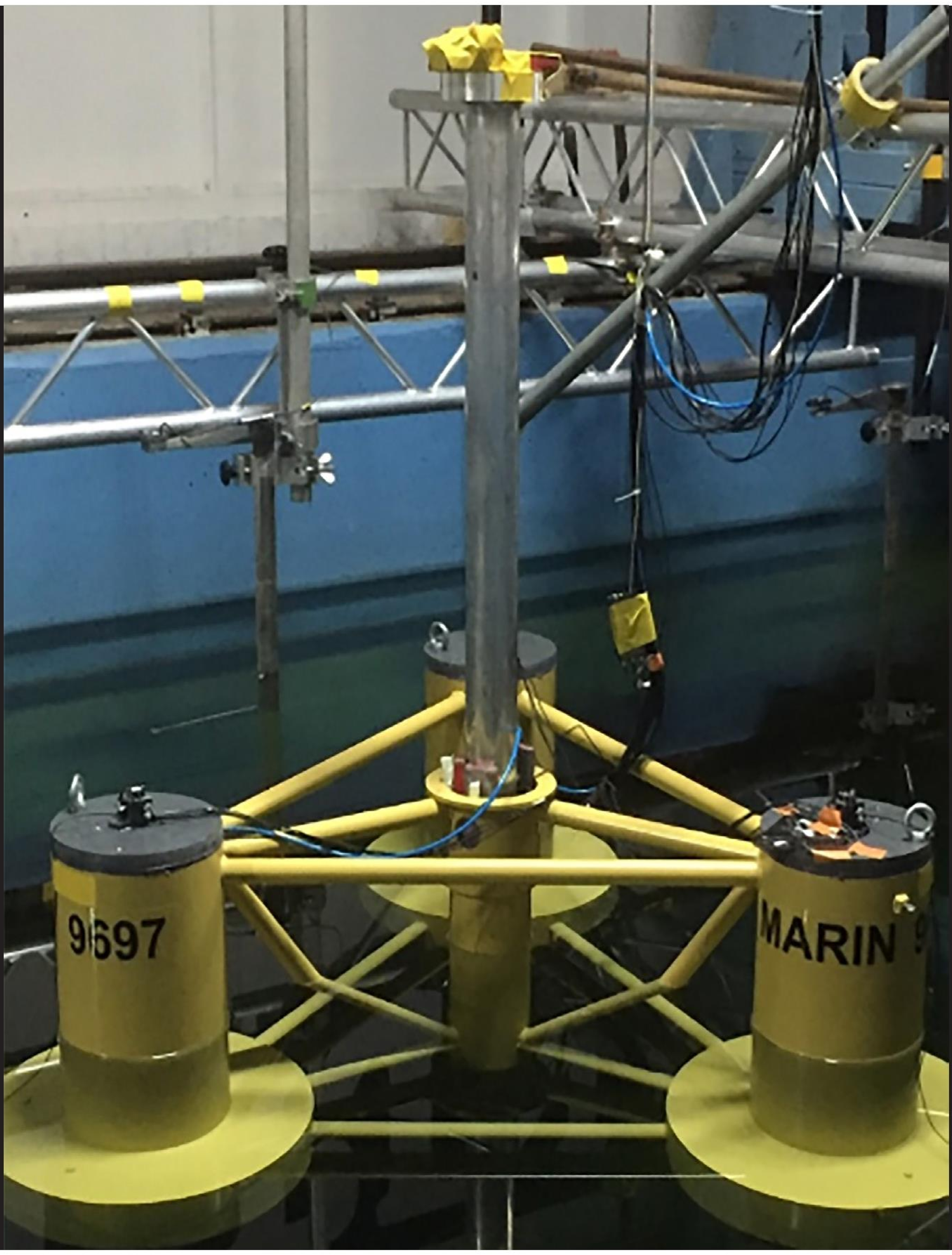


FIGURE 1: CONFIGURATION 1, OC6-DEEPCWIND FLOATING SEMISUBMERSIBLE WITH RIGID TOWER (PHOTO BY AMY ROBERTSON, NREL)

TASK 30 REPORT 2020

Offshore code comparison collaboration, continued, with correlation, and uncertainty

The OC3 (Offshore Code Comparison Collaboration)—The OC6 (Offshore Code Comparison, Continued, with Correlation and unCertainty) 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.

AMY ROBERTSON,
National Renewable Energy Laboratory

The OC6 project builds off the prior work of the OC3-OC5 projects, which 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 who 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 were not well understood. The focus of the new 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 behavior of offshore wind systems, and will be investigated through measurement data obtained across multiple experimental 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 be used to 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 2020, the primary component of Phase I was completed, and significant progress was made on Phase II.

The focus of OC6 Phase I is to examine the underprediction of the response (loads/motion) of a floating semisubmersible at its surge and pitch natural frequencies. To better understand the nonlinear hydrodynamic loading driving this response, two new wave tank validation campaigns were performed at the concept basin at MARIN in 2017 and 2018 using the OC5-DeepCwind semisubmersible design [1]. Constrained tests were performed to examine the radiation and viscous loading under forced surge oscillation, and the diffraction and viscous loading in a fixed condition under waves (see Figure 2). Then, tests were run for a floating configuration, with a simplified set-up, focused specifically on the hydrodynamic loads (see Figure 1).. Phase I of OC6 is dedicated to validating simulation models using the measurements from these experiments to better understand the reasons for the underprediction of the nonlinear hydrodynamic response.

OC6 conducts a three-way validation where the measurements are compared to simulation results from both engineering-level tools that are commonly used to design offshore wind systems and higher-fidelity, computations-fluid-dynamics (CFD) models that better resolve the physics of the system. Significant work was needed for the CFD simulations, so the OC6 Phase I project divided into two subgroups focused on the two fidelities of modelling tools. In 2020, the work of the engineering modelling group was completed. Their efforts concluded that for the test conditions examined, the engineering-modelling tools in general under-predicted both the surge force and the pitch moment, resulting in the underprediction of the floating

TABLE 1. COUNTRIES PARTICIPATING IN TASK

Table 1. Task 30 Participants in 2020		
	Country/Sponsor	**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
4	Germany	Rostock University, Stuttgart University, Fraunhofer IWES, University of Duisburg-Essen, Ramboll, Hamburg University of Technology
5	Japan	ClassNK, Univ. of Tokyo
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
9	Spain	TECNALIA, CENER, SIEMENS Industry Software, IH Cantabria, UPC-Barcelona, SAITEC Offshore, Core-Marine, SENER, eureka!
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

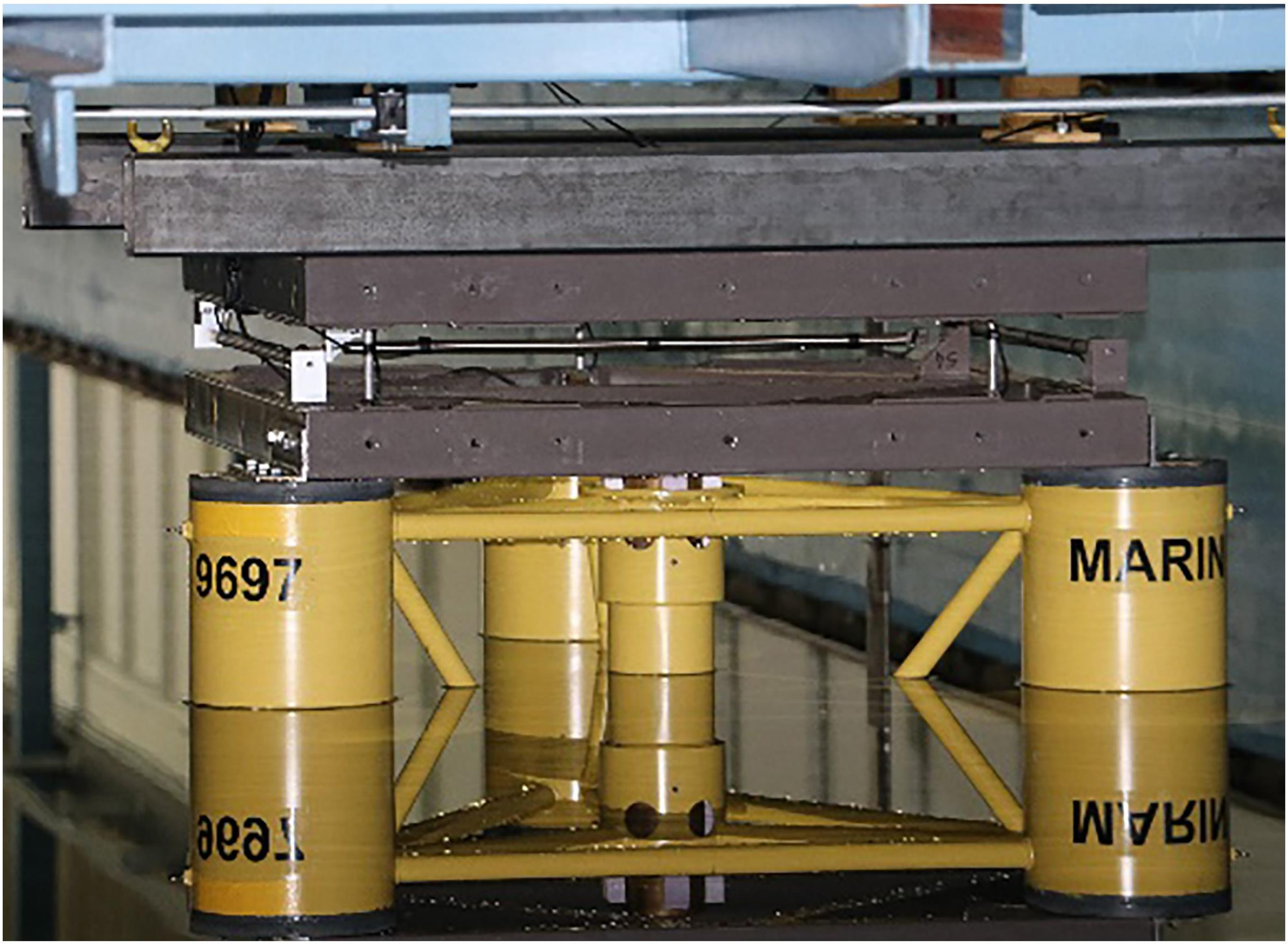


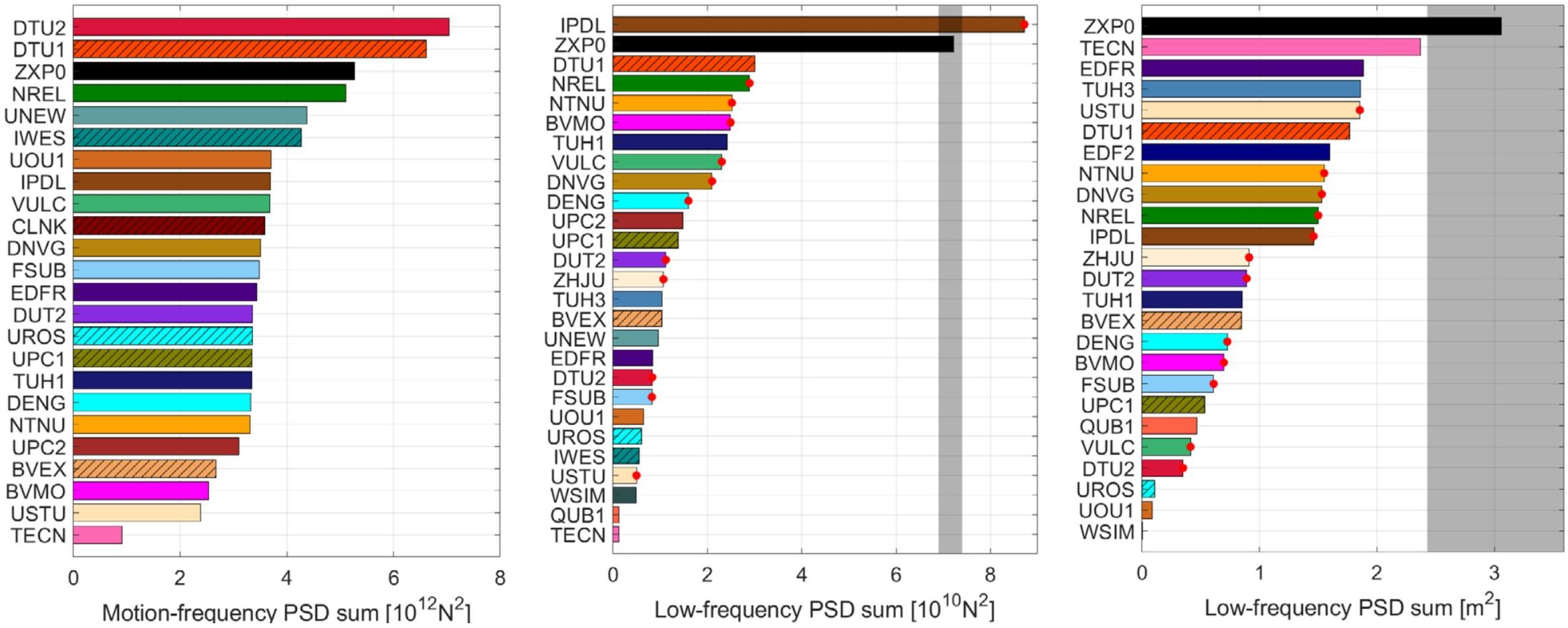
FIGURE 2: CONFIGURATION 2, OC6-DEEPCWIND SEMISUBMERSIBLE ATTACHED TO A CARRIAGE (PHOTO BY: AMY ROBERTSON, NREL)

response at the natural frequencies, as summarized in a paper presented at the TORQUE conference [2]. No specific physical component of the hydrodynamic force was identified as the source for their under-prediction, rather simulations could be tuned to give decent results for one hydrodynamic component, but that tuning worsened results for other components. Some modelling approaches were better able to predict the correct response, but none were able to achieve a successful validation. This points to the need for further improvement of engineering-level models for predicting low-frequency loads on floating wind systems.

Highlight

The figures below show a sample of the results from the validation of engineering-level models in OC6 Phase I, as reported in [2]. The plots focus on a metric used to assess the critical low-frequency loading levels for three different conditions: when the structure is given a prescribed forced motion, when it is held fixed, and when the floating system moves freely. Uncertainty bands were added to the experimental measurement (ZXP0) using grey bars for two of the conditions. Figure 3 focuses on the hydrodynamic loads and response at the semisubmersible's surge natural frequency, whereas Figure 3 focuses on the pitch natural frequency. These plots show that, in general, the modelling tools under-predict the hydrodynamic loads on the semisubmersible in all conditions, and both at the surge and pitch natural frequencies. The best results are seen for the forced motion, pointing to wave loading being the hydrodynamic component that needs further investigation.

Two general modelling approaches are delineated by the solid vs dashed-line bars in the plots. The dashed bars indicate the use of Morison's equation for calculating the hydrodynamic loading. Morison-only solutions tend to work relatively well in surge, especially when fully nonlinear wave kinematics are used, but underpredict pitch load and motion at the pitch natural frequency. The other modelling approach is potential-flow (indicated by the solid bars), in combination with the drag component from Morison's equation. These models tend to better predict the loads, especially

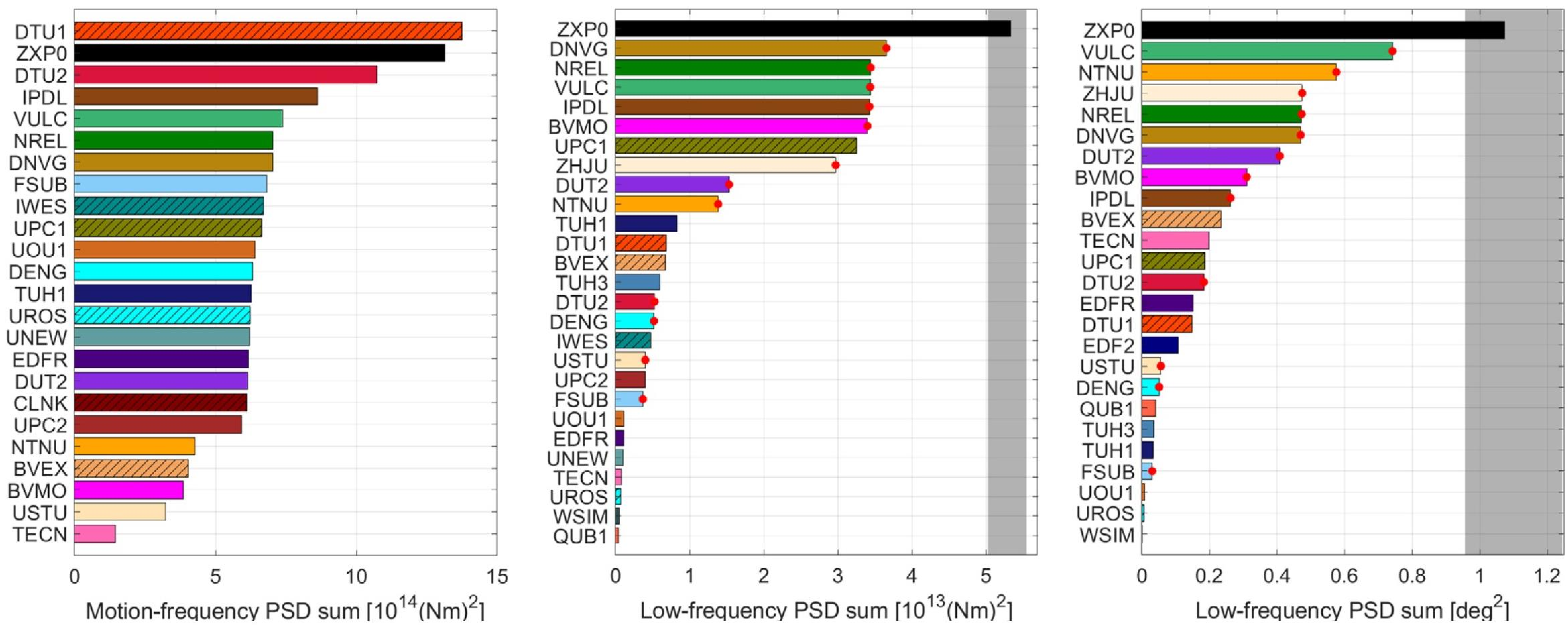


(a) LC 2.1—F_x for forced surge oscillation

(b) LC 3.3—F_x for fixed condition under wave loading

(c) LC 5.3—Surge motion for floating condition

FIGURE 2. COMPARISON OF SURGE-FREQUENCY-RELATED HYDRODYNAMIC LOADS AND MOTION. METRIC COMPARED IS THE INTEGRAL OF THE POWER-SPECTRAL DENSITY OF THE MEASUREMENT AROUND THE SURGE NATURAL FREQUENCY OF THE FLOATING WIND SYSTEM.



(a) LC 2.1—M_y for forced surge oscillation

(b) LC 3.3—M_y for fixed condition under wave loading

(c) LC 5.3—Pitch motion for floating condition

FIGURE 3. COMPARISON OF PITCH-FREQUENCY-RELATED HYDRODYNAMIC LOADS AND MOTION. METRIC COMPARED IS THE INTEGRAL OF THE POWER-SPECTRAL DENSITY OF THE MEASUREMENT AROUND THE PITCH NATURAL FREQUENCY OF THE FLOATING WIND SYSTEM.

when a second-order form is used, and if wave stretching is included.

Outcomes and significance

Validation of engineering models in OC6 Phase I identified limitations in the modelling theories. The work showed a general under-prediction of the low-frequency hydrodynamic loads on semisubmersibles, but more significantly due to wave forcing, rather than the loads resulting from the motion of the structure. These findings give focus to the work that needs to be done to improve the engineering models. At present, we see about a 20% under-prediction in the predicted loads in a floating wind semisubmersible. This level of inaccuracy is acceptable within the design process presently prescribed for offshore wind systems. However, if we want to find more optimized design solutions that will lower cost and decrease risk, more accurate modelling tools are needed. Methodically identifying and addressing the sources of inaccuracy and uncertainty in these tools is critical to advancing the floating wind industry to large-scale commercial viability.

Next steps

The CFD group will finish their modelling work for OC6 Phase I in 2021. Early results indicate that these tools provide a much more accurate estimation of the hydrodynamic loads on semisubmersibles, with validation being successful across many conditions. The goal is to use the CFD tools to identify the physical limitations of the engineering-level tools, and either tune those models or improve them. To help guide this work, a new validation campaign was developed that focuses on understanding the distributed loading better and obtaining hydrodynamic parameters for tuning using biochromatic wave excitation.

Phase II of OC6 will also be completed in 2021.

References

[1] Robertson, A., et al. (2020). "Total experimental uncertainty in hydrodynamic testing of a semisubmersible wind turbine, considering numerical propagation of systematic uncertainty." Ocean Engineering 195: 106605

[2] Robertson, A. N., et al. (2020). OC6 Phase I: Investigating the underprediction of low-frequency hydrodynamic loads and responses of a floating wind turbine. Journal of Physics: Conference Series, IOP Publishing.

Task contact

Amy Robertson (Amy.Robertson@nrel.gov)
Website: https://a2e.energy.gov/projects/oc6