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FAST Model Calibration and Validation of the OC5-DeepCwind Floating Offshore Wind System Against Wave Tank Test Data

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During the Offshore Code Comparison Collaboration, Continued, with Correlation (OC5) project, which focused on the validation of numerical methods through comparison against tank test data, the authors created a numerical FAST model of the 1:50-scale DeepCwind semisubmersible system that was tested at the Maritime Research Institute Netherlands ocean basin in 2013. The OC5 project revealed a general underprediction of loads and motions by the participating numerical models. This paper discusses several model calibration studies that were conducted to identify potential model parameter adjustments that help to improve the agreement between the numerical simulations and the experimental test data. These calibration studies cover wind-field-specific parameters (coherence, turbulence), and hydrodynamic and aerodynamic modeling approaches, as well as rotor model (blade-pitch and blade-mass imbalances) and tower model (structural tower damping coefficient) adjustments. These calibration studies were conducted based on relatively simple calibration load cases (wave only/wind only). The agreement between the final FAST model and experimental measurements is then assessed based on more complex combined wind and wave validation cases. The analysis presented in this paper does not claim to be an exhaustive parameter identification study but is aimed at describing the qualitative impact of different model parameters on the system response. This work should help to provide guidance for future systematic parameter identification and uncertainty quantification efforts.

INTRODUCTION

In 2013, a 1:50-scale model of the DeepCwind semisubmersible floating offshore wind turbine was tested at the Maritime Research Institute Netherlands (MARIN) ocean basin under the direction of the University of Maine. The data from this test campaign were then used in 2015/2016 within the framework of Phase II of the International Energy Agency (IEA) Wind Task 30 Project, also known as OC5 (Offshore Code Comparison Collaboration, Continued, with Correlation). The National Renewable Energy Laboratory (NREL) both led and participated in the OC5 project, which included conducting a series of model calibration studies to characterize the qualitative impact of different model parameters on the response of the model. The goal here was to identify model parameters that have significant impact on the system response and can potentially help to improve the match between the numerical model and the wave tank test data. Several of these studies and their key findings are presented in this paper. The authors modeled the DeepCwind system using NREL's open-source wind turbine simulation software FAST version 8 (NREL, 2015). This paper does not claim to be an exhaustive parameter identification as the interaction of different parameter variations is not considered here. The presented work aims at providing guidance regarding the qualitative impact and the importance of different model parameters for utilization in future parameter identification and uncertainty quantification studies for floating offshore wind systems.

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KEY WORDS: Floating offshore wind turbine, modeling, validation, FAST, calibration, aerodynamics, hydrodynamics, wind field.

MODEL DESCRIPTION

The key properties of the numerical and the physical model as tested in the wave tank are summarized below.

Physical Model Tested in Wave Tank

The system being investigated in this study is the DeepCwind semisubmersible floating wind turbine that was tested at MARIN in 2013 (Helder and Pietersma, 2013), which builds on testing performed for a similar system in 2011. Figure 1 illustrates the geometry of the semisubmersible system, which was designed by the University of Maine. The same platform and mooring geometry was also used in the OC4-DeepCwind semisubmersible system examined within the IEA Wind Task 30 Offshore Code Comparison Collaboration Continuation (OC4) project.

Comparing the OC5 system to the OC4 system, only the turbine changed: the OC4 project and the 2011 wave tank tests used a geometrically scaled version of the NREL 5-MW turbine that did not replicate its thrust and performance, and the 2013 tests and the OC5 project used the MARIN stock wind turbine, which mimics the power, thrust, and torque characteristics of the NREL 5-MW turbine quite well at model scale but has different airfoil geometries and slightly different scaled-mass properties. The appropriate power and thrust characteristics were achieved through special low-Reynolds-number-specific airfoils in combination with a modified chord-length distribution (Goupee et al., 2015).

A cable bundle that connects the measurement sensors installed on the floating system to the corresponding data acquisition system is shown in Fig. 1. Before every model test, the wave elevation at the future model location was measured without the model present. This undisturbed wave-elevation signal was used as input for the numerical simulations. The wind was generated by an array of fans, followed by a nozzle equipped with guides and stators to achieve a homogeneous, low-turbulence wind field (Helder and Pietersma, 2013). MARIN measured the mean wind