International Journal of Offshore and Polar Engineering (ISSN 1053-5381)

Vol. 28, No. 1, March 2018, pp. 54–64; https://doi.org/10.17736/ijope.2018.fv04

http://www.isope.org/publications/publications.htm

Validation of INNWIND.EU Scaled Model Tests of a Semisubmersible Floating Wind Turbine

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The subject of this study is the verification and the validation of existing numerical codes for floating offshore wind turbine structures using wave tank model tests as part of the INNWIND.EU project. A model of the OC4-DeepCwind semisubmersible platform, together with a Froude-scaled rotor model, is tested in a combined wind-and-wave basin. The simulation environment comprises a multibody approach with hydrodynamic and aerodynamic loads and mooring line forces. The focus of this paper is the validation of the hydrodynamics of a modified model hull shape, which compensates for the excess mass of the nacelle. The results show that the simulation model agrees well with the experiment.

INTRODUCTION

At offshore sites with higher water depths, the use of floating structures is more reasonable than the use of large fixed-bottom structures such as monopiles, tripods, and jackets as described by James and Costa Ros (2015) and Beiter et al. (2016). A floating wind turbine experiences many different loading conditions. Floater motion with six degrees of freedom (6DOF) as well as aerodynamic and hydrodynamic loads have to be considered. At this point, few floating wind turbine prototypes have been built, e.g., the Fukushima FORWARD project, which was started in 2013.

To increase the reliability of wind turbines for floating applications, validated simulation codes are needed to predict the forces on the system structure and their dynamic responses for combined stochastic wave and wind loadings (Müller et al., 2016). Although several verification tests have been done by Robertson et al. (2013), Huijs et al. (2014), and Müller et al. (2014), for example, the validation of coupled simulation of floating wind turbines is still part of current research.

This work is associated with task 4.2 of the INNWIND.EU project as part of its model test campaign at LHEEA, École Centrale de Nantes (ECN), France, in 2014. INNWIND.EU, with its 27 European partners, aims to improve the design of beyond-state-of-the-art 10–20 MW offshore wind turbines, including hardware demonstration. A scaled 10 MW model of the OC4-DeepCwind semisubmersible was built at the University of Stuttgart, together with a Froude-scaled wind turbine with low Reynolds rotor blades, developed by the Politecnico di Milano. The public deliverable D4.24 of the INNWIND.EU project by Lemmer et al. (2014) provides a description of the water tank tests, including an overview of the test campaign results. The subsequent validation work of different INNWIND.EU partners' simulation codes is reported in the public deliverable D4.25 by Heilskov et al. (2016). The objectives of the campaign are to increase the experience with scaled experiments of floating wind turbine systems, reduce the uncertainty in the results, and produce another data set of the well-known OC4-DeepCwind semisubmersible together with a performance-scaled 10 MW rotor. New features of this campaign include the implementation of wireless measurement techniques to reduce the additional stiffness of the cable bundle, compensation for the excess mass of the nacelle by additional ballast, and investigation of a 10 MW rotor in comparison to previous tests.

A similar 5 MW floating wind turbine concept was tested at MARIN in Wageningen, Netherlands, by the DeepCwind consortium in 2011; see Jain et al. (2012), Coulling et al. (2013), and Robertson et al. (2013). The model was tested again at MARIN in 2013 with detailed analyses of the second-order wave excitation forces and of the aerodynamics at low Reynolds numbers; see Kimball et al. (2014), De Ridder et al. (2014), Make et al. (2015), Gueydon et al. (2014), and Gueydon et al. (2015). Within the activities of IEA Wind Task 30, the OC5 consortium has used the measurement data for a joint validation task.

In this paper, the multibody system (MBS) tool SIMPACK is used for the simulation of the floating system with NREL's quasi-static mooring line model MAP++. The aero- and hydrodynamic forces are calculated by NREL's software packages AeroDyn and HydroDyn, which are coupled to MBS. ANSYS Aqwa is used in a pre-processing step for the calculation of the hydrostatic and hydrodynamic coefficients.

Through analysis of results from pitch free-decay tests, as well as wave-only, wind-only, and combined wind and wave tests, the numerical simulation model is validated and existing limitations are assessed. The focus lies on the hydrodynamics of the modified hull shape, which compensates for the excess mass of the

Received January 11, 2017; updated and further revised manuscript received by the editors June 23, 2017. The original version (prior to the final updated and revised manuscript) was presented at the Twenty-sixth International Ocean and Polar Engineering Conference (ISOPE-2016), Rhodes, Greece, June 26–July 1, 2016.

KEY WORDS: INNWIND.EU, floating wind turbine, semisubmersible platform, hydrodynamics, multibody system simulation, wave tank test.