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Hydrodynamic Analysis of the Semi-Submersible Floating Wind System for Phase II of OC4

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ABSTRACT

Hydrodynamic analysis of the semi-submersible floating wind system for Phase II of the OC4 project with mooring system is carried out. The simulations are conducted with our in-house solver naoe-FOAM-SJTU based on the open source code OpenFOAM. The finite volume method (FVM) is employed for solving Reynolds-Averaged Navier-Stokes (RANS) equations. The SST $k-\omega$ model is chosen as the turbulence model. The Pressure-Implicit with Splitting of Operations algorithm (PISO) is used to solve the pressure-velocity coupling equation. The impact of the wind turbine is simplified into equivalent forces and moments. The forces and the moments, as well as the motions of the floating system are generated by the naoe-FOAM-SJTU solver. The simulation results are compared with those without mooring system which have been done before. And discussions on the impact of the mooring system are presented.

KEY WORDS: Semi-submersible; OC4 project; naoe-FOAM-SJTU solver; hydrodynamic simulation; mooring system.

INTRODUCTION

Different from the traditional onshore wind turbines, the floating offshore wind turbines (FOWTs) are working in more complex environment. Besides the prediction of aerodynamic performance of the wind turbine, the hydrodynamic simulation of the supporting system of the FOWT is of great importance. The majority of the nowaday software for analyzing the FOWTs has advanced aerodynamics and limited hydrodynamics, because they were developed from analysis tools for onshore wind turbines. So, much attention has been paid to the hydrodynamic simulation of the supporting system of the FOWT.

Three types of floating foundations are widely used as the supporting system of the FOWTs: the tension leg platform (TLP), the spar platform and semi-submersible platform (Sclavounos, 2008). The linear and nonlinear wave loads on the Tension Leg Platform (TLP) moored to gravity anchors is obtained with the methods developed for the design of oil and gas offshore platforms (Sclavounos et al , 2010).
Karimirad et al (2011) got the extreme responses for the ultimate limit state design checks for a parked spar type platform of FOWT, considering coupled wave and wind induced motion and structural response in harsh condition. Based on different hydrodynamic theories, Kvittem et al (2012) examined the dynamic response of a single semi-submersible wind turbine.

The semi-submersible floating system for Phase II of OC4 (Robertson et al, 2012) is chosen in this paper. The Offshore Code Comparison Collaboration Continuation (OC4) project, which was formed in 2010 under the International Energy Agency Wind Task 30, is a project to verify the accuracy of the simulation tools and codes for the offshore wind turbine (Robertson et al, 2013). In this paper, the focus is on the hydrodynamic simulation of the semi-submersible floating system coupled with the mooring system. To take the impacts of the wind turbine into consideration, the NREL offshore 5-MW baseline wind turbine (Jonkman, et al., 2009) is simplified into equivalent steady forces and moments (Zhao et al, 2014).

In this paper, our in-house code naoe-FOAM-SJTU is described first, followed by the introduction of the governing equations, the VOF method and the geometry model including the mooring system. And the wave generation and absorbing validation is presented. Then, the numerical simulation results are discussed. At last, a proper conclusion is given.

MATHEMATICAL MODEL AND NUMERICS

naoe-FOAM-SJTU

The solver used in this paper is our in-house code naoe-FOAM-SJTU (Shen, Cao and Wan, 2012), which is based on open source tool packages OpenFOAM. The naoe-FOAM-SJTU solver employs the two-phase incompressible RANS equations, which is discretized by the finite volume method (VOF), and use volume of fluid (VOF) method to capture the free surface and the dynamic deformation mesh approach to handle the motions of the structures(Shen, Ye and Wan, 2012). So our in-house code can deal with the hydrodynamic problems on naval architecture and ocean engineering effectively. Based on the above, a numerical tank system is developed, which includes the wave generation and damping module, the six-Degree of Freedom (6DoF) motion module and also the mooring system module. Hydrodynamic simulation of a floating platform coupled with mooring system was conducted by Cao using naoe-FOAM-SJTU (Cao et al, 2013), and some verification was made before(Zhao, and Wan, 2015), which proved that naoe-FOAM_SJTU is a good choice to deal with this kind of problems.