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Hydrodynamic Performance of a Novel Floating Foundation for an Offshore Wind Turbine Under a Storm Condition

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A novel semi-submersible platform, referred to as HexaSemi, is proposed with a completely new designed heave plate. Compared with the WindFloat-type design, the new heave plate has a single hexagonal shape with a moonpool. From a structural point of view, its integral design can increase the integrity of the structure. In this paper, we mainly study its hydrodynamic performance for an offshore wind turbine. A numerical model is set up to simulate the motion characteristics of the floating wind turbine system, based on WADAM, Star-CCM+, and FAST. The comparative analysis of HexaSemi and WindFloat-type platforms under the storm condition is conducted and discussed. It is found that the integral design can increase the viscous hydrodynamic damping and reduce the heave response and the mooring cable force.

INTRODUCTION

Offshore wind energy is a kind of clean, abundant, and renewable resource, and it has become one of the most promising power generation methods in new energy (Karimirad, 2013). Compared with the land and shallow water, the deep-water areas have the advantages of steadier and stronger wind speed. Therefore, it is an inevitable trend for future wind farms to develop from the fixed type in shallow water to the floating type in deep sea (Gao et al., 2010). The semi-submersible platform is characterized by its small draft combined with hydrostatic stability during installation and substantial waterplane restoring. The structure stability is the foundation of the safe operation of the floating offshore wind turbine. One of the common challenges to the design of floating offshore wind turbine (FOWT) is the ability to predict the dynamic load responses of the coupled wind turbine and platform system, which usually combines a wind loading wave and a stochastic wave (Jonkman, 2010; Tran and Kim, 2015). It is necessary to study the dynamic response of the floating platform under the loading of the marine environment.

The concept of a floating offshore wind turbine was first proposed in 1972 (Heronemus, 1972), without any advance because of technical and cost constraints. Chung (1976) developed a method based on a potential flow theory to compute the hydrodynamic forces and six degrees-of-freedom (DOF) motion for a three-column platform (SEDCO-135) at arbitrary heading in waves of water of uniform depth, and the predicted results are close to the experimental data. In addition, Chung measured added mass and damping on a circular column with a submerged sharp-cornered circular footing from the experiments to get accurate values of those coefficients for force computations (Chung, 1994). Bulder et al. (2002) put forward the conceptual design schemes of various floating foundations, and the triangle platform was found to be superior to the others. In 2004, the Dutch Tri-floater was proposed based on the Drijvende floating wind turbine project. In 2006, MiniFloat was developed in the United States. Zambrano et al. (2006) simulated the basic structure and hydrodynamic response based on the storm conditions in Mexico Bay. In 2007, Ishihara et al. (2007) designed the Shimizu Semi-sub, a semi-submersible platform equipped with three sets of turbine towers. The motion response characteristics under the wave and wind load were studied through numerical simulation and a scale model test. In 2008, the American Principle Power Inc. company developed a new semi-submersible platform, WindFloat. Roddier et al. (2010) studied the feasibility of the WindFloat from three aspects: design criteria, hydrodynamic characteristics, and strength. Lefranc and Torud (2011) introduced the latest development of the semi-submersible platform, WindSea. Robertson et al. (2014) proposed a semi-submersible floating turbine scheme for the OC4-DeepCwind project and studied the hydrostatic and hydrodynamic characteristics of the platform. Tang et al. (2014) designed a triangular semi-submersible floating turbine base for the 5 MW turbine and studied its performance under different working conditions. One of the most common methods used to investigate the performance of FOWT platform is computational fluid dynamics (CFD) simulation, which can directly include all related physical effects (flow viscosity, hydrostatic, wave diffraction, radiation, wave runup, slamming, etc.) of the floating platform (Christensen et al., 2005; Chen and Yu, 2009; Ramirez et al., 2011). The other is a combination of the National Renewable Energy Laboratory's FAST (Jonkman et al., 2005), which is a well-known software code for the floating wind turbine and is computationally time efficient, and the diffraction/radiation panel program WAMIT (2000), which provides the added mass matrix, the matrix of hydrostatic restoring force, and the matrix of retardation for the platform.

In this paper, a novel floating foundation to support the National Renewable Energy Laboratory (NREL) offshore 5 MW wind turbine, named HexaSemi, is designed conceptually, based on the

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KEY WORDS: Offshore wind energy, floating foundation, wind turbine, integral damping plate, FAST.