Comparison of Numerical and Experimental Analyses of Motion Response of a Spar-Type Floating Offshore Wind Turbine in Waves

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ABSTRACT

Spar platform accommodating to intermediate and deep water is a reliable offshore structure that can support large floating offshore wind turbines (FOWT). In this paper, the hydrodynamic performance of FOWT is investigated by using experimental and numerical methods. The experiments are carried out for two models of 1:80 scales, one cylindrical spar and the other with heave plate at the bottom, respectively. In addition, at rated and extreme sea state, the wind force on the spar is modeled by a pulley-weight system attached to the spar top. The hydrodynamic force and motion response for both models are computed using combination of potential theory and Morison formulation. The viscous force on heave plate is approximated by choosing reasonable drag coefficient in the Morison formulation. The numerical and tests results are presented for the regular and irregular waves cases. Hydrodynamic prediction of the cylindrical spar is validated by the tests. But the difference of the cylindrical spar with heave plate exists between numerical prediction and the tests due to the behavior of the heave plate.

KEY WORDS: offshore wind turbine; spar; hydrodynamic performance, hydrodynamic model test.

INTRODUCTION

Wind power has been the fastest-developing type of renewable energy worldwide, with increasing efforts being focused on installing bottom mounted offshore wind turbines. However, the current offshore fixed-bottom technology cannot be economically applied at a water depth more than 50 m in Robertson & Jonkman (2011). Therefore, in recent years, FOWT was designed to capture power from offshore wind resources with the focus on deep water operation.

Spar platform in offshore industry has been validated as a reliable concept for deep sea areas. Statoil (2009) installed the world’s first operational deep-water floating large-capacity wind turbine, Hywind, in Norway. Karimirad & Moan (2012) dealt with the motion analysis of FOWT in harsh environmental condition. They have shown that the coupled dynamic response is dominated by wind induced response. The motion response of a rigid and elastic FOWT in harsh conditions is found to be almost same. Nielsen et al. (2006) studied the dynamic response of the Hywind concept, under both winds and waves by numerical simulation and experiment. They have shown that the responses around the natural frequencies are in most cases overestimated by the simulations, and this is an indication of higher damping in the experiments than in the simulations.

In this paper, the motion response of a cylindrical spar and the same spar with heave plate in regular/irregular waves have been examined by numerical simulation and model test. Hydrodynamic forces acting on the cylindrical spar and added mass effect of the heave plate are calculated by HydroD. Viscous force acting on the cylindrical spar and heave plate is approximated using the Morison drag formulation. To simulate the wind force acting on the wind turbine, a pulley-weight system was designed for irregular wave cases. The motion responses of two models for all cases are computed by using SIMO (2012).

TEST MODEL DESCRIPTION

A SPAR prototype is designed to support 5MW wind turbine. Due to the limitation of wave tank depth, the scale factor was selected to be 1:80 in the model test. The proposed two models are illustrated in Fig.1. SPAR-FOWT model without heave plate (Model 1) consists of a lower spar providing the buoyancy and an upper wind turbine tower. Ballast is located at the bottom of the spar to adjust the center of gravity (COG) and moment of inertia of the test models. For the SPAR-FOWT model with heave plate (Model 2), this plate was installed on the bottom of the spar. Table 1 and 2 list the main parameters.