The Wind-Wave Tunnel Test of a New Offshore Floating Wind Turbine with Combined Tension Leg-Mooring Line System

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ABSTRACT

In this work, a new conceptual floating offshore wind turbine structure with square buoy and the combined Tension legs-Mooring lines system was proposed, which was based on the National Renewable Energy Laboratory 5MW offshore wind turbine model. Taking the coupled effect of dynamic response of the top wind turbine, tower support structure and lower mooring system into consideration, not only the 1/60 scaled model test for investigating the coupled wind-wave effect on the novel floating wind turbine system was done in HIT wind-wave tunnel according to the typical design conditions in IEC 61400-3 code, but also numerical simulations corresponding to scaled model tests were performed by advanced numerical tools. The results of model tests and numerical simulations had a good agreement, so the availability of the numerical model has been validated. In addition, the surge responses of the square buoy were compared with those of the circle buoy under typical regular wave cases. Furthermore, the test results of traditional TLP wind turbine without mooring lines were given and compared with the results of the new floating wind turbine system. As a result, the good performance of the combined Tension legs-Mooring lines system was effectively proven, which might play an active role in the development of future floating offshore wind turbine.

KEY WORDS: floating offshore wind turbine (FOWT), combined tension leg-mooring line system, wind-wave tunnel test, numerical simulation.

INTRODUCTION

At present, the exploitation of offshore wind energy has been becoming an important development direction of wind energy industry. Tens of offshore wind farms have already been built near the shore, and a considerable amount of new large offshore wind farms are on the drawing table, especially for China, America and European countries. As the design water depth of offshore wind farms is becoming deeper and deeper, the foundation of offshore wind turbine is changing from the traditional fixed-bottom type to innovative floating type, which may be more suitable and more economical for deep water. The most representative one is the “Hywind” in Norway (2009), which is the first floating offshore wind turbine in the world. A deep draft spar floating foundation was applied to “Hywind” with the water depth of 220m. Now, more and more researchers have been paying their attentions to the innovative floating offshore wind turbine (FOWT) system design.

Hederson (2003) proposed a new five wind turbine semi-submersible floating platform system, and the performance of the new floating system was successfully studied by numerical methods. He developed the analytical tools for modeling the floating turbine loads and used a double Fourier transform to study the fatigue damage due to the vessel motion. What’s more, Zambrano (2006) proposed a three wind turbine semi-submersible floating platform system, and the dynamic response of which in the case of Gulf of Mexico storm was investigate by WAMIT program. Phuc (2007) made more time domain numerical simulations for wind-wave coupled effect on the three wind turbine system performance, which covered many typical design cases. Furthermore, Ishihara (2007) performed a 1/150 scaled rigid model experiments about the three wind turbine floating system in a wave tank and compared the experimental data with the corresponding numerical results. Then, the validation of the numerical method was effectively verified and the feasibility of the new floating system was also further confirmed. In addition, the effect of aerodynamic damping and hydrodynamic damping on dynamic responses of the new floating system was successfully investigated.

On the study of the single wind turbine floating system, Nielsen (2006) used both numerical method and 1/47 scaled experiment test to study the dynamic responses of the deep draft spar floating wind turbine, “Hywind”, the feasibility of which was well proven. Utsunomiya (2009) used 1/22.5 and 1/100 scaled test model to focus study on wave loads of the “Hywind” floating system, and the related numerical method was further verified. Sultania (2010) investigated the motion performance of a spar type floating wind turbine system during extreme sea conditions by (wind-wave coupled) time-domain numerical simulation. In addition, Jonkman (2006, 2010, 2011) made a great contribution to the development and verification of a fully coupled simulator of floating offshore wind turbines. He upgraded FAST to include the additional loading and responses representative of floating offshore wind turbines. Additionally, he used WAMIT code to calculated hydrodynamic loads. He applied the coupled simulator to three FOWT concepts (TLP, spar, semi-submersible). Roddier (2010) proposed a new semi-submersible FOWT system with an additional water-entrapment plate structure, the