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The Motion Performance of Two Offshore Wind Turbine Floating Platforms with Combined Tension Leg-Mooring Line System

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ABSTRACT

Based on the 5MW offshore wind turbine model developed by National Renewable Energy Laboratory (NREL), two new conceptual offshore wind turbine floating platforms with combined Tension legs-Mooring lines system were proposed in this paper. Taking the coupled dynamic responses of the top wind turbine, tower support structure and lower mooring system into consideration, the time domain hydrodynamic analysis coupled with wind loads has been done for the two offshore floating platforms: the single offshore wind turbine (S-OWT) platform and the multiple offshore wind turbines (Multi-OWT) platform. According to the sea statistical historical data for China East Sea and the typical design cases in IEC61400-3 code, the motion performances of the two OWT floating platforms have been studied by numerical simulation technique, respectively. Furthermore, during the irregular wave analysis, the effects of the current force and the slow drift force on the motion responses of the two OWT platforms were also clarified. As a result, the performance of the new combined Tension legs-Mooring lines system on controlling the motion responses of the OWT floating platforms has been verified in both views of theoretical analysis and numerical simulations. In a word, the two new conceptual OWT floating platforms would play an active and instructive role in the future design of OWT floating platforms.

KEY WORDS: offshore floating wind turbine, combined tension leg-mooring line system, motion responses, Pierson-Moskoweitz wave spectrum

INTRODUCTION

At present, as the continued increase of energy demand of the whole world, more and more nonrenewable fossil fuels are consumed. However, the emissions by burning these can strongly influence the global environment. Considering the supply limitation and the price volatility of conventional fossil fuels, many countries are paying more and more attentions to the exploitation of the offshore wind energy resource. Comparing with the onshore wind resource, the offshore wind resource has the advantages of high wind speed, low turbulence intensity, land saving, no noise annoyances and near the coastal developed areas. So far, almost all the European offshore wind turbines are installed on fixed-bottom substructures and these turbines are mostly installed in water shallower than 20 m by driving monopiles into the seabed or by relying on conventional concrete gravity bases, except for the first offshore floating wind turbine, “Hywind”, which was installed in a water depth of 220m and began to operate in 2009. However, much of the offshore wind resource potential in the United States, China, Japan, Norway, and many other countries is available in water deeper than 30 m, where the conventional fixed support structure technologies are not economically feasible. Instead, floating support platforms will be more economical for this water depth.

Both IEC 61400–1（2005）design standard and upcoming IEC 61400–3（2009） design standard require that an integrated loads analysis should be performed when a machine is certified. Such analysis is also beneficial for conceptual design, which allows designers to conceptualize cost-effective wind turbines that can achieve favorable performance and maintain structural integrity. Comparing with the fixed-bottom OWT load analysis, the floating OWT analysis must account for the dynamic coupled effects between the motions of the support platform and the wind turbine, as well as for the dynamic characterization of the mooring system for compliant floating platforms.

So far, many researchers have studied fixed-bottom OWT structures by using the famous Morison’s equation for the hydrodynamic loading calculations (Cheng, 2002; Veldkamp and Tempel, 2005; Zaaijer, 2006; Agarwal and Manuel, 2009; Zhang, 2010). However, the Morison’s equation ignores the potential effects of free-surface memory and atypical added-mass-induced coupling effects between modes of motion in the radiation problem, so these neglects inherent in Morison’s representation limit its applicability for analyzing the proposed offshore floating wind turbines. A number of studies have also assessed the preliminary design of OWT floating platforms, using Linear Frequency domain analysis. For example, Wayman, Sclavounous, etc. (2006) used Linear Frequency domain hydrodynamics techniques to analyze multiple TLP and a shallow-drafted barge design for a 5MW OWT. In these studies, the aerodynamic loads were simplified as a thrust force acting on the rotor and the elasticity of the wind turbine was ignored. One limitation of these linear frequency-domain analyses is that they cannot capture the nonlinear dynamic characteristics and transient events that are important considerations in wind turbine analysis. Using what they