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Experimental Study of Floating Offshore Platform in Combined Wind/Wave/Current Environment

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The development of offshore wind energy in Taiwan is moving toward the establishment of a demonstration wind farm before the end of 2016. The aim of this study is to investigate the dynamic motion of a floating platform in a wind-wave-current flume through the use of a 1:50 Froude-scale model. Compared to the target-scaling properties, the errors in the geometric dimensions and weight of the scale model are less than 2%. A series of experiments were conducted, including free decay tests and complex operating conditions, which combined the irregular waves, current, and wind. The drift and drag force was measured when the floating platform was subjected to the waves, wind, and current.

INTRODUCTION

For harvesting wind energy in deep water, floating foundations are considered to be a more economical solution than fixed foundations. Many scientists and engineers are thus developing suitable floating platforms for supporting wind turbines. Deep-water oil platform technology can provide a basis for designing floating offshore wind turbines (FOWTs); however, differences exist between these types of platforms because of the additional wind forces acting on the turbines and the higher center of gravity due to the tower height. For example, platforms for FOWTs attempt to minimize the pitch and roll motions for effective wind energy production, whereas oil platforms attempt to reduce the heave motion (Muskulus and Schafhirt, 2014).

Three typical offshore floating structures are commonly considered: a spar, a semi-submersible, and a tension-leg platform (TLP). Koo et al. (2014) compared three floaters in a number of wind and wave environments with an emphasis on global motions, wind excitation and damping effects, nacelle acceleration, and mooring loads. They concluded that the performance of floaters can change when specific loads and local environmental conditions are considered; that is, to get an overview of specific FOWT motions, the dynamics of FOWTs in the local environment must be investigated.

There are a few multi-megawatt FOWTs in existence. They include Norway's Hywind, built in 2010 (Statoil, 2014), and WindFloat, a semi-submersible-type FOWT installed in Portugal in June 2012 (EWEA, 2013). Recently, Japan established a spar-type FOWT that survived a typhoon (Utsunomiya et al., 2014).

Taiwan's Bureau of Energy made plans to increase the percentage of renewable energy from 7.7% in 2009 to 11.2% in 2015 and to make further efforts to reach 15.1% in 2025. The goal for the percentage of wind power was 0.8% in 2009 and 3.4% in 2015 and will be 5.3% in 2025. Wind power is expected to become the fastest growing and most dominant among all renewable energy types. Taiwan has substantial wind resources. Some onshore wind power plants have been built and are under operation; however, offshore wind power has richer potential but has not yet been developed. For water depths of 5 to 20 m on the western coast of Taiwan, the total area is approximately 120,000 hectares, with speeds greater than 6 m/s at 50 m above sea level. If 3-MW wind turbines are arranged at intervals of four to ten times the rotor diameter according to a perpendicular and parallel wind orientation, the total installation of wind turbines is initially estimated to be about 3,000 units, which would provide approximately 9 GW. Compared to shallow water (water depth < 30 m), the most fruitful wind power (> 1500 W/m^2) is located in the coastal regions of Hsinchu and Miaoli where the water depth is deeper and ranges from 50 to 90 m. FOWTs are considered to be economical solutions in this area. The external forces in the Taiwan Strait include not only the wind and waves but also the current, where the wave direction is not parallel to the current. For example, one potential wind farm location is 8 km off the coast in Fun-Yan County. Based on a field investigation (Chen et al., 2010), the direction of the dominant waves is toward the west and west-northwest, and the mean current direction is mostly toward the northeast. The maximum local current in this area is 1.0 m/s with a mean current speed in the range 0.3–0.6 m/s, which is a depth-averaged current for both tidal and wind-driven currents. An angle of 90° between the waves and the current is used in this study.

The eastern coast of Taiwan has a unique geographic environment with high potential for natural disasters (typhoons and

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KEY WORDS: Floating offshore wind turbines, response amplitude operator, wind-wave-current flume, semi-submersible floater, drift force.