

EXPERIMENTAL AND NUMERICAL INVESTIGATION OF A FLOATING OFFSHORE WIND TURBINE PLATFORM

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ABSTRACT

The present study investigated the dynamic response of a novel design 1:50 scaled semisubmersible floating offshore wind turbine platform, consisting of three cone-shaped columns aiming to reduce wave load, maintain draft, and allow operation at shallower depths via model tests and numerical simulations (Figure 1). The experimental test including, free decay, regular wave and operational and extreme irregular wave, wave-wind combination conditions were conducted at wave basin in Hydrodynamic Research Laboratory at Yildiz Technical University. The numerical simulations were performed via OpenFOAM software. The results showed that the model has reasonable natural periods considering wave period ranges and was also stable under operational and extreme conditions. The numerical simulation results were found consistent with experimental results.



Figure 1 - 1:50 Scaled Semisubmersible Floating Offshore Wind Turbine Platform

INTRODUCTION

The growing global demand for sustainable and renewable energy has led to the development of wind turbines, which can be classified into onshore and offshore categories (Breton and Moe 2009). Offshore wind turbines can be affixed to fixed-bottom platforms or floating platforms, which are more suitable for offshore areas with large depths. Hybrid floating concepts, such as the semi-submersible platform, combine the stability principles of barge, spar, and tension leg platforms, offering superior stability efficiency in pitch and roll motions (Butterfield, et al. 2006). This approach is a promising solution for advancing offshore wind

technology. Several researchers have undertaken model tests on different conceptual designs of semi-submersible and other types of floating platforms. Ishihara et al., (2007) introduced a multi-turbine concept featuring for a semi-submersible structure. They conducted experiments at a 1:150 scale in a wave tank at Japan's National Maritime Research Institute. Initially, they conducted a series of free decay tests to assess the natural periods of the platform. Subsequently, they performed a series of regular wave tests to assess how the floater responded to varying wave periods. Irregular wave tests were then carried out to simulate operational and survival conditions. Notably, the influence of wind was not examined in these tests, but the weight of the turbine and nacelle were included in the experimental setup. Goupee et al., (2012) extensively examined the behavior of three different designs of floating wind turbine platforms in 2012. These experiments were conducted in a wave basin at the Maritime Research Institute Netherlands. The three types of platforms tested included semi-submersible, tension leg platform (TLP), and spar buoy designs.

MATERIALS AND METHODS

The motion characteristics of a 1:50 scale model platform were observed through testing in the wave basin at the Hydrodynamic Research Laboratory (HRL) of Yildiz Technical University (YTU). The wave basin is equipped with a forty-eight-pedal piston-type wave generator, which can generate regular or irregular, unidirectional or multidirectional waves. An active device damps the reflected wave energy. The platform is comprised of three truncated cone-shaped legs, with each leg positioned on a circular heave plate. The central deployment of a main shaft on the platform functions as the supporting structure for the turbine's carrier tower. The interconnection between the main shaft, buoyancy legs, and heave plates is facilitated through the utilization of cross braces. The platform's position was maintained through the installation of a catenary mooring system, which comprised of three steel mooring lines affixed to heave plates at angles of 120 degrees (Figure 2). Several devices were utilized to track the movement of the floating wind turbine platform, such as an inertial measurement unit, a Raspberry Pi panel computer, and a GoPro camera. The mooring tension was assessed using loadcells that were affixed to the fairlead of the mooring line. The thrust of the wind was produced via the use of a drone. The wave heights and wind velocities were determined utilizing wave probes and anemometers. Free decay tests were conducted on heave, pitch, and surge modes of motion to identify natural periods in each degree of freedom. The natural periods and damping coefficients were evaluated using

the time series results. A set of regular waves test were conducted with varying heights and periods to identify hydrodynamical response characteristics of the system. Irregular wave-only, irregular wave-steady wind tests were also conducted for operational and extreme environmental conditions. The irregular wave and wind cases were created using wave climate obtained from a study conducted by Islek et al.(2020) with 40 years of wind data analysis. OpenFOAM was used to discretize Unsteady Reynolds-Averaged Navier-Stokes equations for CFD simulations. By utilizing the Overset meshing tool, a fitted mesh was generated around a floating platform. Precise free surface motions were captured by utilizing a region with the fitted mesh and a high-resolution free surface area. The numerical simulations were performed and validated for free-decay tests, regular and irregular wave tests.

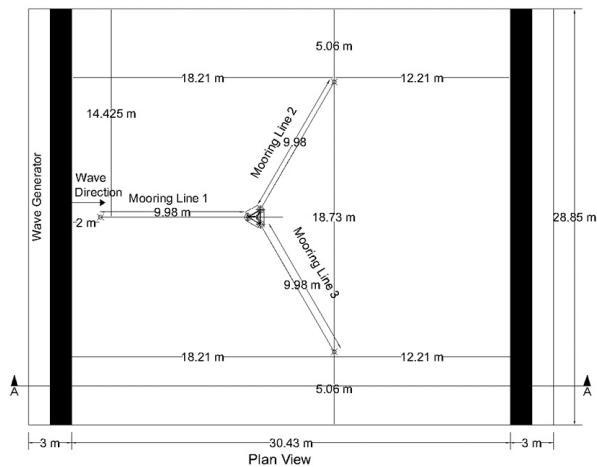


Figure 2 - Mooring Line Configuration

RESULTS AND DISCUSSION

Free decay test result showed that the natural periods of the model in heave, pitch and surge modes of motion are 17.25, 50.56 and 62.18 seconds for full-scale. The natural periods are way beyond the wave period range indicating that there is no risk of resonance in related modes. The model was stable under operational and extreme environmental conditions. Surge motion response of the model were increasing with increasing wave periods. The maximum tension force on the mooring line were detected at the mooring line attached on the wave generation direction. The simulation result of the analyzed experimental load cases were found consistent with slight discrepancies and calibration process is continuing to detect and eliminate these discrepancies.

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