Practical Simulation on Motions of a TLP-Type Support Structure for Offshore Wind Turbines

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ABSTRACT

The development of offshore wind farms commenced in shallow water areas with the fixed (seabed mounted) structures. However, countries with limited shallow water areas, requires innovative floating platforms to deploy wind turbines offshore to harness wind energy in deep sea. The hydrodynamic interaction of such platforms with ocean waves and the understanding and quantification of the non-linearity involved in these interactions is of vital importance while designing a cost effective and durable floating platform. This paper describes a numerical time domain modeling developed to simulate dynamic behavior of the TLP type floating offshore wind turbine system. The effect of change in platform configuration on its response has been examined in detail. A limited comparison of the numerical results with the experimental data is also presented, showing acceptable accuracy of the model.

KEY WORDS: Rigid body motions; offshore wind turbine; TLP; Morison’s equation.

INTRODUCTION

Climate change and the need to manage dwindling fossil fuel reserves are the biggest challenges faced by the energy suppliers worldwide. The growing awareness about environmental concern uplifts the use of renewable energy for making these challenges manageable. Wind is the world’s fastest growing renewable energy source and has become an integrated part of the modern power production in many countries. This trend is expected to continue with falling costs of wind energy and the urgent international need to tackle CO2 emissions to prevent climate change. Future development of onshore wind farms are hampered by concerns about turbine noise, aesthetic (visual) impact and scarcity of land for turbine placement near major population (and energy load) centre where energy cost and demand is high. Locating wind turbines offshore alleviates these concerns and also offers advantages of higher and steadier wind speed, and availability of larger area sites than onshore.

In offshore areas having deeper water depth, the fixed offshore wind power structure installation practice of driving piles into the seabed becomes economically infeasible. Therefore it is strongly desired to develop a cost effective floating platform to support wind turbine. Several concepts of floating offshore wind turbines were studied and some of them are under research. The examples include MUFOW by Baltrop (1993), toroidal shape floater by Bertachhi et.al (1994), FLOAT study by Tong (1998), Tri-floater by Delft University (2003) and NREL TLP by Musial et al (2004). On the other hand, Blue H technologies (2007) launched a TLP-type floating wind turbine to work in 108m water depth at a distance of 10.6 miles offshore in south Italy. Recently, StatoilHydro (2009) launched a spar type floating (2.3MW) wind turbine, Hywind, in water depths of 220m, at roughly 12 km southeast of the Norwegian island of Karmoy.

In the present study, a TLP-type floating offshore wind turbine has been considered due to its possible cost effectiveness. The major goal of this research is to develop a fast numerical time domain model which can simulate dynamic behavior of the structure under given environmental condition. In the past study (Shim, et al., 2008), similar structure was analyzed and the effect of increase in blade size on the platform motion and tether tension was examined. In the present study the effect of change in platform configuration on its response has been examined in detail.

The combined wind turbine and its supporting platform have been referred as FOWT (Floating Offshore Wind Turbines) system throughout this paper.

NUMERICAL SIMULATION MODEL

Co-ordinate System and Governing Equation of Motion

The FOWT system is assumed to undergo rigid body motions in the standard modes of motion that are considered in wave-body interaction theory. Modes 1-3 are surge, sway and heave, representing translations along x, y, and z axis, respectively. Modes 4-6 are roll, pitch and yaw representing rotations about the x, y, and z axes, respectively. The co-ordinate system and the corresponding modes of motion at or about CoG (centre of gravity) of FOWT are shown in fig.1.

Two co-ordinate systems are used to describe the motions of a FOWT system. One is a space fixed system with its z axis being upward and its origin at the center of gravity of FOWT system when it is at rest. Other one is a body fixed system with its z axis along the vertical centerline and its origin always at the centre of gravity and hence moving with the