Coupled MBS-CFD Simulation of the IDEOL Floating Offshore Wind Turbine Foundation Compared to Wave Tank Model Test Data

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ABSTRACT

A two MW floating offshore wind turbine is currently developed within the EU-FP7 project FLOATGEN. A wave tank test of the floater model at 1/32th scale has been performed in extreme wave conditions. In the present study numerical calculations of the floating foundation with regular waves using coupled MBS-CFD methods are compared to experimental data enabling a validation. Results of the wave elevation, floater motion and mooring line tension show a very good correlation. Flow phenomena like vortex shedding at the hull of the floater are shown. The presented methodology provides detailed knowledge allowing analysis of wave impact and resulting load assessment of floating offshore structures.

KEY WORDS: Floating offshore wind turbine; Wave tank model test; Computational fluid dynamics; Multibody system; Numerical wave tank (NWT); Vortex shedding; Mooring line

INTRODUCTION

The potential for floating offshore wind energy in Europe is immense and already the North Sea could meet today’s EU electricity consumption by multiple times. The European Wind Energy Association (EWEA) states based on research of the EU-FP7 project ORECCA (2012) that two thirds of the North Sea have water depths between 50 m and 220 m which could be used to install floating offshore wind turbines (Arapogianni, 2013). Recently, the EU-FP7 project FLOATGEN has been kicked off to demonstrate and benchmark a floating wind turbine system for power generation in the Atlantic Ocean. The FLOATGEN demo project will deploy a two MW floating offshore wind turbine (see Fig. 1) at the SEM-REV test site located twelve nautical miles from the French Atlantic coast (FLOATGEN, 2014). SEM-REV is operated by École Centrale de Nantes, owner of the test site. Ebenhoch (2015) finds that the estimated target Levelized Cost of Energy (LCOE) for floating concepts which includes all capital-, operational- and decommissioning expenditure over the project lifetime is around 15.2 Eurocent per kWh. EWEA (Arapogianni, 2013) recommends further development and validation of numerical simulation tools to optimise and improve the design of floating turbines to be more competitive compared to fixed-bottom concepts with a LCOE of 13.5 Eurocent per kWh (Ebenhoch, 2015). The environmental conditions of a floating wind turbine system are dominated by turbulent winds, non-linear waves and currents. The floating structure affected by the wind turbine controller interacts with the surrounding fluids leading to induced motions, loads and deformations. For design optimisation realistic and detailed load estimates are needed. Hydrodynamics of offshore structures are commonly modelled in numerical codes using Morison equation, a semi-empiric approach, and potential flow theory. However, simple methods are not capable of including all effects as flow physics are often non-linear and highly complex. Matha (2011) explains limitations of the above mentioned hydrodynamics modelling techniques. Especially non-slender and non-cylindrical floating foundations like IDEOL’s ring-shaped concept (see Fig. 1) modelled in this paper require the consideration of wave diffraction, added-mass and radiation damping (Choisnet, 2014). These effects are inherently included in a Computational Fluid Dynamics (CFD) approach.

Fig. 1: Illustration of the two MW floating offshore wind turbine system within EU-FP7 project FLOATGEN (source: IDEOL)

Literature Study

Only limited analyses on loads and dynamics of floating offshore wind turbines using CFD modelling techniques have been published in the