Parametric Analysis of a Cylinder-like Shape Floating Platform Dedicated to Multi-Megawatt Wind Turbine

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ABSTRACT

The paper presents a parametric study of the design space of a cylinder-like shape floating platform dedicated to multi-megawatt wind turbine. The parametric design architecture considered is a both concrete and sea water ballasted cylinder. It ranges from shallow drafted barge with stability provided by water plane area to slender spar buoy characterized by heavy ballast placed at the bottom of the cylinder. Various configurations are investigated: permanent ballast only or with both dynamic and permanent ballasts, and with or without heave plates. The results show the sensitivity of the system to various parameters in terms of hydrostatic stability, resonance periods, and motion amplitudes.

KEY WORDS: wind energy; floating wind turbine; platform design; parametric study.

INTRODUCTION

Offshore wind is an emerging field where floating wind turbine is said to be the best alternative to fixed wind turbine when depth exceeds 50 m. So new solutions are currently being explored, with, in particular, the development of floating supports. To this end, IFPEN is working on the design of new concepts dedicated to multi-megawatt wind turbines to be installed along the French coasts.

The challenge here is to propose a device with a competitive cost of energy. First, it is necessary to design a floating support and a mooring system that enables the turbine to operate in optimal conditions whatever sea, wind and current loads. Secondly, the whole system needs to be able to withstand extreme 50-year return period sea-states.

Different design options have already been presented in the literature. They are all usually classified into three different categories with respect to the strategy they use to achieve stability: buoyancy based, ballast based and mooring lines based.

Various studies have been performed by IFPEN on several concepts. Here focus is made on cylinder-like shape floating platforms dedicated to multi-megawatt wind turbine. Hence, in this study, a typical barge proposed by the MIT/NREL (Wayman, 2006) is considered as the starting design of the parametric analysis. Such a device is known to behave with large amplitude of motion mainly because the floater has its resonance period in heave and pitch within the predominant wave periods. It is, however, reported in (Wayman, 2006) that it is one of the simplest types of floating structure from a design, implementation and cost point of view. Minimizing the motion response of the floater is hence the main design driver of the present study.

Several design options are investigated in the paper. One of the key aspects is to investigate the effect of heave-plates on the motion of the floater. Heave-plates are traditionally used in the offshore industry to increase the added mass and damp the motion through radiation and vortex shedding. Designs with one, two and three heave-plates are hence analyzed successively. The use of an active ballast system to control the tilt angle of the floater in function of wind speed and direction is also assessed. All the design options are analyzed and compared with respect to their hydrostatic properties, their frequency responses and their behaviors to irregular waves.

CONCEPTUAL DESIGN STAGES

Basis of Design

Turbine Type & Properties. The reference wind turbine considered here is the NREL 5 MW as described in (Passon, 2007), whose main characteristics are presented in Table 1.

In the different stages of the conceptual design, the wind loads is calculated in simplified manner by means of momentum theory. The rotor thrust is hence estimated by the following expression,

\[ F_{\text{thrust}} = \frac{1}{2} \rho_a C_T A_{\text{rotor}} U_{10}^2 \]  \hspace{1cm} (1)

for which \( \rho_a \) is to the air density, \( U_{10} \) is the far-field 10-minute mean wind speed, \( C_T \) is the thrust force coefficient and \( A_{\text{rotor}} \) is the rotor swept area.

Values were chosen according to the 5 MW NREL wind turbine properties described in Table 1.