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Risk Assessment and Sensitivity Analysis for Offshore Wind Turbines

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ABSTRACT

A comprehensive risk assessment framework is discussed in this paper for the support structure and the tower of an offshore wind turbine under extreme wind and wave conditions. The framework is founded on a probabilistic characterization of the uncertainty in the models for the excitation, the turbine and its performance. A comprehensive computational model is used for describing the dynamic behavior of the turbine and stochastic simulation is proposed for evaluating the associated stochastic integral quantifying risk. For improvement of the computational efficiency, a surrogate modeling approach is introduced based on moving least squares response surface approximations.

KEY WORDS: Offshore wind turbines; risk assessment; sensitivity analysis; stochastic simulation; probabilistic uncertainty.

INTRODUCTION

Offshore Wind Turbines (OWTs) (Fig. 1) represent nowadays an attractive alternative solution to the onshore wind turbines, offering multiple benefits and addressing effectively the well- known obstacles and problems associated with the latter ones (Henderson et al. 2003; Breton and Moe 2009). However, their design and operation are characterized by high complexity and uncertainty due to extensive variability of components, intense interaction among components and assemblies, multiple uncertain loading sources acting on the OWT's parts, and different OWTs' operating/loading conditions. For an efficient design such uncertainties need to be explicitly addressed, indicating the necessity for a risk-informed approach. Under this consideration, Cheng at al. (2003) presented a reliability-based approach for determining the extreme response distribution of OWTs. Thöns et al. (2008) and Thöns et al. (2010) performed a reliability analysis for the support structure of a fixed bottom OWT, considering the ultimate, the fatigue and the serviceability limit states. The analysis was performed utilizing stochastic finite elements in conjunction with an adaptive response surface algorithm and an importance sampling Monte-Carlo algorithm. The dynamic response analysis of the support structure of an OWT under wave and seismic loading including uncertainty was performed by Kawano et al. (2010). The dynamic response was obtained using the substructure method for a two-dimensional model of the OWT's support structure with pile-soil foundation. The Monte Carlo Simulation method was applied to evaluate the maximum response characteristics of the OWT's support structure, in conjunction with the second moment approach.

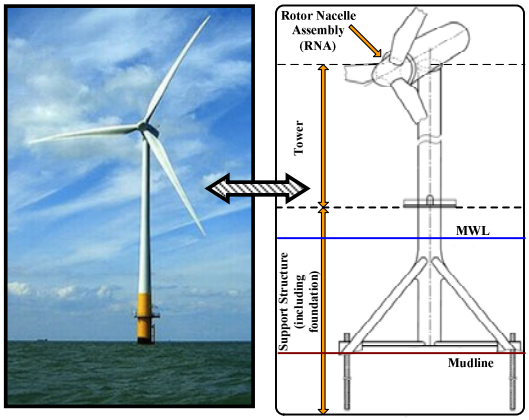

Fig.1: Offshore wind turbine.

In the present paper, a comprehensive risk assessment framework is presented for the support structure and the tower of an OWT under extreme wind and wave conditions. The structural model is based on the Finite Element Method (FEM). The Morison equation is applied in order to calculate the hydrodynamic forces on the support structure of the OWT, with water particle kinematics evaluated using a higher order wave theory. Characterization of the uncertainty in the parameters of these structural and excitation models, through appropriate probabilistic descriptions, leads then to quantification of the overall risk. This risk is