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Fatigue load estimation of a spar-type floating offshore wind turbine considering wave-current interactions

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Abstract

This paper considers the effects of current and wave-current interactions in fatigue analysis of floating offshore wind turbines (FOWTs). Surface water waves experience frequency shifts and wave shape modification when traveling on underlying currents. The wave-current interactions are known to be important for the responses of offshore structures, however have not been considered in FOWT fatigue analysis. To include such interactions, a nonlinear mooring hydrodynamics model is presented which is able to consider the cable geometric nonlinearity, seabed contact, and the current effect. The mooring model is then coupled with a spar-type FOWT model which simulates the structural dynamics of turbine blades and tower; aerodynamics of the wind-blade interaction and wave-current actions on the spar. Analytical wave-current interaction models based on Airy's theory considering the current effect are applied for generating the flow field. Based on a spar-type FOWT and the wave-current interaction model, numerical simulations have been performed for three cases with only waves, wave and current without and with interactions. The comparison of the structural responses shows that the current and the wave-current interaction can have significant influences on FOWT tower and cable responses. Furthermore, cable fatigue life is estimated for two particular cases when the cable tension is decreased and increased due to the presence of current. It is found that if the current tends to increase the cable tension, neglecting the current and wave-current interactions leads to overestimate of the cable fatigue life.

Keywords: Wave-current interaction; Fatigue analysis; Spectral method; Floating offshore wind turbines; Nonlinear mooring dynamics.

1. Introduction

Offshore wind turbines are subjected to wind, wave and current loads in operational condition [1]. In design and numerical simulation of these offshore structures, the modeling of the loads is critical [2]. It has been an ongoing topic of research. For floating offshore wind turbines (FOWTs) in deep water, the nonlinear mooring dynamics needs to be additionally addressed. The mooring load was originally considered using linearized models based on cable static solutions or using quasi-static models in fully coupled aero-hydro-servo-elastic simulations [3]. Recent studies have demonstrated the importance of mooring dynamics on FOWT responses [4], and focus is placed on the coupled analysis [5], validation of efficient models [6, 7], dynamic modeling in extreme conditions [8] and dynamic characterization of mooring cable behaviors in renewable energy applications [9]. A review on modeling mooring systems for wave energy devices can be found in [10]. The FOWT simulations carried out in these papers are able to consider the nonlinear mooring dynamics, including the geometric effect, the seabed-cable interaction and the hydrodynamic load. Note that most existing studies have still ignored the current effect on mooring cables. However, the current load

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