Comparison of four design configurations of inter-array power cables for a semi-submersible floating offshore wind turbine

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ABSTRACT

The objective of the study is to investigate the dynamic responses of inter-array power cables for a floating offshore wind turbine. Four design configurations of the 66kV power cable, including a lazy wave, a steep wave, a Chinese lantern, and a catenary shape are designed and compared. The structural responses of various configurations were evaluated by time-domain coupled dynamic simulations and a modified fitness function. The cable length and the position of buoyancy section are found as important factors affecting the cable's tension and curvature. The lazy wave and the steep wave configurations overall present good performances across design variants.

KEYWORDS

Cable configuration; dynamic cable; floating offshore wind turbine; inter-array cable design; riser configuration.

INTRODUCTION

Offshore renewable energy is imperative for achieving carbon neutrality. Current offshore wind turbines are mostly limited to shallow waters and mostly rely on fixed-bottom foundations [1]. However, in order to harvest more energy-dense wind energy sites, one must go further away from the coast and build floating offshore wind turbines (FOWTs). With a water depth exceeding 40 metres and above, a fixated foundation may no longer be suitable and a floating platform represents a more promising solution from the structural and economic perspectives [2,3]. For any floating offshore energy device, a dynamic power cable—an umbilical power cable connecting a floating platform to a more static transmission grid—is a crucial component of the entire system. Unlike other existing underwater power cables, the dynamic cables are designed to withstand loads brought by the floater's movements together with external environmental loads. These loads and movements result in axial forces and bending curvatures in the dynamic cable, posing a novel engineering challenge to design and ensure the mechanical integrity together with the mission critical water-resistant protection for the electricity transmitting conductors.

Umbilical structures connecting to a moving floating platform are not uncommon in the oil and gas industry for their usage of tubular umbilicals connecting floating platforms to the anchor point deep onto the seabed. Such umbilicals are commonly referred to as risers [4]. Similar to the dynamic cables studied in this paper, the risers used in the oil and gas industry are subjected to movements of floaters in tandem with ocean environmental loads such as currents and waves. Fig.1 showcases a few different riser configurations found in related literature [4,5]. These riser configurations aim to alleviate the extreme loads caused by the floater movements and/or waves and currents.

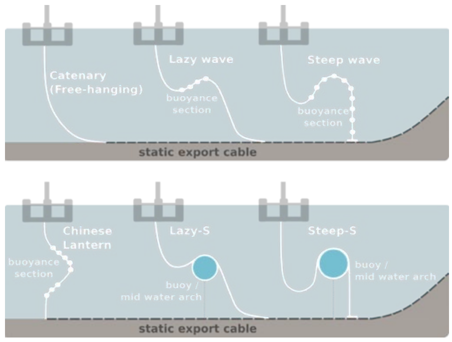

Fig. 1: Common riser configurations [6]

Rentschler et al. [7,8] presented dynamic analyses on two cable configurations, catenary and lazy wave, over various cable orientations and water depths using a genetic algorithm and a hybrid MATLAB-OrcaFlex simulation environment to calculate the fatigue life of the power cables under the environmental loads of wave and wind. It was concluded in their studies that a realistic modelling on the environmental loads is important to capture the deformation and force responses of the power cables. Thies et al. [9, 10] also presented OrcaFlex based dynamic cable simulations for different configurations and analysed load distributions on the cable. In their work, the lazy wave configuration is found to be beneficial to reducing maximum tension forces and avoiding compressions, and is thus deemed more suitable for their modelled conditions. The lazy wave configuration for the applications of FOWT and floating substations was studied in [11] and [12], respectively; strong connections are found between the design parameters and structural responses of the cable.

The objective of this paper is to evaluate the effect of adopting different riser configurations as part of the dynamic cable designs on the structural responses of the dynamic cables. As compared to aforementioned references, the present study contributes to a comprehensive comparison of different cable configurations and design variants. Finally, factors that are important for the structural responses of the power cable are identified and discussed.

METHODOLOGY

In this section, we introduce the simulation software, evaluation metric, reference FOWT model, together with the simulated environmental conditions used in the study.

Simulation software

Existing literature on simulating the dynamic responses of the power cables either opt for OrcaFlex developed by Orcina Ltd [7-12] or SIMA developed by DNV [6] as their software analytic tool. In this paper, we opted for SIMA [13] as our simulation software. There are two solvers under SIMA, namely SIMO [14] and RIFLEX [15], to respectively