Numerical and Empirical Determination of the Influence of Hydrodynamic Loads on the Fatigue Life of Submarine Cables

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ABSTRACT

In this paper, a concept for the study of the fatique life of submarine power cables is presented. Here, different hydrodynamic phenomena are described as relevant type of loads causing fatigue damage. Accordingly, methods for the statistical description of the loads and the derivation of according design load cases are derived. Furthermore, the structural composition of commonly used cable types is described and the lead sheathing of the cables is identified as the component most likely to fail. Finally, a concept for the numerical simulation of the design load cases and the determination of the internal stresses and strains in the cables is derived. Required input parameters for the simulations as well as their determination are defined. Finally, the availability of the required data as well the potential outcomes of the method are discussed. This paper presents a concept for a study on submarine cables fatigue life. As cause for loads of the cable, hydrodynamic phenomena are described. In addition, the lead sheathing of the cable is identified as a major failure risk. A study for the determination of statistical is specified by explaining statistical, numerical and experimental methods.

KEYWORDS

Power cable, fatigue life, fatigue analysis, offshore, FEM, statistical analysis, statistical loads, stress distribution, lead layer, waves, currents, tides, hydrodynamics

INTRODUCTION

The significance of the offshore wind industry continuous increased during the last decades. One of the major challenges in this industry segment is the reliable transport of the produced energy. Even though offshore installations became a well-established discipline of engineering during the last century, the economic and technical effort exceeds the one required for comparable onshore projects by far. Nonetheless, due to better and more constant wind conditions compared to onshore sites, the offshore sector is interesting, important and profitable for the wind industry.

The concept presented hereinafter is developed in the context of a project involving wind farms located in the German North Sea. Wind farms in this area are built at water depths between about 20 and 40 m, with the upper part of the original seabed consisting mainly of slightly muddy fine sand and shells [1]. In this paper, specifically the cables used to transport energy from the wind farms to the mainland (export cables) will be considered. Here, in order to transfer the energy, the generated electrical power of several wind turbines is transformed to high-voltage direct current (HVDC) level on converter platforms.

Failures on submarine export cables lead to high economic losses. On the one hand, repairs and replacements results in enormous costs in comparison to onshore cables. On the other hand, breakdown times can be extended by adverse weather conditions and long repair setup times. While it is comparatively simple to protect onshore cables against e.g. bending and mechanical shocks, the offshore industry operates in an area with considerably harsher environmental conditions. Thus, e.g. hydrodynamic loads due to waves, currents and vortices cause significantly higher loads on submerged structures. In order to address these issues, cables are buried about 1 to 10 m beneath the sea floor [1]. However, due to scour around the converter platform's foundation structure and the lack of suitable technical solutions, it is currently not possible to safely lead the cable out of the structure below ground level. Accordingly, the export cables exit the foundation structure through so-called *J-Tubes* above the sea floor. Here, the J-Tubes fix the downwards directed cables at a defined angle with the aim of providing a clamping without increasing local stresses in the cable. Consequently, in this area a section of the cable hangs freely between the foundation structure and the touch down point of the cable on the sea floor (free span).

Cable free spans are exposed to hydrodynamic loads as described above. Accordingly, it must be ensured, that load induced strains and stresses in the cable do not lead to system failures during the desired life time. In addition, both the J-tube and the seabed represent relatively stiff clampings. This limits the degree of freedom of rotation of the cable and could cause increased local stresses. As a consequence, suitable protection measures have to be applied to the cable design. Thus, submarine cables consist of diverse layers to provide a maximum protection. Furthermore, in order to reduce bending deflection and mechanical shocks, tubular cable protection systems (CPS) can be employed to the cable. In this context, one important challenge is the shielding of the conductor against water. Therefore, a layer of lead alloy guarantees water tightness. Taking into account the bad fatigue characteristics of this material [2], this layer can be assumed as the major risk for load induced cable failures.

CABLE DESIGN

In this section an exemplary cable structure is shown and described. With regard to HVDC export cables, this study will neglect more complex three core high-voltage alternate current cables. As shown in Fig. 1, extruded single core HVDC cables are sheathed by multiple insulation and protective layers. Following descriptions are based on Mazzanti & Marzinotto [3] which provides detailed a detailed overview on the subject. Beside special applications, copper conductors are commonly used for offshore HVDC export cables. These conductors consist of several wires. Surrounding semi-conductive tapes ensure a satisfying adherence and form fit of the different