Modelling and simulation for offshore laying of a trefoil submarine cable bundle

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ABSTRACT

The mechanical behaviour of a trefoil cable bundle during offshore laying process has been studied. The present trefoil cable bundle configuration consists of three cables of similar size, i.e., two main HVDC cables and one metallic return (MR) cable, bundled together by helically-wound yarns or ropes.

Numerical finite element (FE) models have been developed to analyze the mechanical response of the constituent cables and bundling yarns/ropes in terms of the axial load on the cables, the tension of the ropes/yarns, the slips in-between the cables and slips between the bundling ropes and the cables. The overall structural robustness of the trefoil cable bundle has been studied as a function of the tightness of the bundling.

The results from the present FE simulations have provided detailed insights on the setup of the bundle for controlling the structural stability of the trefoil cable configurations.

KEYWORDS

Submarine cable, Trefoil cable bundle, Offshore laying and installation, Bend stiffness, Helically-wound rope/yarn.

INTRODUCTION

For bipolar HVDC systems, simultaneous laying of the two cables in a bundled configuration is an established installation method that has been successfully executed in a large number of submarine projects, see for instance [1], [2]. To ensure the two cables are positioned side by side on the seabed, the cables are normally bundled together using rope or yarn before passing over the vessel chute as shown in Fig. 1. It is also common to include a Fiber Optical (FO) cable as part of the bundle.

Fig. 1: Two HVDC cables bundled with a bundling rope

Some of the next generation, 2 GW 525 kV HVDC offshore grid connections that are under development [3], will feature a bipole with a dedicated metallic return (MR) cable, i.e., three submarine cables. In case of a poles outtake the MR allows transition to a monopole operation, thereby maintaining 50% of the transmission capacity.

The MR cable will have similar mechanical properties as the HVDC cables but with slightly smaller outer diameter and weight.

Installation of three cables together in one bundle can be considered attractive, since it will reduce installation time and the spatial footprint of the cable system compared to if installing the cables in two or more separate campaigns.

Two-cable bundles are installed in a flat configuration where the main function of the bundling yarn is to keep the cables together from the vessel to the seabed. The bundling must have sufficient strength to not break when passing over the chute and to prevent cables from separating when the bundle is exposed to hydrodynamic forces. Overall, the selection of bundling design (stiffness, lay-length, etc.) is quite flexible for a two-cable bundle.

For a three-cable bundle, the design of the bundling will be much more important. The introduction of the third cable, with similar mechanical properties as the two others, will mean that much larger forces can be induced if the bundle is too tight. If the bundle is too loose, this can lead to an unstable configuration where the cables shift position relative to each other during laying. With a FO cable in the bundle, this will introduce the risk of squeezing and damaging the FO cable. This new concept of cable bundle will therefore introduce some additional complexities in comparison to a more traditional bundle with only two large cables.

In comparison to, e.g., a flat bundle configuration, a trefoil cable bundle offers a more robust and stable configuration from structural point of view; the position of the cables within the trefoil bundle can be adequately maintained during installation. The trefoil configuration will also have a more compact cross section, thereby reducing the hydrodynamic loads during installation compared to if a flat bundle is used. However, trefoil cable bundle can be challenging particularly during bending, e.g., when the cable bundle goes around the chute and upon touch-down at the bottom of the seabed, during subsea installation.

In the present work, the mechanical behavior of a trefoil cable bundle during cable laying is studied. The focus of the study is a three-cable bundle consisting of two main HVDC cables and one metallic return (MR) cable. The cables are arranged in a trefoil shape and bundled together using helically-wound yarn.

Numerical finite element (FE) models have been developed to analyse the mechanical responses of the cables, as well as the overall structural stability of the trefoil cable bundle during an installation scenario. In the model, the three cables and the bundling yarn have been explicitly modelled to enable detailed study on the overall responses of the bundle, e.g., the axial load on the cables, the tension of the ropes/yarns, the slips in-between the cables, as well as between the bundling ropes and the cables. In particular, the influence of setup for the bundling ropes/yarns for the tightness of the bundle (a loose bundle vs. tight bundle) and its consequences are evaluated.