Wide-frequency modelling of Submarine Cables for Deep Water DC Power Delivery

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ABSTRACT

The main objective of this study is to present a methodology for developing frequency dependent models to be used in submarine power cables design and simulation analysis of subsea DC power transmission and distribution systems in deep water applications. The proposed methodology consists in using finite element methods for determining cable electrical parameters and frequency response estimation, and the development of a state space representation of the desired configuration by vector fitting technique.

KEYWORDS

Submarine power cables, FEM, vector fitting, deep water applications.

INTRODUCTION

Submarine power cables have been employed in several applications for over a century. Initially, the main usage was to supply mainland nearby islands. Since the 60s, they have been applied for interconnection of bulky power systems separated by water arms, in order to enhance stability and increase energy provision. Recently, submarine power cables have been used for connection of offshore wind farms to the continent. In the near future, power will be supplied to offshore oil and gas (O&G) subsea production through submarine cables.

For many of these applications, power transmission in direct current (DC) is one possible solution to reduce power losses in long distance scenarios. DC power converters produce harmonic currents and voltages on the cables and, depending on the converter topology, large dv/dt associated to switching. Recently, DC power transmission and distribution systems have been considered for power delivery to subsea O&G processing systems. As these subsea applications may be in ultra-deep water, offshore dynamics will demand special designs of the DC cables, possibly resulting in novel cross-sections not yet adopted by the industry. Therefore, having accurate frequency dependent models of power submarine cables is of paramount importance for the reasonable design of power conversion and transmission systems for subsea processing in ultra-deep water.

In Figure 1 the magnetic flux distribution inside of a two-core cable fed with DC and AC currents is depicted. It is noted that for DC current, the field is concentrated between the two conductors. On the other hand, for high frequency current, the distribution is between the conductors and their associated metal outer layer. This change on the magnetic flux distribution affects the electrical parameters of the cable, making them frequency sensitive and justifying, then, the necessity of a frequency dependent cable model.

In this sense, this paper presents a frequency dependent model of a submarine two-core DC power submarine cable that can be used in several simulation tools. Electrical parameters and the frequency response for this cable topology were determined by Finite Element Method (FEM). From the obtained frequency response, the state space model of the cable was generated using the Vector Fitting technique developed by Gustavsen et al in [1]. Finally, the state space model of the cable was exported to three different simulation tools and numerical simulation results were analyzed and compared with a benchmark model.

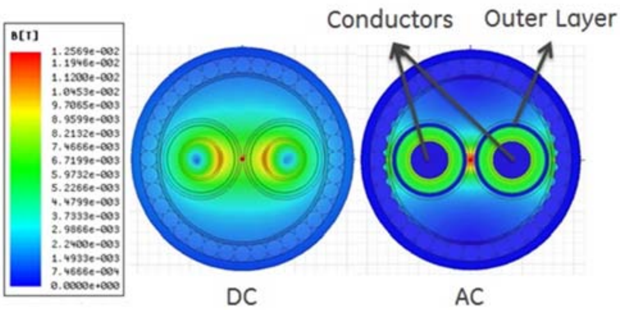

Fig. 1 - Magnetic flux distribution inside a two-core cable fed with DC and AC currents.

TWO-CORE CABLE DESIGN

As mentioned by Oliveira et al in [2], the dynamic riser integrated umbilical with power cables is a key component of an offshore system in ultra-deep water applications. Due to integrated umbilical constraints, a DC two-core cable is proposed in this study instead of two single-core cables. In Figure 2 the cross-section drawing of the cable is depicted.

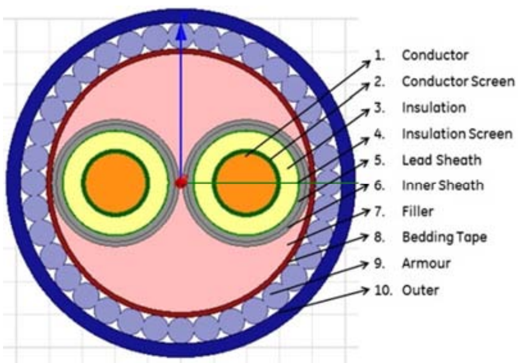

Fig. 2 - Cross-section drawing of the two-core cable modelled.

The two-core cable modelled was designed for the medium distance scenario presented by Oliveira et al in [2], in which the subsea power demand is 20MW (mostly pumping loads) and 50 km tie-back. Thus, the selected conductors cross-section and cable rated voltage were,