Wide-frequency modelling of submarine cables for deep water DC power delivery

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Submarine power cables have been employed in several applications for over a century. Initially, the main usage was to supply mainland nearby islands. From the 60s, they were 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. Power converters produce harmonic currents and voltages on the cables, and depending on the converter topology, large dv/dt, associated to switching. Moreover, many of these subsea applications will be in ultra-deep water, where 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 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 dependent and justifying, then, the necessity of a frequency dependent cable model.

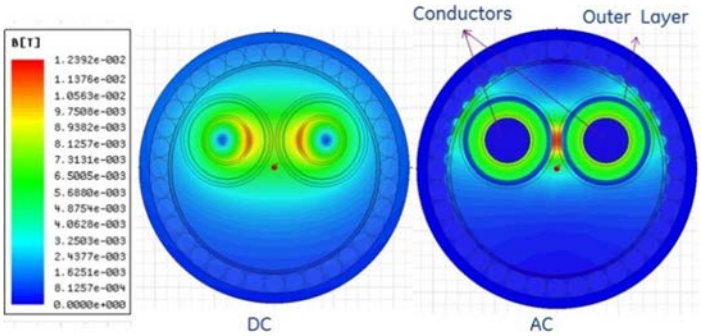

Figure 1 - Magnetic flux distribution inside of a two-core cable fed with DC and AC currents.

In this sense, this paper presents a frequency dependent model of a DC two-core 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 and all 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 and an equivalent model of PI sections in series.

Reference

[1] - Gustavsen, B. and Semlyen, A (1999). “Approximation of Frequency Domain Responses by Vector Fitting”. IEEE Transactions on Power Delivery, Vol. 14, NO. 3.