FEM analysis on influence of semiconductors in 3-core submarine power cables regarding cable losses

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ABSTRACT

The influence of a conductive connection between cable sheaths in 3-core submarine power cables is investigated using 3D-FEM simulations. In case of not bonded cable installations, a conductive connection influences the cable losses in total. Because of the connection, additional circulating currents in cable sheaths can occur, resulting in sheath losses comparable to bonded configurations. Crucial parameters are the conductivity of the connections as well as the cable length. An overall conductive surrounding is considered and additionally an attempt is made to model semi conductive coating. Both ways of modelling give similar results regarding cable losses.

KEYWORDS

FEM-Simulations, 3-core submarine power cables, cable sheaths, semiconductors, eddy currents, circulating currents

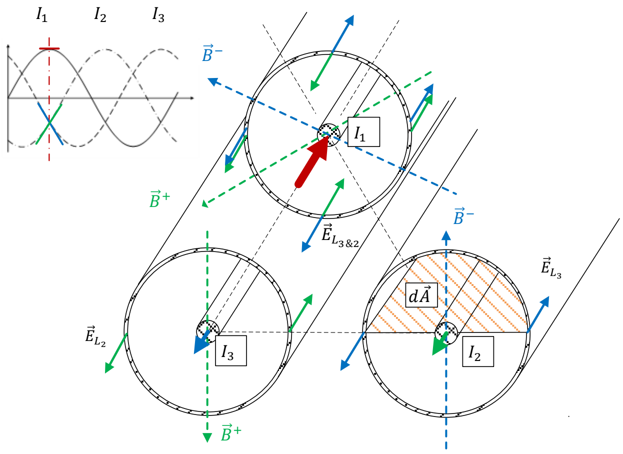

Fig. 1: Illustration of eddy currents in cable sheaths due to alternating magnetic flux density of adjacent conductors

THEORY TO SHEATH AND SEMICONDUCTOR LOSSES

At this point the general occurrence and behaviour of sheath losses shall be explained to better understand the possible influence of semiconductors (often labelled SC). Generally, the alternating magnetic flux densities in the area next to the sheaths induces circulating and eddy currents losses according to Maxwell´s induction law.

In case of submarine power cables the installation is usually performed with bonded sheaths. Single point or no bonding configurations as well as cross bonding arrangements occur far less. Nevertheless, the loss mechanism responsible for eddy current losses in sheaths is also relevant for circulating current losses in a bonded configuration and both mechanisms influence possible additional losses in semiconductors. The key to understand eddy current losses is Faradays law of induction:

$$-\int \vec{E}\,d\vec{s} = \iint \frac{\partial \vec{B}}{\partial t}\,d\vec{A} \qquad [1]$$

The alternation of the magnetic flux density within a certain area results in an induced electric field and therefore a current revolving this area. The occurrence of eddy currents in one cable sheath is due to the presence of neighbouring conductors. A graphical illustration is shown in Fig 1.

Indicated is the basic cable set up and the direction of the alternating magnetic flux density due to currents in conductors. The phase angle is marked by the lines in the diagram showing the currents in conductors. To display less induced electric fields/currents in the illustration the phase angle is chosen where the current in I_1 is at it´s maximum. As induced currents are a result of a change of magnetic flux density the induced currents by I_1 are zero too.

At this specific phase angle I_2 increases while I_3 decreases. The in- and decrease of $\vec{B}$ defines the direction of the eddy currents in sheaths. Next to the vectors indicating the flux in Fig. 1, marking signs "+" and "-" visualise the change of magnetic flux. In sheath of conductor 1 (I_1, at top of illustration) the induced electric fields overlap resulting in de- as well as increases of induced currents depending on the position along the circumference of the sheath. The surface $d\vec{A}$ is the area within a cable sheath, also indicated in one sheath in the picture, responsible for occurring eddy currents. Therefore, if the distance of cable cores increase eddy current losses will decrease.

For circulating currents in cable sheaths the identic physical mechanism (Equation [1]) is relevant, however, responsible for circulating currents is the alternating magnetic flux density outside of the cable sheaths as illustrated in Fig 2.