Evaluation of cross-talk in power cables by use of 3D finite element computations

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ABSTRACT

Finite element computations are presented, studying the effect of cross-talk between cable elements of different lay lengths. 3D computations with twisted conductors and screens are compared to the more traditional 2D cross-section approaches. Current flow in screens and impedances of cables are obtained. The results show that for the cable studied the calculated system parameters greatly depend on the approach chosen.

KEYWORDS

Power cables, modelling, cable screens, induced currents

INTRODUCTION

Identifying the system parameters of power cables is important for simulating the response of the transmission line system in the field. The system parameters are usually obtained either by measurements on the cable, or by a theoretical approach considering a semi-infinite extrusion of the cable cross-section [1-4]. In many cases, for example in the offshore industry, power cables are integrated in a custom designed umbilical cable consisting of hydraulic tubing, signal cables, metallic strength wires, and other elements. In these situations it is not practical to rely on measuring the response of the cable, as it is necessary to verify its functionality prior to production of the (expensive) umbilical cable. Thus, one relies on mathematical modelling work in the design phase to simulate the behavior and optimize the layout of the umbilical cable.

Conductors, screens, armor and other elements in power cables are twisted. In many cases the cross-section may be asymmetric and/or consisting of elements twisted differently. Asymmetry and twisting may be important for the system impedances (positive-, negative- and zero-sequence), and induced currents and voltages. 2D computations are not always well suited to reproduce this cross-talk, as artificial constraints are usually introduced to enforce behavior similar to that expected in twisted configurations. For example, in metallic screens consisting of multiple elements (strands/tapes), currents may be expected to be identical in each element (if current is not allowed to jump between elements). This can then be enforced in the model by applying voltages to these elements to counteract the induced currents. This is usually a fair assumption, but some effects related to circulating (eddy) currents may be erroneous when using this twisting approximation.

Maybe more important is the case when current may jump between elements by crossing a non-zero resistive transition, and the current distribution is not intuitive. An example may be a metallic tape twisted oppositely to a stranded screen, or two layers of oppositely twisted strands. Then, clearly a 2D approach is not ideal. An improved modelling method for more accurate simulations of the cable response can prove to be a valuable tool in the cable design process.

The objective of this work is to study the effect of twisted cables and screens by use of finite element (FE) modelling. A 3D model of a 3-phase power cable consisting of three screened cables is built in the FE software, and the resulting currents and impedances are obtained. These results are compared to the more traditional 2D cross-section approach for obtaining the system parameters.

METHOD AND MODEL DATA

A 3-phase power cable is modelled in the COMSOL Multiphysics FE software in both 2D and 3D. The cross-section of the cable is shown in Fig. 1. Only the three conductors (green in figure) and the metallic conductor screens (blue) are included. All other elements are for the purpose of this analysis regarded as a homogeneous non-conductive domain (grey). The conductors are arranged in a triangular configuration with centre-centre separation 80 mm. The cable conductor cross-sections are 150 mm^2, and are considered to be copper with conductivity equal to 58e6 S/m. The shape and size of the cable screen is varied in the simulations; both a full circumferential screen and a screen consisting of six tapes are investigated, and screen thicknesses from 1 mm to 2.5 mm are considered. The three different cases are summarized in Table 1. The inner diameter of the screens is 40 mm.

Table 1: Description of calculation cases.

Case	Description
1	Tape screen, 6 pcs, each 7 mm x 1 mm
2	Tape screen, 6 pcs, each 7 mm x 2.5 mm
3	Full circumferential (sheathed) screen with thickness 1 mm

In the 3D model the cable and screens are twisted with lay lengths equal to 0.5 m and 0.25 m, respectively. Though unusually short, these lay lengths are chosen to reduce the geometrical size of the model and to exaggerate the effect of twisting. In order to further reduce the computational requirements the screens are modelled as boundary elements using the "transition boundary condition" available in COMSOL.