SC-IES CABLES- SINGLE CORE CABLES WITH INTEGRATED ELECTROMAGNETIC SHIELDING

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ABSTRACT

The SC-IES cable is a solution for highest shielding demands in combination with high transmission capacities. With an effective design, the conductor – and screen currents have the same magnitude and nearly opposing phases. This approaches the behaviour of an ideal coaxial transmission line with lowest magnetic fields outside the cable trench. The SC-IES cable is discussed with respect to design aspects, the shielding effect, cable losses and current capacity.

KEYWORDS

SC-IES cable, IES cable, ferromagnetic shielding, shielding tapes, coaxial cable, finite elements method FEM, shielding factor

INTRODUCTION

To decrease the power frequent magnetic fields of three phase systems, several shielding measures can be applied. Examples can be found in [1] [2] [3] [4] [5]. A comprehensive description was published by CIGRE [6]. Depending on the requirements, shielding measures can be realized with limited complexity, e.g. by application of compensation conductors ("passive loops" [3] [4]). For higher requirements, the complexity can increase significantly, for instance when cable systems must be laid in steel pipes, which may have a significant influence on additional losses and current capacity.

For the demand of lowest magnetic fields outside the cable trench, this study analyzes a high permeability shielding which is integrated into high voltage AC-single-core cables with enlarged copper screens. Figure 1 illustrates the design of SC-IES cables and their shielding elements:

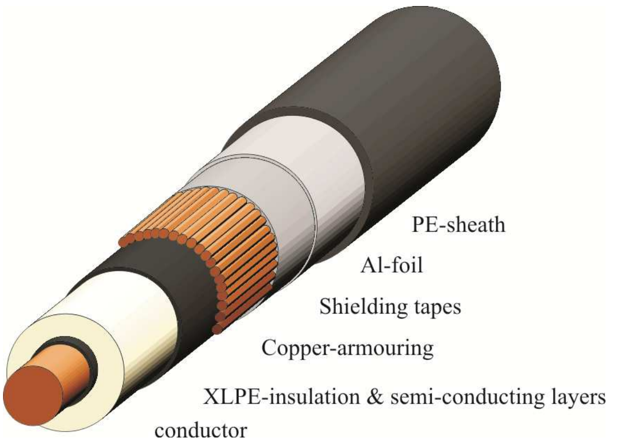

Fig. 1: Single core AC cable with integrated electromagnetic shielding (SC-IES cable)

Common copper screens have a cross-sectional area of 50 mm² up to 200 mm². The presented cable design has a reinforced copper screen - a copper armouring.

The copper armouring is enhanced by means of high-permeability tapes. Such tapes have been already introduced into a so called three-core IES-cable (cable with Integrated **E**lectro- magnetic **S**hielding [7])

By means of this cable design, extreme high shielding factors can be achieved, independent from the laying distance.

The high permeable tapes have ferromagnetic material parameters. It is strongly recommended to consider this, when such materials are applied in a cable design. The method of finite elements (FEM) is able to take the nonlinear material characteristic into account. In the next paragraph, it is described shortly:

FINITE ELEMENT CALCULATIONS FOR NONLINEAR MAGNETIC FIELDS

The finite element method (FEM) replaces the field area by a non-uniform, adapted grid of finite elements, which all may be different in shape or size. The field distribution in each finite element is approximated by a polynomial function

$$A_{z\Delta}(x,y) = c_1 + c_2 \cdot x + c_3 \cdot y + c_4 \cdot x^2 + c_5 \cdot y^2 + c_6 \cdot x \cdot y + ... \quad [1]$$

which approximates the distribution of the magnetic potential A_z with x and y the coordinates within the finite element. Applying the variational calculus the differential equation is converted to a functional equation and has to be differentiated to each node potential A_{zi} to get the minimum of the stored magnetic energy:

$$\frac{\partial W'_m}{\partial \underline{A}_{zi}} = \nu \cdot \sum_{j=1}^{n} \underline{A}_{zj} \cdot \iint_{A_\Delta} (\alpha_{ix} \cdot \alpha_{jx} + \alpha_{iy} \cdot \alpha_{jy}) dA_\Delta +$$

$$j\omega\kappa \cdot \sum_{j=1}^{n} \underline{A}_{zj} \cdot \iint_{A_\Delta} (\alpha_i \cdot \alpha_j) dA_\Delta - -\sum_{j=1}^{n} \hat{\underline{S}}_{zj} \cdot \iint_{A_\Delta} (\alpha_i \cdot \alpha_j) dA_\Delta = 0 \quad [2]$$

with $\alpha_i(x,y) = g_{1i} + g_{2i} \cdot x + g_{3i} \cdot y + g_{4i} \cdot x^2 + g_{5i} \cdot y^2 + g_{6i} \cdot x \cdot y + ...$

the form functions only depending on the geometry of the finite element. Minimising this functional equation not only leads to the field distribution at the grid points but also to the distributions within the elements. When calculating AC-problems, eddy currents have to be taken into account. An integration over all components of the