Estimating the losses in three-core submarine power cables using 2D and 3D FEA simulations

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ABSTRACT

2D and 3D FEA (Finite Element Analysis) simulation models are described and the solutions are discussed in comparison with the losses calculated according to IEC 60287. 2D FEA results have already shown significantly lower armour losses than IEC ones although the compensation of circulating currents in armour wires due to opposed stranding is not considered that way. Armour wire losses calculated by means of 3D FEA are even lower but through interaction of occurring losses shield losses increase. The influence of different magnetic permeability of steel wires and material temperatures is estimated to get an overview of developing losses. Finally, all calculated losses are compared and assessed.

KEYWORDS

IEC 60287-1-1; armour losses; three-core submarine power cable; FEM/FEA

INTRODUCTION

Several recent publications have described and discussed the losses in armour wires of three-core submarine power cables [1] – [4]. Especially in case of larger cables they seem to be much lower than calculated using the IEC 60287 standard. Different approaches with measurements and simulations were made to investigate the losses in submarine power cables and the results clearly outline a too high loss factor λ_2. Thanks to large computation resources 3D FEA calculations with a huge amount of mesh elements can be performed and evaluated. The simulations are done for a three-core submarine power cable with copper conductors and a cross section of 1200 mm^2, screen is made of lead while armour consists of wires of ferritic steel. Consequently several investigations were performed to estimate occurring losses in consideration of magnetic permeability of armour wires and cable temperatures.

SIMULATION MODEL

The 3D FEA model consisting of conductors (A), screens (B) and armour wires (C) is shown in Fig. 1. It is evident that all metallic components interacting with magnetic fields have to be considered. Other parts, namely semiconducting sheets, optical fibres with surrounding metal wires and XLPE fillers are neglected here.

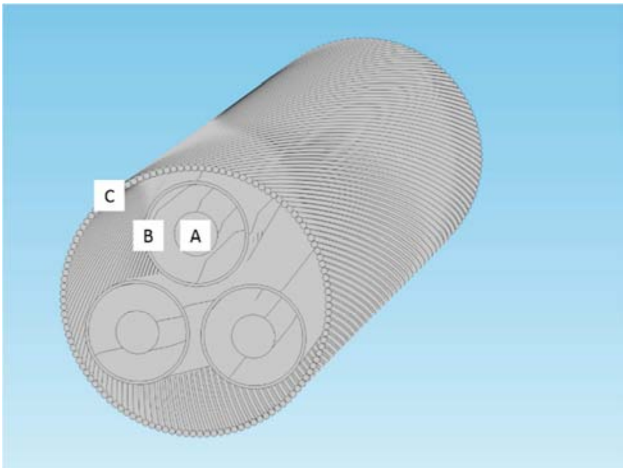

Fig. 1: 3D FEA Simulation model of submarine power cable

As a necessary simplification the copper wires of the conductors have to be summarized to reduce the complexity of the simulation model and thus the number of mesh elements. The complex stranding of single copper wires in Milliken conductors and additionally the unknown contacts are easier manageable by measurements than by FEA calculations. Undeniably, there is small difference because of the changed current distribution due to stranding of copper wires but here it is assumed that the effects due to electric and magnetic fields are similar for both massive and Milliken conductors. Stranding of conductors and armour wires is opposed and for both the pitch is in the range of a few metres. Sufficient simulation model length is chosen so that each armour wire crosses every conductor one time. In Table 1 the used material properties are listed.

	Conductivity at 20°C (S/m)	Cross section (mm^2)	Magnetic permeability μ_r
Conductor	$5.8\ 10^7$	1200	1
Screen	$4.67\ 10^6$	820	1
Armour	$7.25\ 10^6$	3350	50, 300, f(B)
Semiconductor	2	-	1
Other components	0	-	1

Table 1: Material and geometrical properties used in FEA simulations

The material properties are according to IEC 60287-1-1. Investigations with higher temperatures are performed with conductivities determined by temperature coefficients