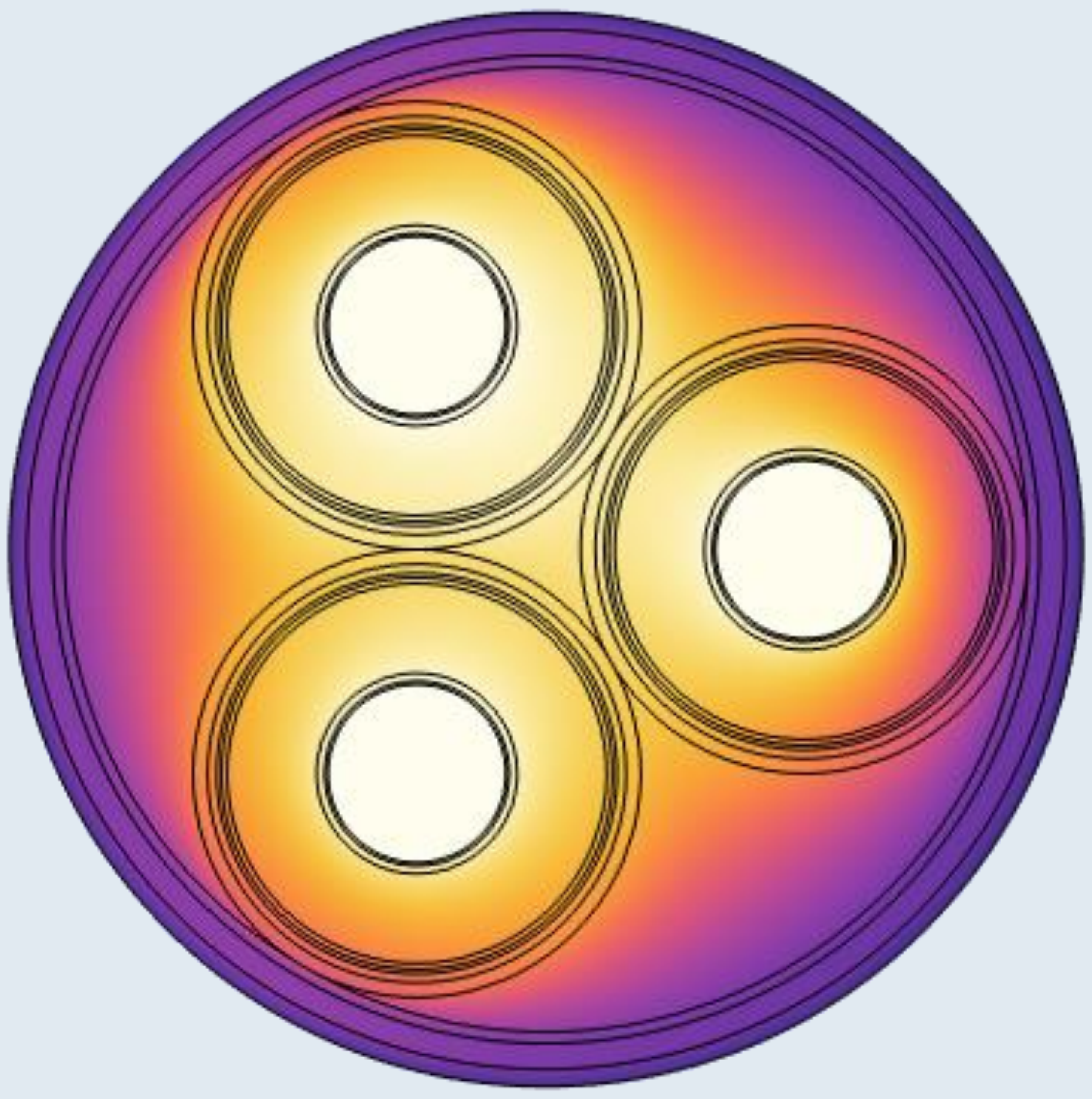

Direct FEM Ampacity Calculations for Submarine and Underground Power Cables

To ensure the safe and reliable operation of power cables, it is crucial to estimate their ampacity most accurately and efficiently. The purpose of the developed 2D FEM model is to compute the ampacity of the investigated cable in a direct manner, given the predetermined upper thermal limit.

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Abstract

The use of power cables has been rapidly increasing during the last decades, both in land and subsea applications. To reduce the cable cost, design optimization is necessary. The current-carrying capacity of cables, namely the “ampacity”, is an important factor, if not the most important one, significantly affecting the cable design. To optimize the latter, accurate ampacity calculations are required. The international standards, such as IEC 60287 [1], are typically used for ampacity calculations. However, they often adopt simplifications which may not lead to the optimum design. Two-dimensional heat transfer models, developed with the finite-element method (FEM), are presented. By using COMSOL Multiphysics® software, the typical ampacity calculations are improved both in accuracy and efficiency terms. By comparing FEM and Standard results, interesting findings occur and are discussed.

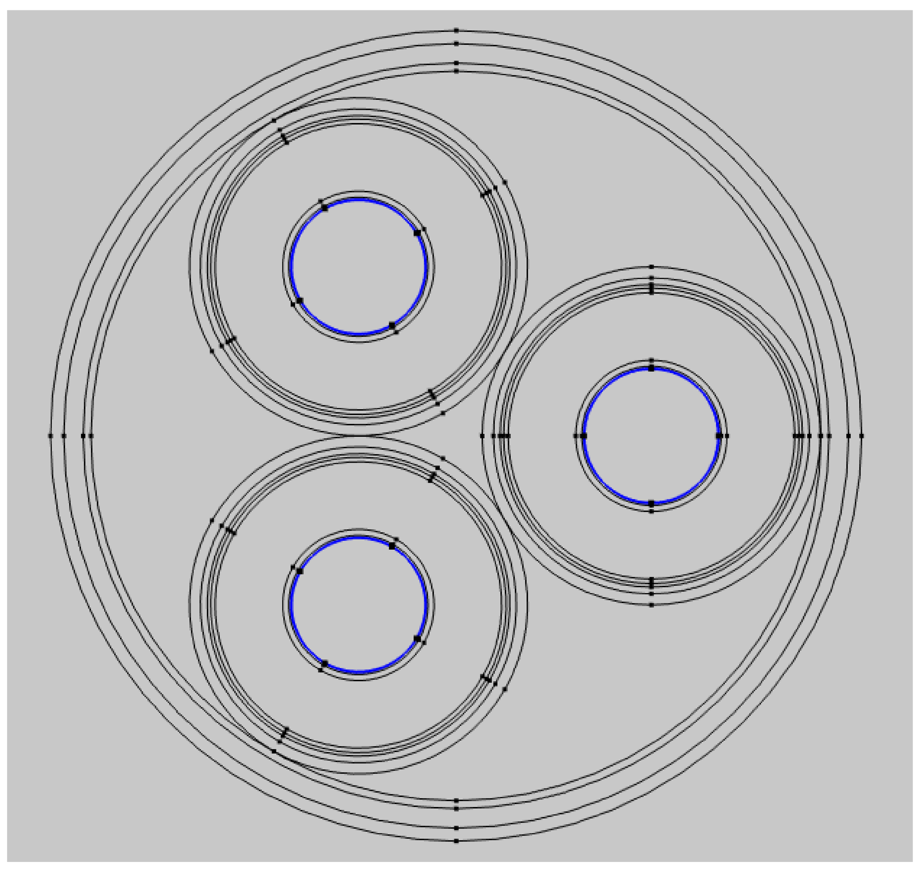

Fig. 1. Applied Dirichlet BC on the conductors’ outer surface in the direct ampacity method.

Methodology

In the case of the direct ampacity method, a Dirichlet BC is imposed on the outer surface of the conductors, as illustrated in Fig. 1, with the temperature, T_{cond}, set to the thermal limit. By utilizing an integration operator applied to the same surfaces, the conductor losses and the cable ampacity can be determined:

$$W_c = \frac{|intop1(ht.ntflux)|}{3\pi r_c^2} \longrightarrow I_{ac} = \sqrt{\frac{W_c \pi r_c^2}{R_{ac}}}$$

A model that utilizes the Optimization Module is also implemented. This analysis is formulated as a least-squares optimization problem, where the attainment of the maximum permissible temperature of 90℃ is set as the objective and the conductor current excitation as the control variable.

Results

The performance of the proposed model using the direct ampacity method is demonstrated in Tables 1 and 2. The results are compared with those obtained from both the optimization-based method and a commercial software implementing the IEC the IEC 60287 standard.

It is evident that the two FEM-based methods yield identical ampacity values, thereby validating the accuracy of the direct ampacity method. The inadequacy of the IEC 60287 standard in the submarine cable case can be attributed to its assumption of isothermal sheaths, which is not applicable to 3C SL-type cables, along with the limitations of the considered geometric factor, which are discussed in detail in [2], [3].

Submarine three-core SL-type cable

Table 1: Ampacity comparison for the examined methods in the submarine cable case.

Method	Ampacity (A)
Direct ampacity	936.5
Optimization-based	936.5
IEC 60287 standard (+CIGRE TB 880 [2])	961.2

Underground single-core cables in flat formation

Table 2: Ampacity comparison for the examined methods in the underground cable case.

Method	Ampacity (A)
Direct ampacity	859.3
Optimization-based	859.3
IEC 60287 standard (+CIGRE TB 880 [2])	859.4

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