3D Thermal Analysis Of Complex Cable Crossings

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Abstract

Cable crossings can affect the performance and ratings of cables. Cables installed adjacently to other power cables are subject to higher temperatures than the expected ones, due to mutual heating between them. In this work, the thermal behaviour of more than 20 cable crossings (Fig.1) consisting of cables of different voltage levels installed in various depths and angles is analyzed. This is an actual installation case commonly used at High Voltage (HV) substations. To account for the thermal effect of the crossings, this analysis can only be conducted in three dimensions. Heat transfer in Solids and Surface-to-Surface Radiation physics are solved with the appropriate conditions applied.

Selections feature becomes critical for so complex geometries. It is apparent that a high number of domains may result to incorrect selections if performed manually, while it would be very time consuming as well. Perhaps the biggest challenge for this type of analysis is the mesh creation. The short distances and angles between cables, as well as the small dimensions of the cables' internal layers and the cables' bending, make the mesh process impossible to complete effectively. Several techniques are utilized to build a successful mesh, which mostly consists of swept mesh instead of free tetrahedral. This significantly reduces mesh size and improves solution time, while the accuracy is kept at relatively good levels by increasing the mesh density along the swept mesh. This way, the temperature gradient along conductors expected due to longitudinal heat cooling can be well captured.

Different solver configurations are examined; Quadratic Lagrange discretization with direct solver cannot be used due to the large mesh size which can be as high as 17 million elements or more, while the AMG solver appears to be less stable, also providing questionable results. Linear discretization with the more consistent direct solver is selected, however, this method may not give as accurate results as with the Quadratic Lagrange discretization. To overcome this, an extensive sensitivity analysis against mesh is done and the finest mesh, no longer affecting the derived temperature results, is eventually selected. Additionally, the solver tolerance is reduced at 1E-6. The results allow us to improve the installation conditions of cables installed in critical areas, such as at the crossings and/or select cables with appropriate ratings.

Efficient use of Comsol resources is demonstrated throughout the analysis. The presented work can be used for the examination of multiple cable crossings at different crossing angles. This is the first time in the existing literature that such a complicated geometry is examined. While, the existing approach is only applicable in crossings with straight cables (FEA models have been verified in [1] against other analytical approaches and IEC 60287-3-3 [2]), the proposed method can be applied at geometries including bent cables. The findings of this work are useful for the optimization of cable installations such as HV substations, since it provides information about the temperature increase of cable crossings under different installation conditions and can eventually lead to more cost-efficient solutions.

Reference

[1] A. I. Chrysochos, D. Chatzipetros, D. G. Kontelis, “Ampacity Calculation of Multiple Cables with Different Crossing Angles”, 11th International Conference on Insulated Power Cables, Lyon, 2023.
[2] IEC 60287-3-3, “Electric cables – Calculation of the current rating - Part 3-3: Sections on operating conditions – Cables crossing external heat sources”, 2007.

Figures used in the abstract

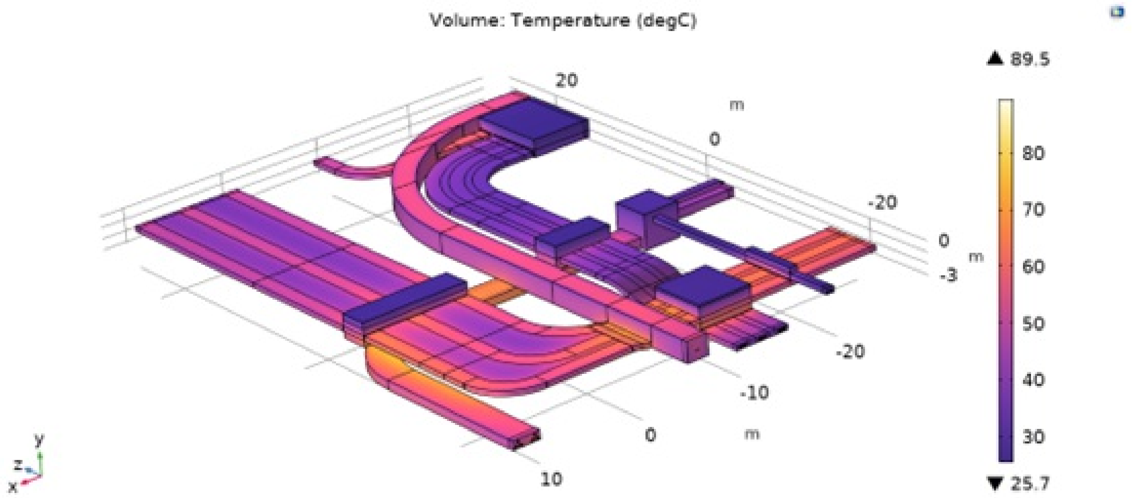

Figure 1 : Fig. 1 - Temperature distribution on geometry with backfills.