

Ampacity simulation of a high voltage cable to connecting off shore wind farms

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Introduction: When designing or choosing a cable oftentimes a desired maximum current has to be carried. One restriction that usually has to be met is the maximum allowable temperature, dictated by the used insulator materials. The cross section area of the conductor directly influences the temperature distribution. Since material are high a reliable calculation of the ampacity is necessary. Initially this study describes the comparison of the standard analytical calculation methods with a COMSOL simulation. Then a complete model of a more complex cable application is described.

Comparison of standard calculation with COMSOL simulation: The ICE standard method for ampacity calculation uses analytical and empirical models to calculate the temperature distribution in the geometry generated by the thermal power losses. This method gives good results for simple configurations, but for more complex designs the calculations might lead to more conservative results. Figure 1 shows the two compared cable designs, for which the analytical methods are expected to give the same results as the simulation. The second geometry shows three bundled cables, which adds small complexity.

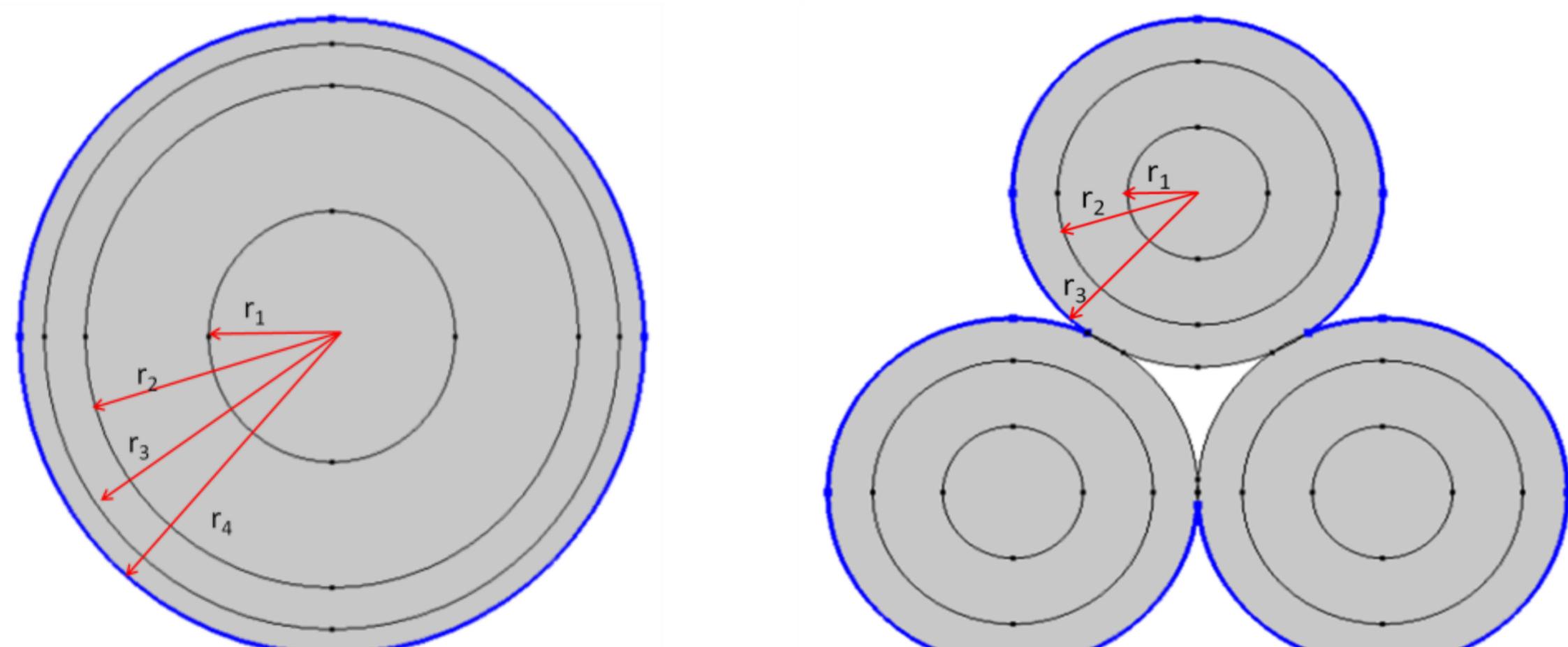


Figure 1. Compared cable configurations

In both models a heat source generated by a current is used to generate a heat flux across the cable, the cable surface is cooled by a convective coefficient as well as surface to ambient radiation. The two models shown in Figure 1 are implemented in COMSOL, using the Heat Transfer in Solids mode the temperature in the cable is evaluated.

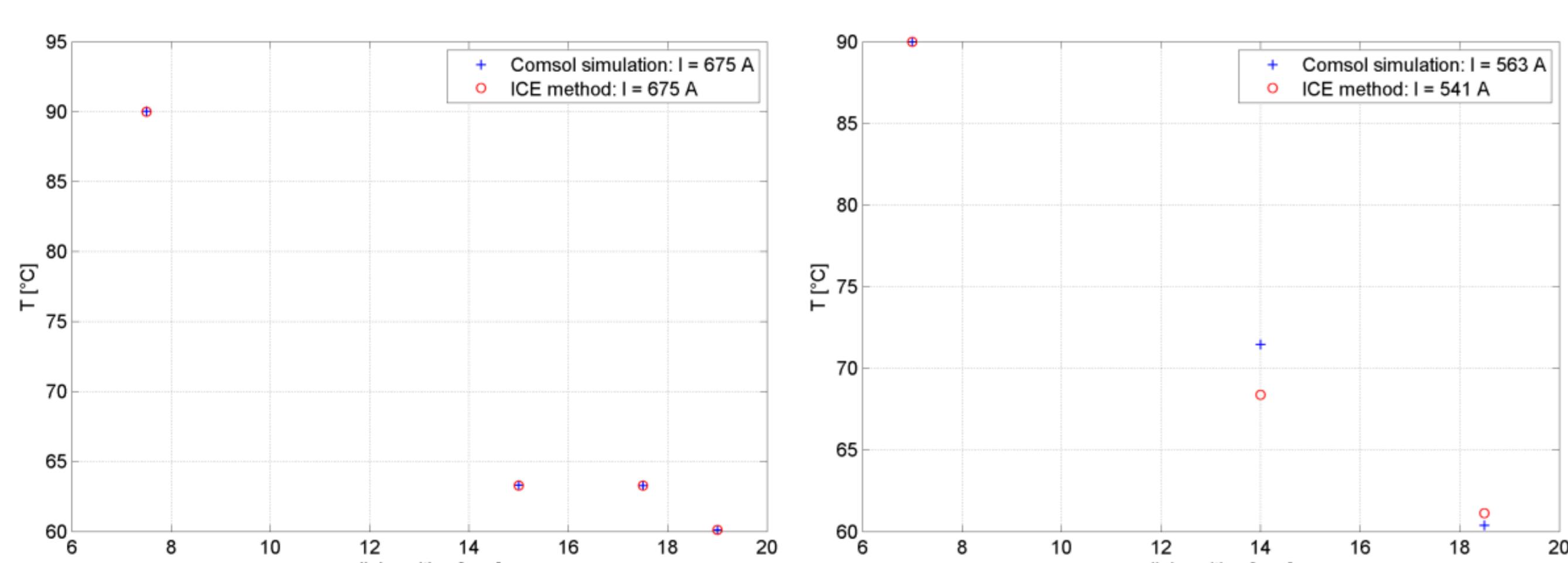


Figure 2. Results of analytical and simulation results

For the standard model an iterative process is used to calculate the current for a maximum temperature of the conductor. In COMSOL a global equation is used to iterate the maximum current.

Figure 2 shows the iteration results as expected the simple radial system shows the same results for the maximum load as well as the temperature distribution. The bundled single-conductor configuration already shows that the simulation gives different results, here the ICE standard model accounts for the more complex geometry by introducing a simple factor whereas the COMSOL model can resolve the temperature distribution across the geometry more correctly.

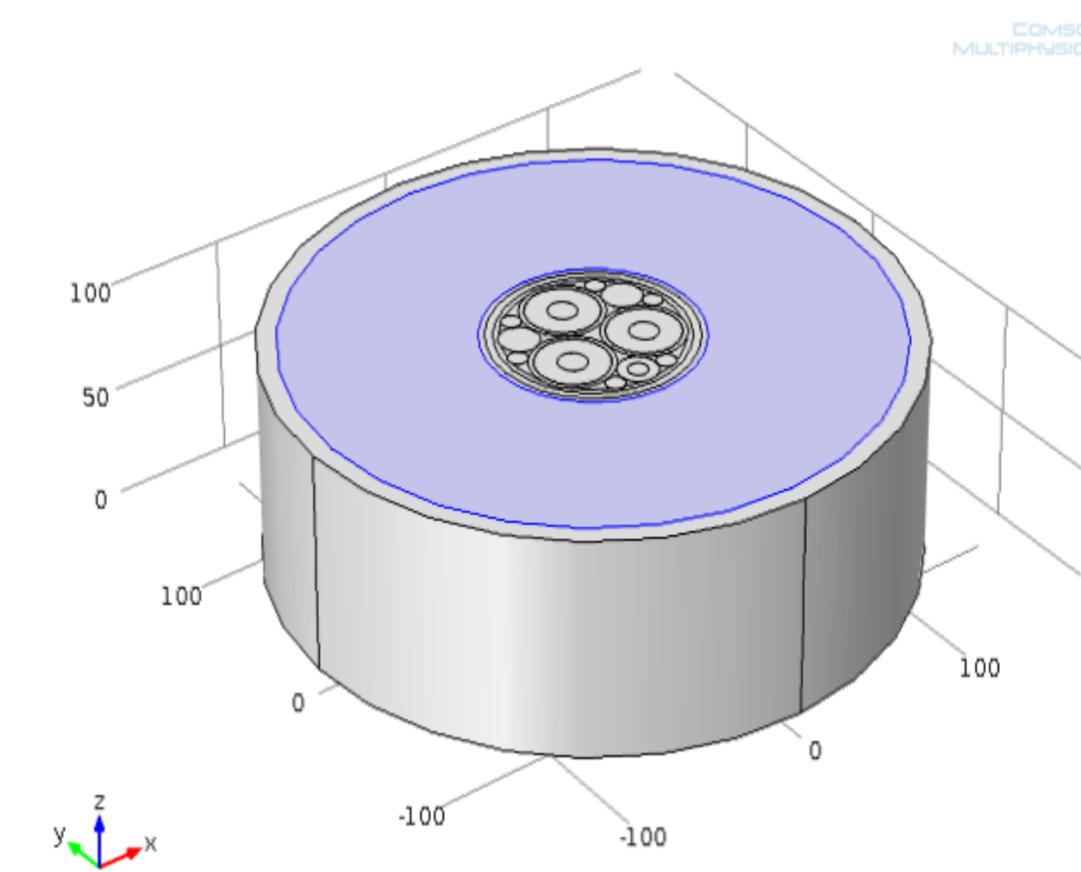


Figure 3. Extruded geometry of cable in cylinder, blue shows air domain

Building a more complex model: In the next step a model representing a upright cable surrounded by a air filled steel cylinder is implemented in COMSOL. This represents a typical application in off shore wind farms, where the cable is routed inside the wind turbine towards the generator. Here the cable itself is a more complex design, accounting for heat losses in the conductors the armour and the screen. Figure 3 shows a small 3D extrusion of the complete cable, the entire length can easily be over 10 m.

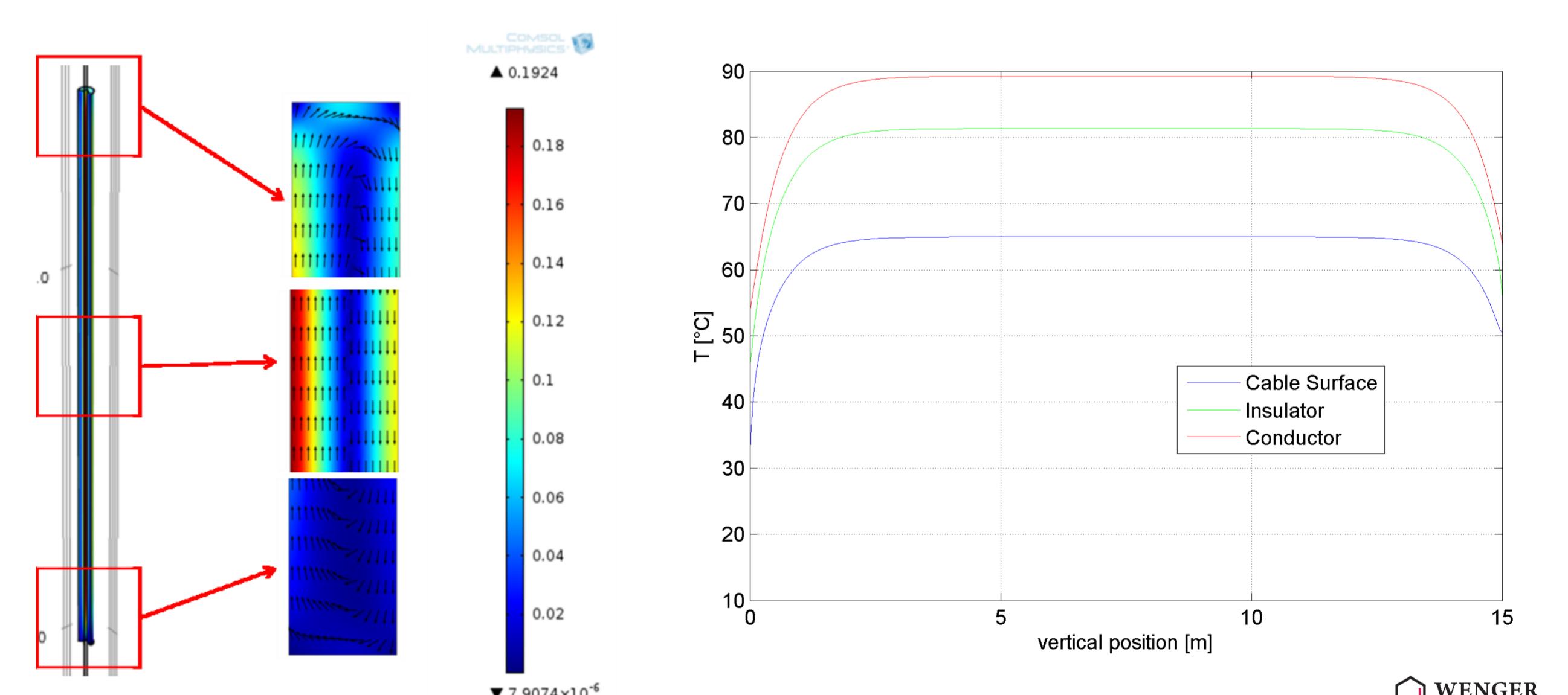


Figure 4. Results of cable simulation

For this model the Conjugate Heat Transfer mode is used to solve for the temperature and take the free convection inside the cylinder into account. The outer casing is again cooled by a convective cooling boundary condition as well as surface to ambient radiation. Figure 4 shows the generated flow in the closed cylinder at different positions as well the temperature distribution for a defined load case.

References:

1. L. Heinhold, R. Stubbe, Kabel und Leitungen für Starkstrom, MCD Verlag, (1999)