Design and Optimization of Cable Accessories using COMSOL Multiphysics®

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Objectives:

- Demonstrate the process of modelling and optimization involved in the design of cable joints using COMSOL Multiphysics®.
- Perform electrostatic and thermal calculation at steady state and magnetostatic and mechanical estimations at transient state

Figure 1. Straight cable joint from Lovink

Background and Problem space:

Cable joints are important and critical components in electrical network used for a smooth connection between two cable ends.

The cable joint used for simulation is a 12/20kV (U_0/U) silicon filled straight joint as shown in fig.1. Geometry specifications are given below in table:1

Table 1: Geometry specifications

Cable dimensions	
Conductor and size	Aluminium 3003 H-18, 185 mm^2
Diameter	15,9 mm
Thickness of insulation	5,5 mm
Thickness of conductive screen	1 mm
Thickness of HDPE	2,5 mm
Current ratings	
in air	550 A
buried cable	460 A
Insulation	
Cable Insulation	XLPE (ε_r=2,5)
Liquid silicon insulation	XLPE (ε_r=2,73)

The joint is modelled to be under 1m deep in 'peat' type of soil

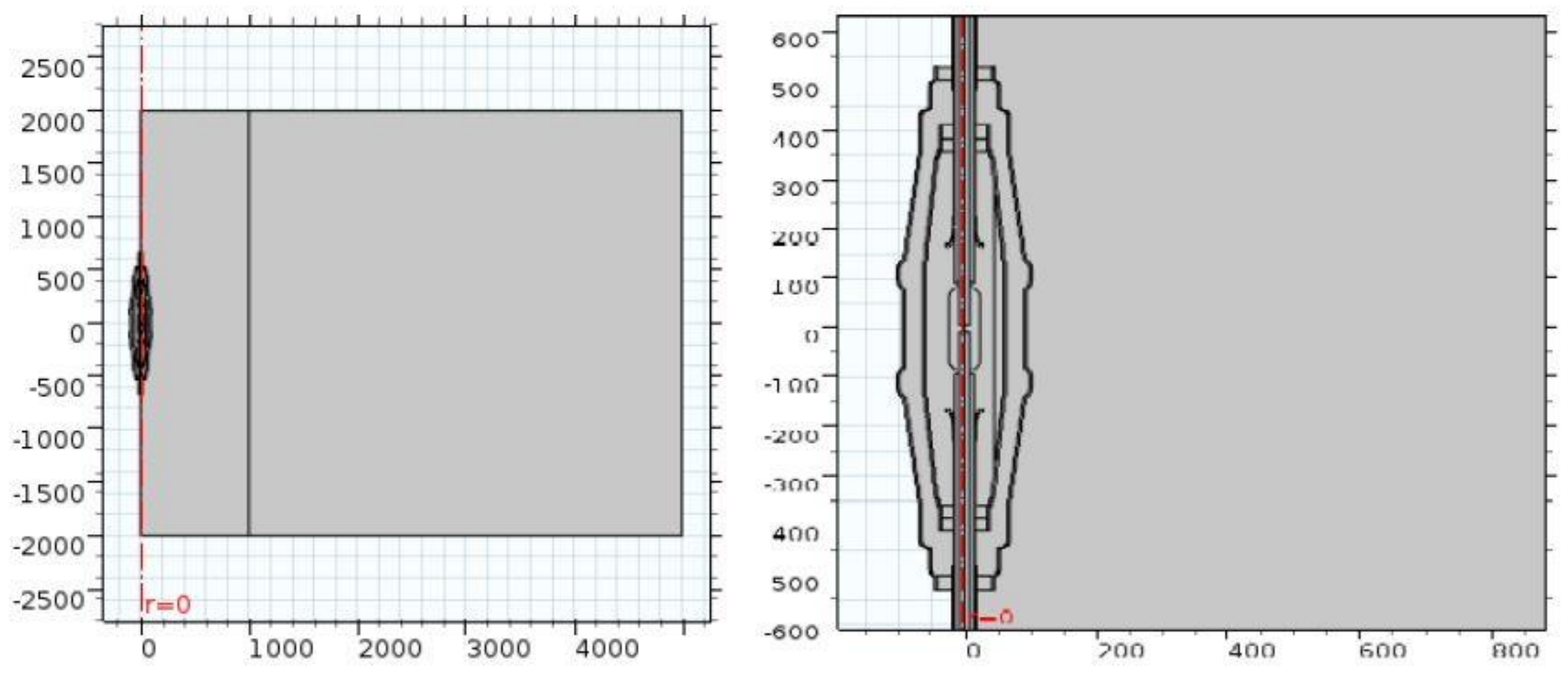

Figure 2. COMSOL geometry of the problem space

Methodology and Results

I. Electrostatic Simulation

The Electrostatics interface in COMSOL® solves the Gauss' law for electric fields using the scalar electric potential (V) as the dependent value, given by the equation;

$$\nabla . D = \rho$$

Where, $D = \varepsilon_o \varepsilon_r E \text{ and } E = -\nabla V$

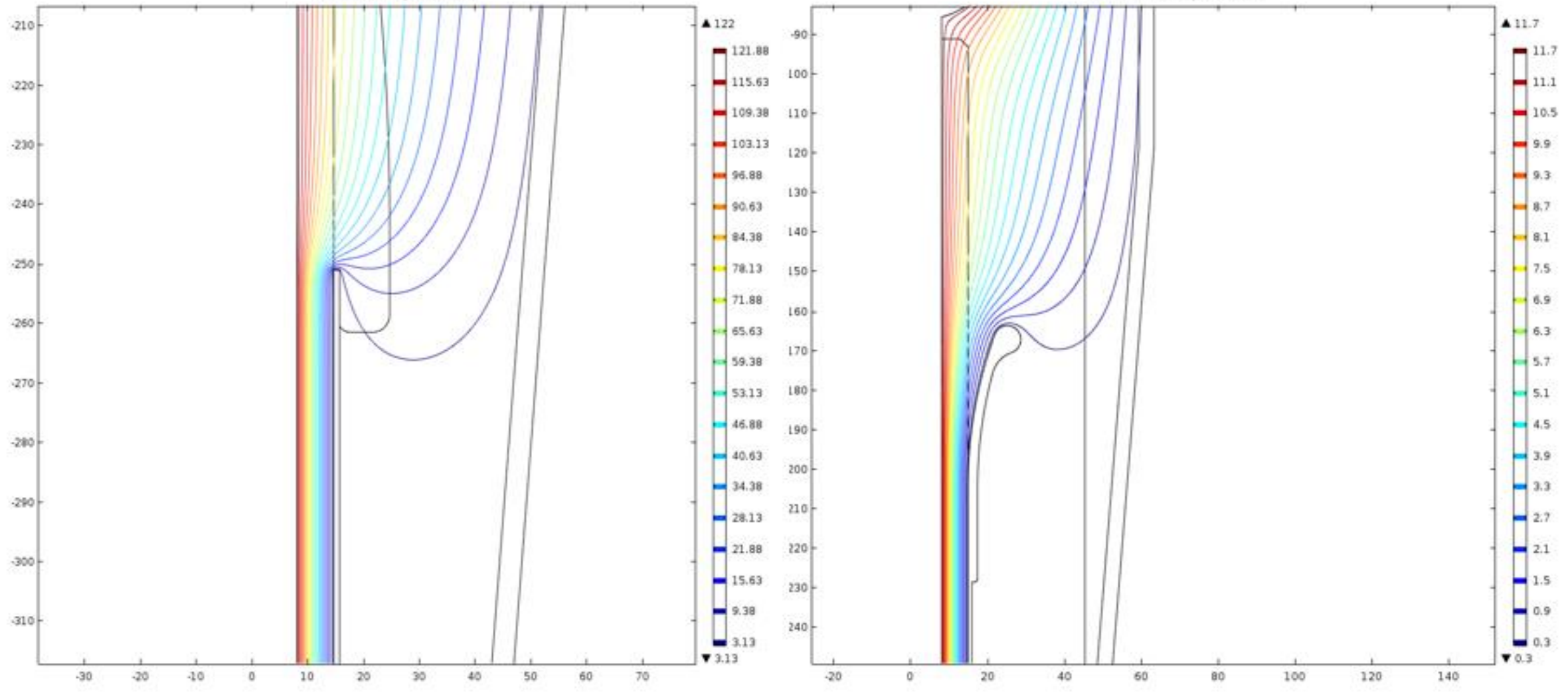

Figure 3. Plot of potential lines without field control (left) and with field control (right).

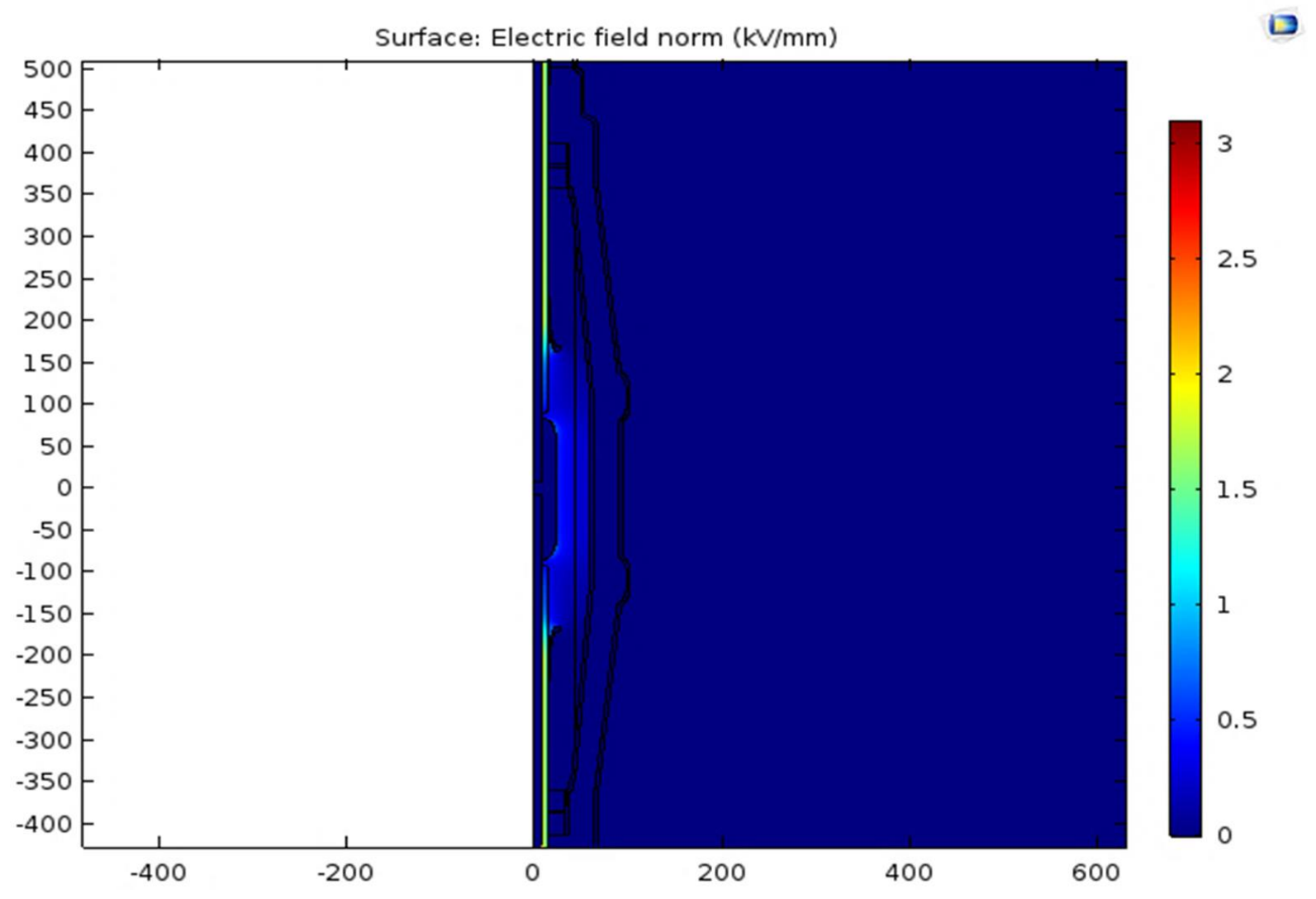

Figure 4. Plot for normal component of electric field

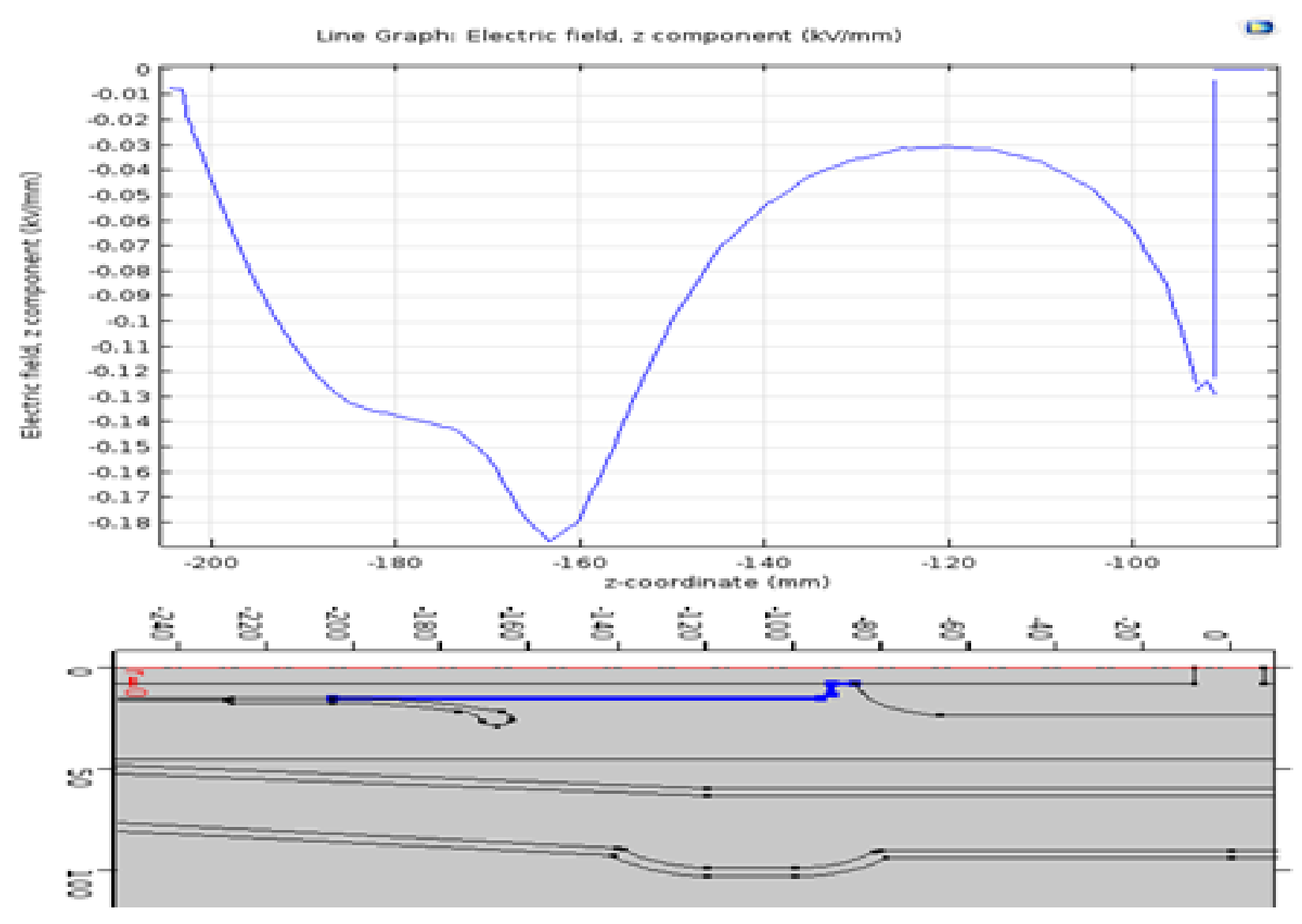

Figure 5. Plot for tangential component of electric field

II. Thermal Simulation

Losses due to eddy currents and skin effects at AC conditions are dissipated as heat inside the joint resulting in temperature rise which can be determined by heat transfer physics interface which solves the following equations;

$$\rho C_p \frac{\partial T}{\partial t} = -\nabla . q + Q$$

Further thermal expansion because of joule heating can be calculated by using a combination of joule heating and thermal expansion Multiphysics interface, given by;

$$\epsilon_{th} = \alpha(T - T_{ref})$$

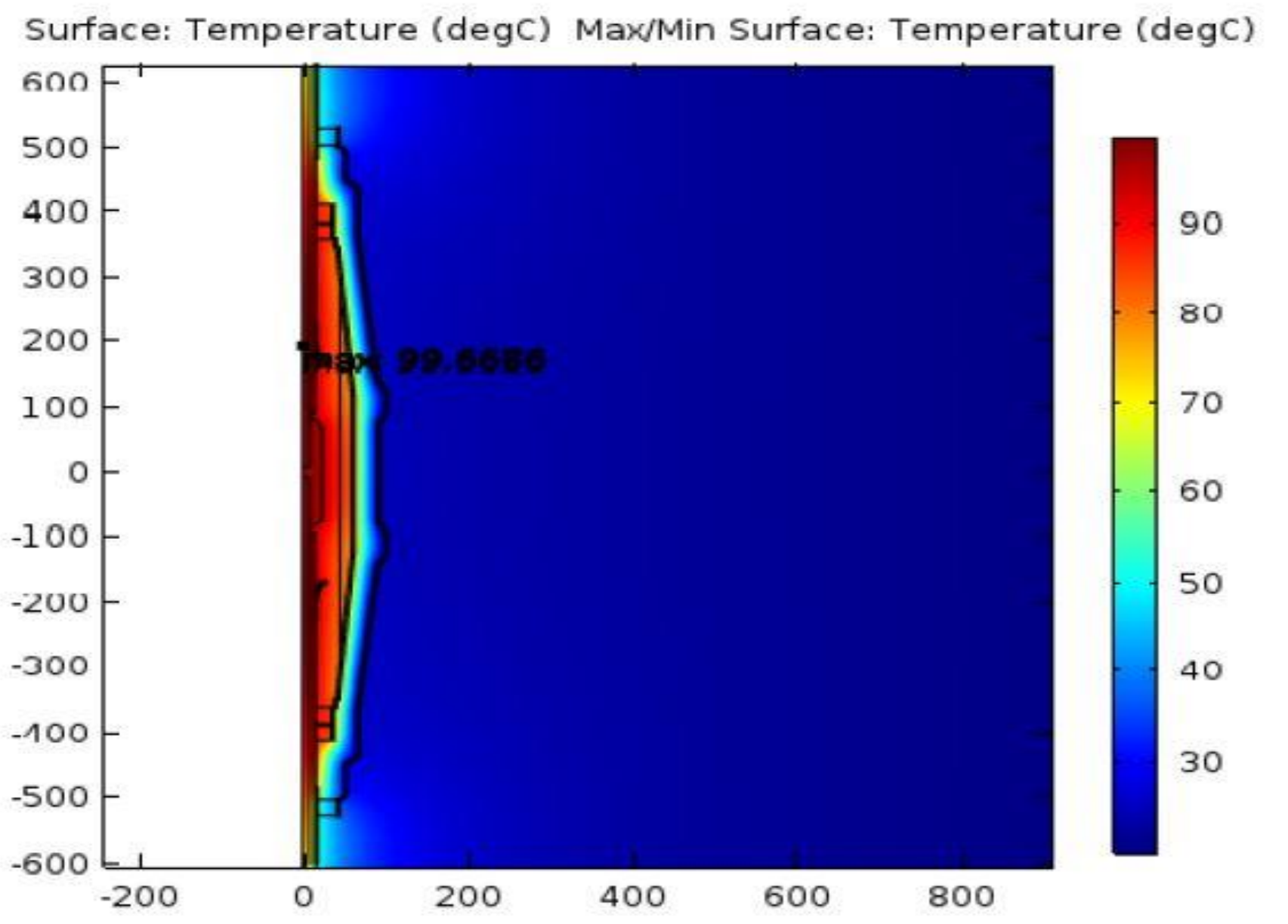

Figure 6. Temperature plot

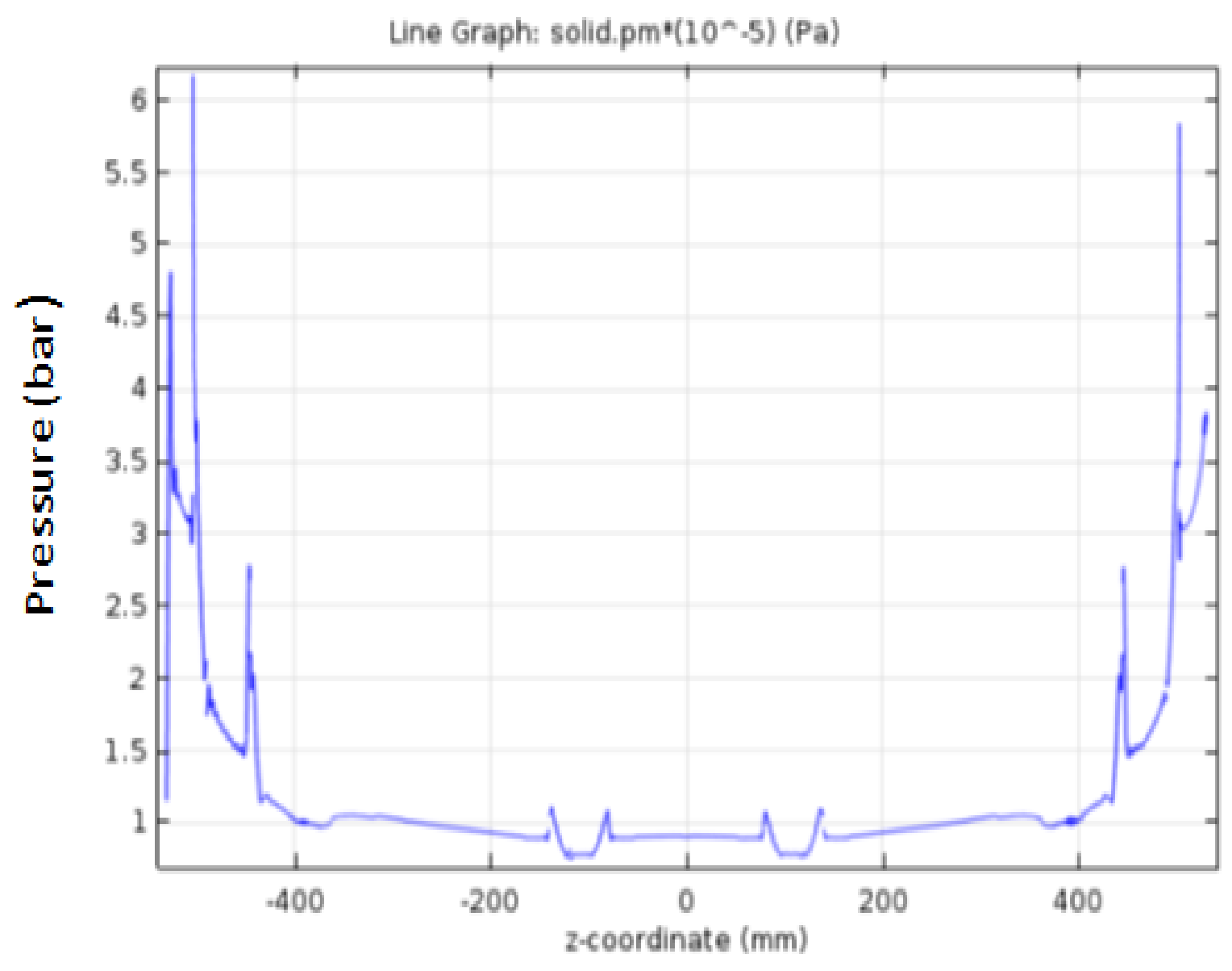

Figure 7. Steady state pressure over the joint outer casing

III. Short Circuit Simulation

The magnitude of Lorentz forces that act on the conductors at a short circuit of 26,3 KA for 1s is calculated by the use 'Electro mechanics' and the 'Joule heating' interface for the temperature of conductor at the end of the S.C . The value of the Lorentz force from simulation can be checked against the analytical calculation given below;

$$F_L = BIL\ sin\theta = 1{,}2 \times \left(\frac{26{,}3\ kA}{\sqrt{2}}\right) \times l \times sin90^{\circ} = 22{,}316 N/m$$

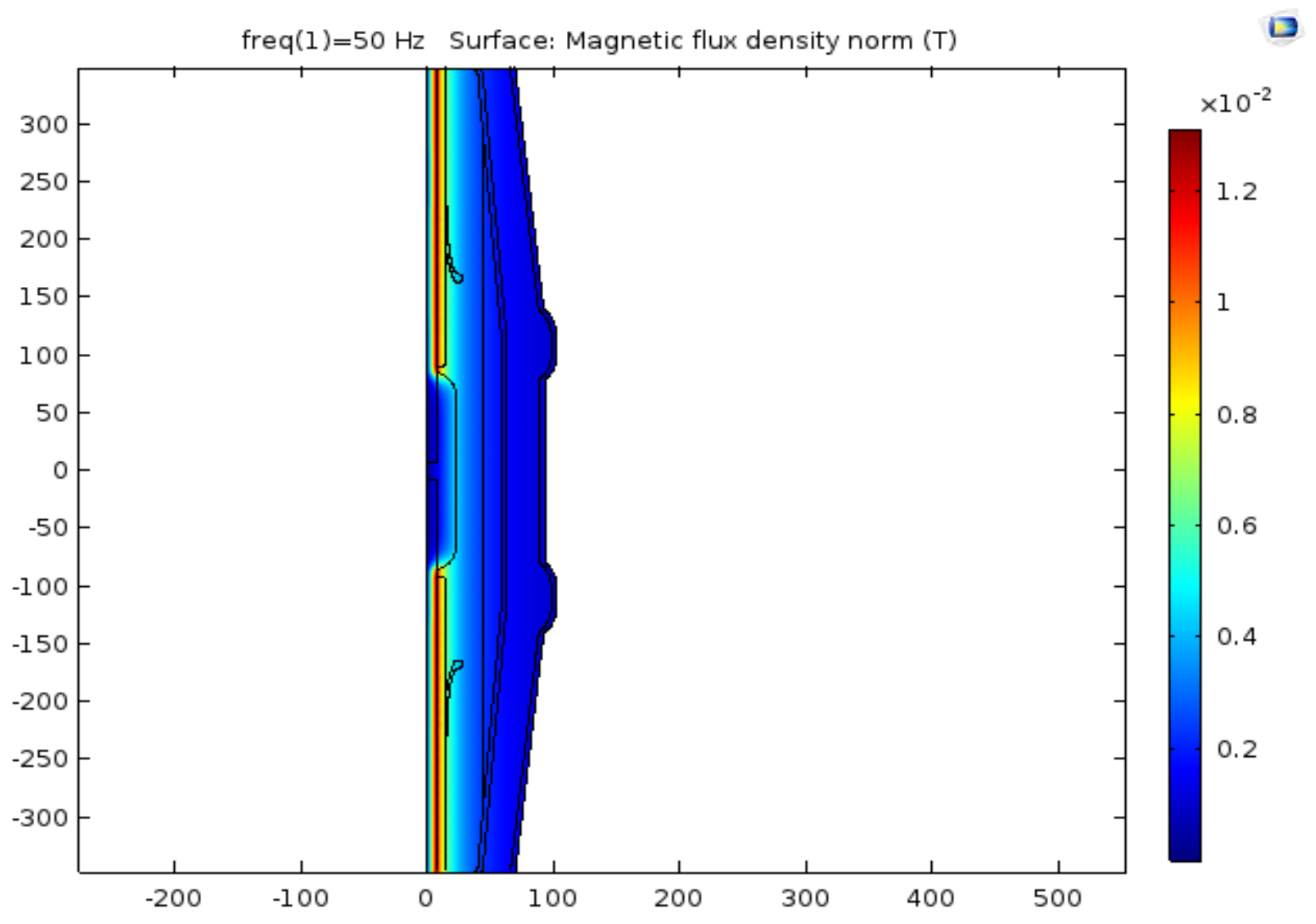

Figure 8. Magnetic field plot

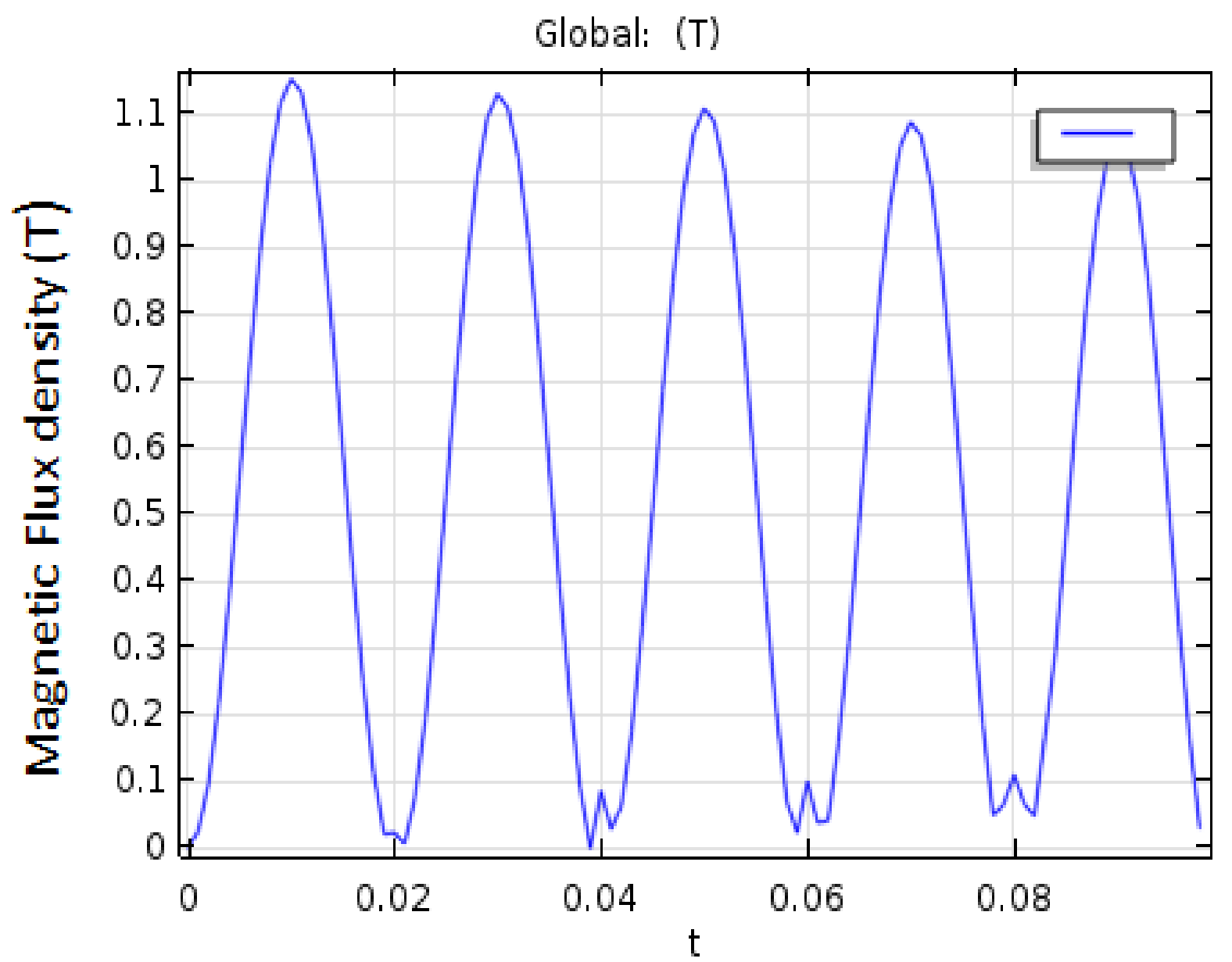

Figure 9. Magnetic field variation during a short citcuit

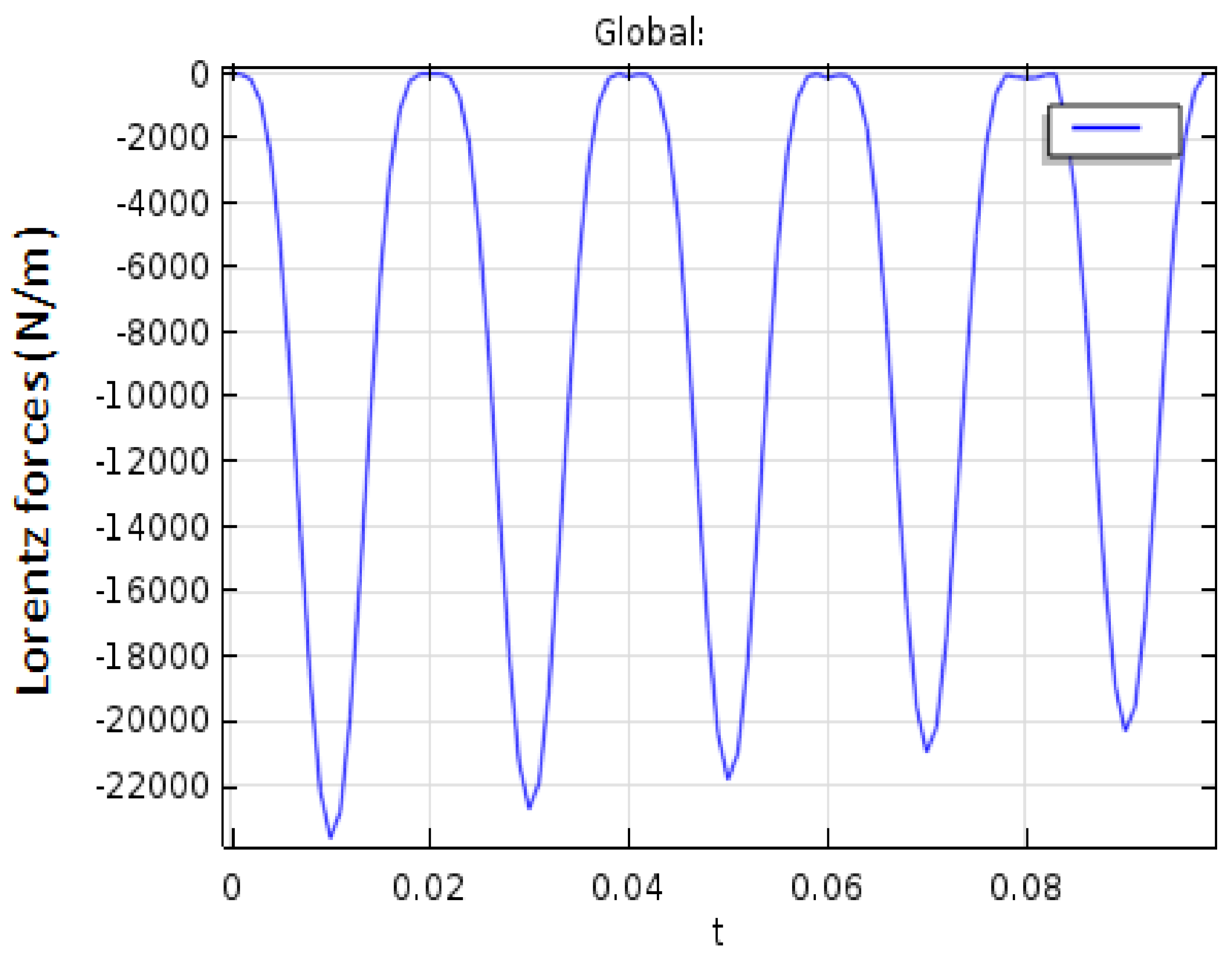

Figure 10. Lorentz force on the conductor during short circuit

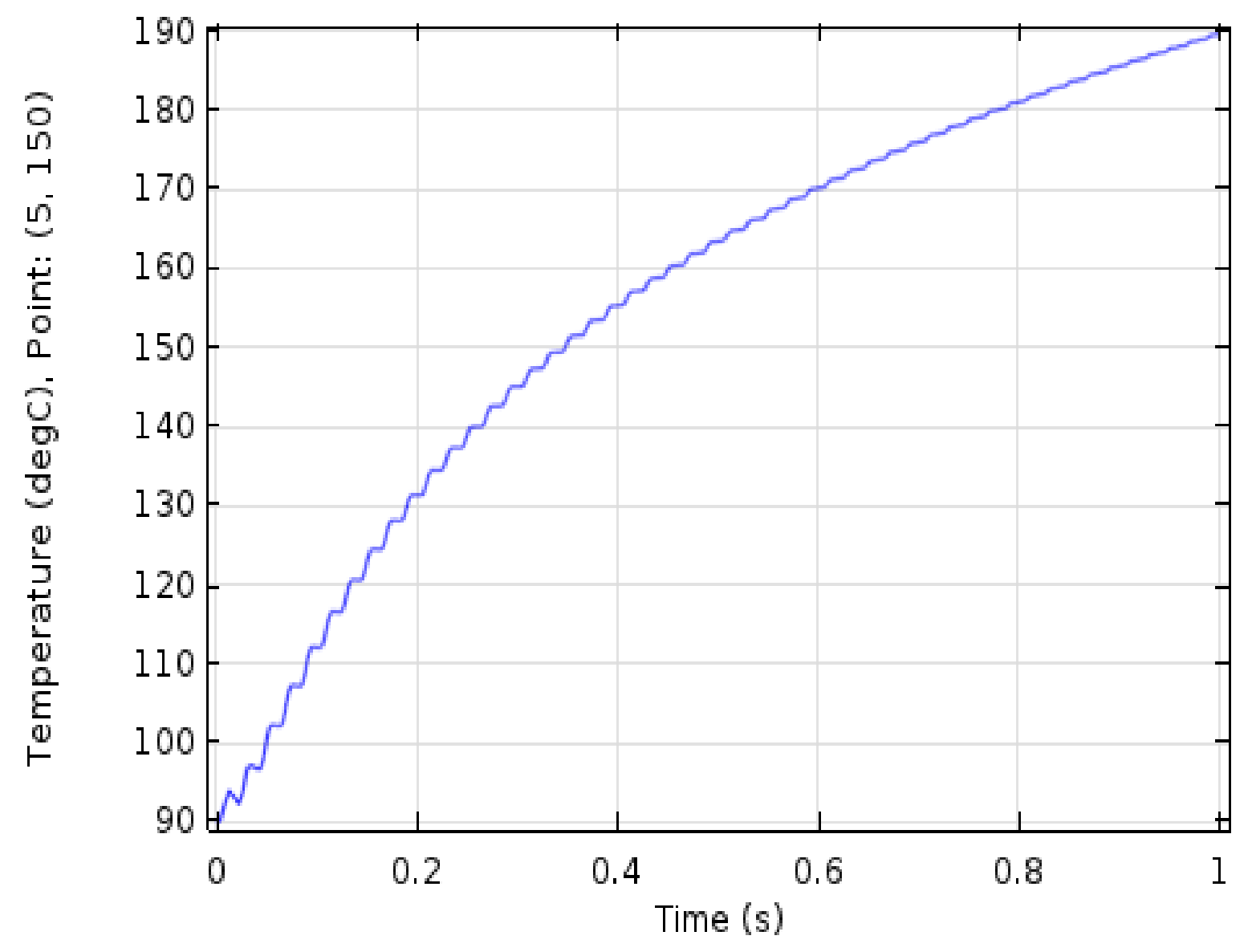

Figure 11. Temperature at short circuit current

Conclusions:

The paper demonstrates the developmental process of a cable joint with the help of COMSOL Multiphysics®. The repetitive testing through trial and error involved in the design and optimization can be avoided using COMSOL Multiphysics®. There is still a scope to develop a simulation for ageing of insulation material in cable joints through the heat cycle tests as defined in the IEC and HD testing standards using COMSOL Multiphysics®.

References:

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Excerpt from the Proceedings of the 2017 COMSOL Conference in Rotterdam