Heat Transfer Modeling of Power Cables in Tunnels

Fahd Boukrouche[1], Christophe Moreau[1], Wilfried Frelin[1],
1. EDF R&D, Laboratory of Electrical Materials, EDF Lad des Renardières, 77818 Moret-sur-Loing, France

Introduction:
In dense urban area or for power plant outflow, electricity is more often transmitted through underground cables placed in tunnels. They are usually located beneath the road surface and are of two types : unventilated tunnels where the air flows naturally, and ventilated ones where fans help the cooling of the cables and the environment. These tunnels run for hundreds of meters underground and are several meters wide.

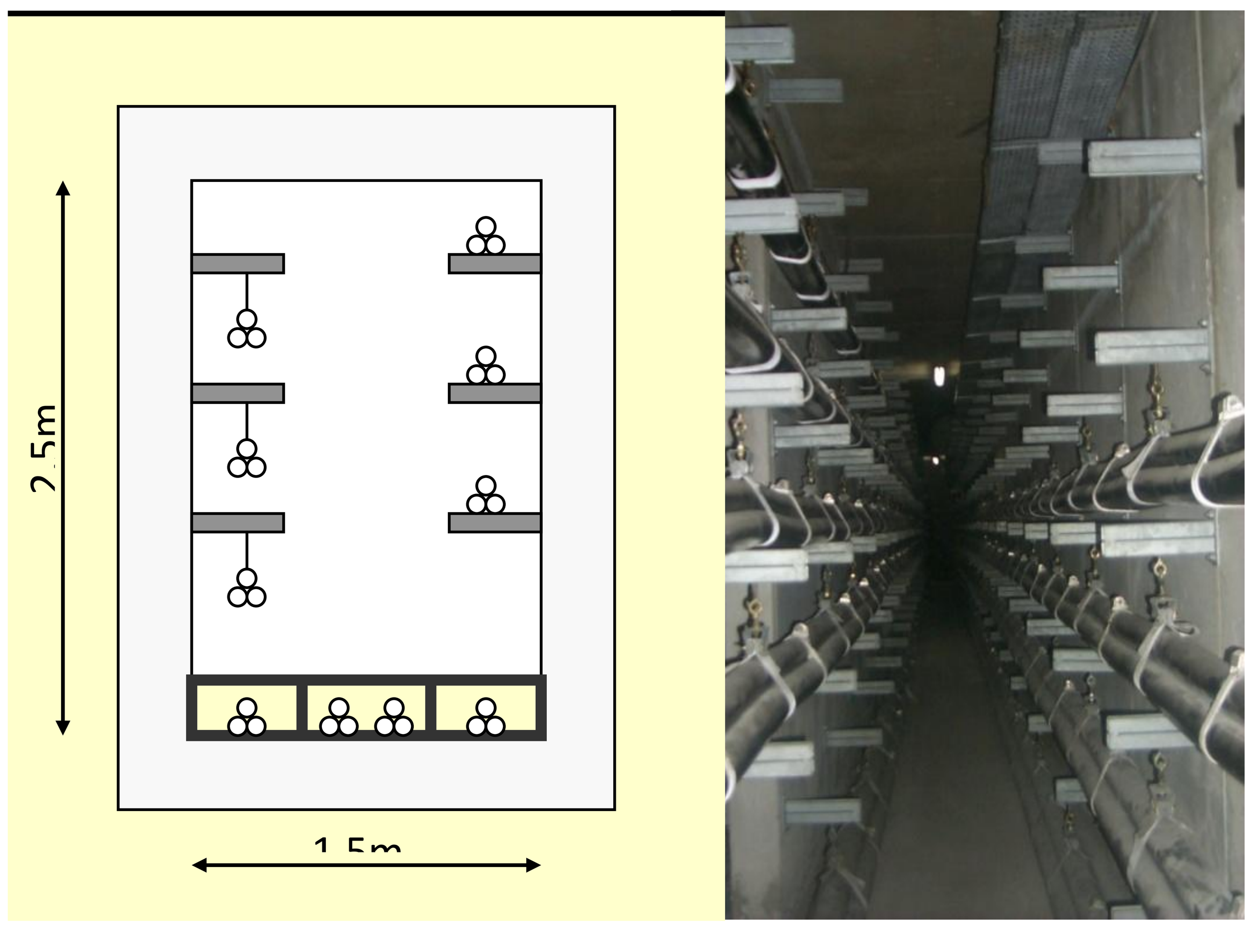

Figure 1. Typical underground power tunnel facility

Computational Methods:
Three model types have been developed, each are confronted with the empirical model currently in use. Steady states simulations with heat sources located at the cables core and fixed temperature boundary conditions give the final insulator temperature.

For unventilated tunnels, only 2D models are developed even if tunnels are sometimes tilted.

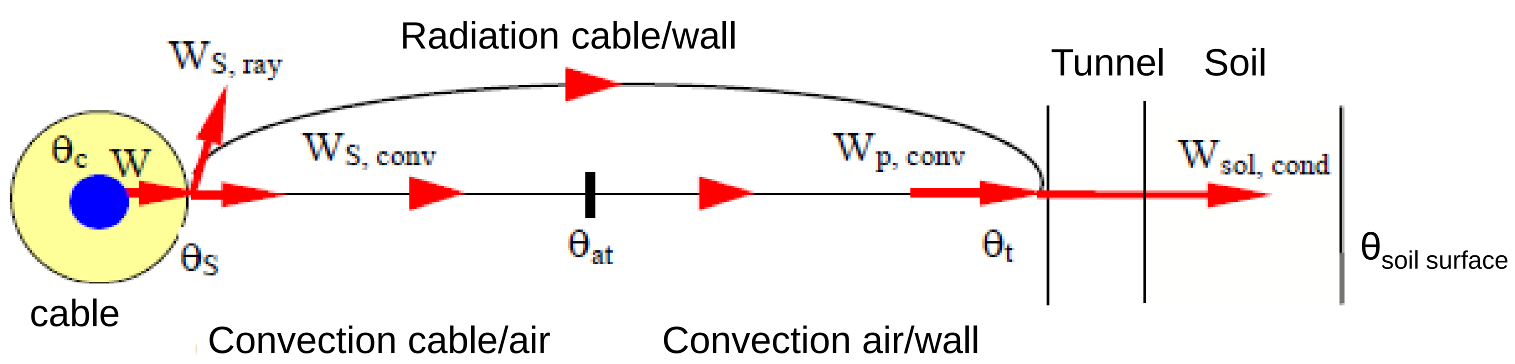

Figure 2. Heat transfer diagram for a cable installed in tunnel

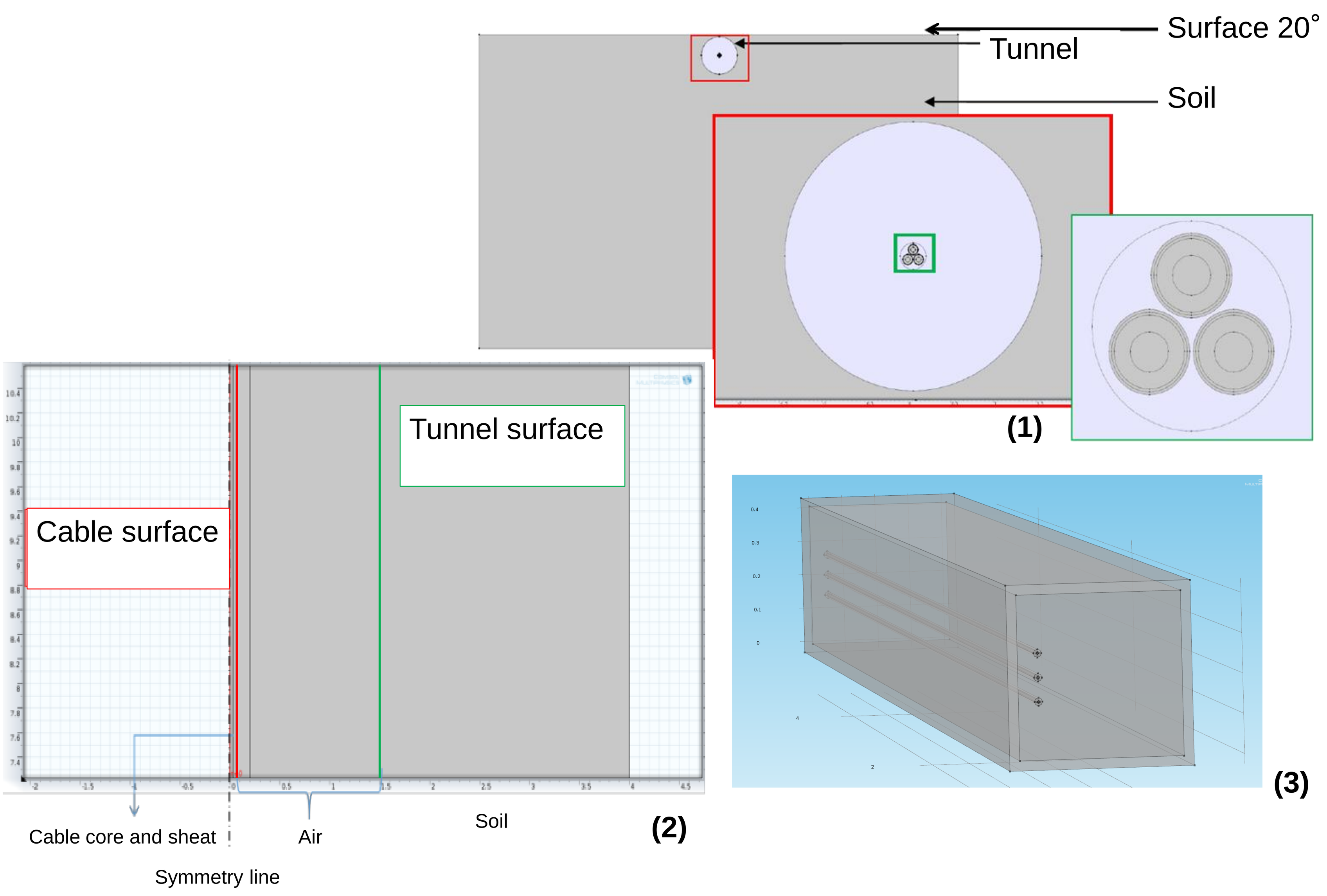

Figure 3. Geometric models 2D unventilated tunnel (1), axisymetric ventilated tunnel (2) and 3D ventilated model (3)

Results:
Unventilated tunnels : simulations showed the inaccuracy of the empirical models in use for ratings, IEC international standard, due a strong hypothesis of all surfaces to be isothermal. Proximity effects of groups of cables are also too simplified (Figure 6).

In ventilated tunnels, previous CFD studies have been found too optimistic in the cooling performances of the cables due to the use of a k-ε turbulence model (Figure 7).

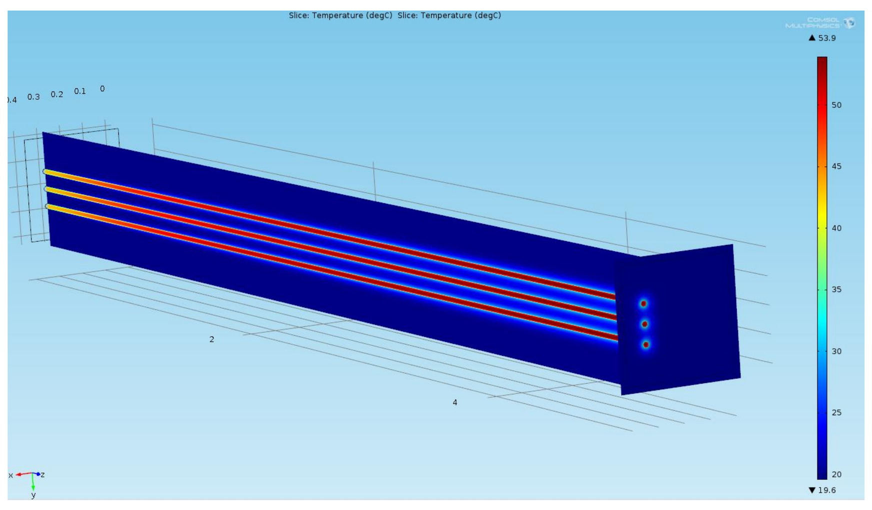

Figure 4. Ventilated three cables case

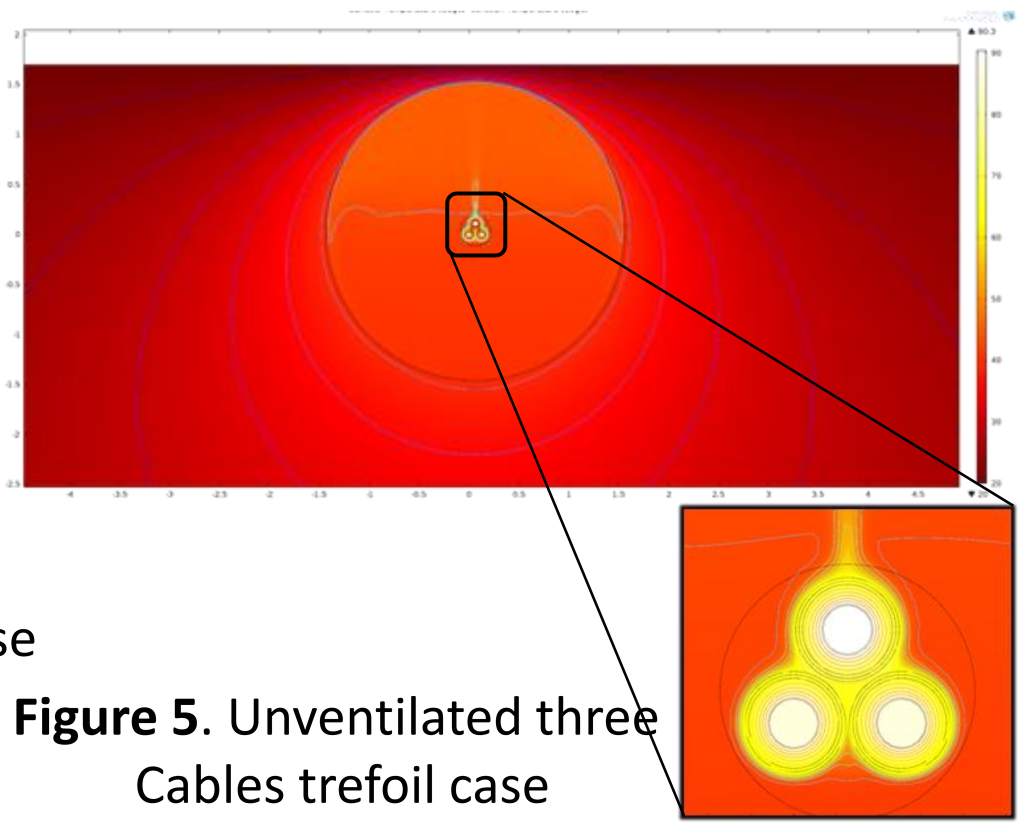

Figure 5. Unventilated three Cables trefoil case

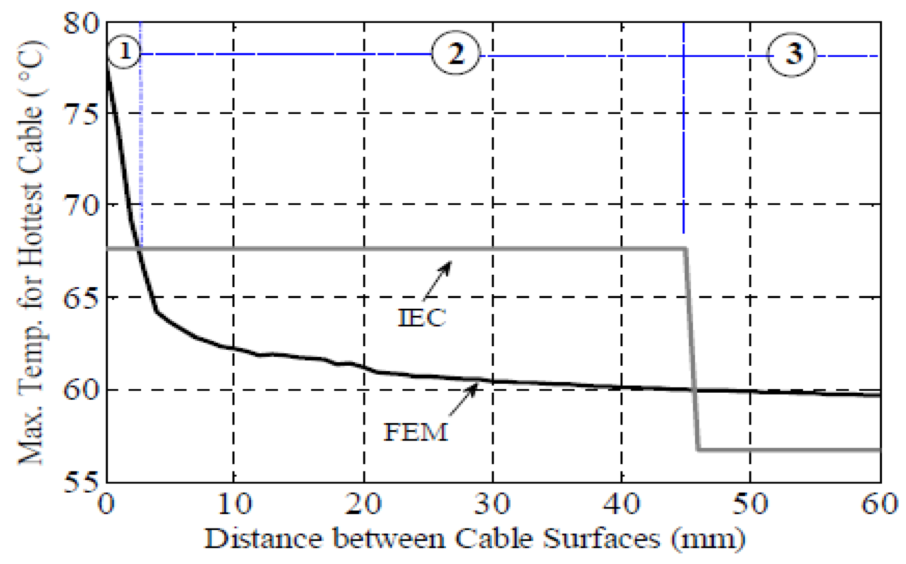

Figure 6. Temperature evolution of the hottest cables with proximity
① cables touching ② cables heating each other
③ thermally independent

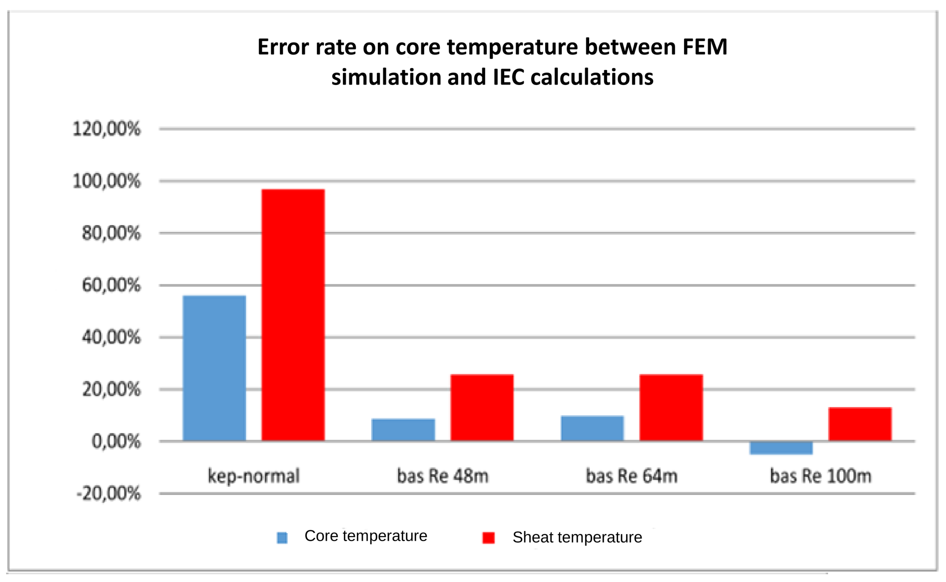

Figure 7. Empirical/CFD results shift for two turbulence model and three model length

Conclusions:
The current misrepresentation of turbulence pattern and cable proximity effects are the two main factors that can lead up to a consequent error rate on the temperature of the cable core. Experimental data are necessary to better simulate them in both ventilated and unventilated tunnels.

For these issues, a mockup tunnel is being developed and an the use of data from an instrumented underground tunnel for ground test is under discussion.

References:
1. Calculation of Temperatures in Ventilated Cable Tunnels. 21-08, Working Group. s.l. : ELECTRA, 1992,
2. Toward a more flexible rating method for cables in tunnels. Pilgrim, J.A, et al. 2010, IEEE Transaction on Power delivery.
3. Shedaghat, A. et de Léon, F. Thermal Analysis of Power Cables in Free Air : Evaluation and Improvement of the IEC Standard Ampacity Calculations. s.l. : IEEE, 2013.

Excerpt from the Proceedings of the 2014 COMSOL Conference in Cambridge