Calculation of the current rating for complex cable arrangement in a deep tunnel

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Due to congested infrastructure in urban centres, increasing number of cable circuits is installed in deep tunnels. An analytical model for rating of cables in such installations has been described in the Jicable'11 paper by Dorison and Anders. They observed that due to the soil thermal inertia, a long duration is necessary to reach the steady-state value; thus, instead of using the standard IEC formula for the cable external thermal resistance, a more appropriate approach would be to use the transient analysis algorithm and iteratively find out what value of the current would give desired temperature at the end of the study period. They defined a fictitious equivalent depth of the cable circuit that with the application of the steady state algorithm would give the same value of the current as the one obtained from the transient analysis.

The analytical approach discussed in the above mentioned paper is applicable to simple cable geometry. However, in a recent project involving installation of four 230kV cable circuits located in a new concrete tunnel, due to personnel safety of people entering the tunnel for maintenance and inspection, two of the above four circuits will be installed inside ducts embedded in concrete on the tunnel side wall (see Fig. 1 below) or in trough at the bottom floor of the tunnel.

The calculation of the current rating of such installations is not easily amenable to analytical approaches. The paper discusses how such installations can be rated and shows the results for ventilated and unventilated tunnel 3 m in diameter 30 m deep.

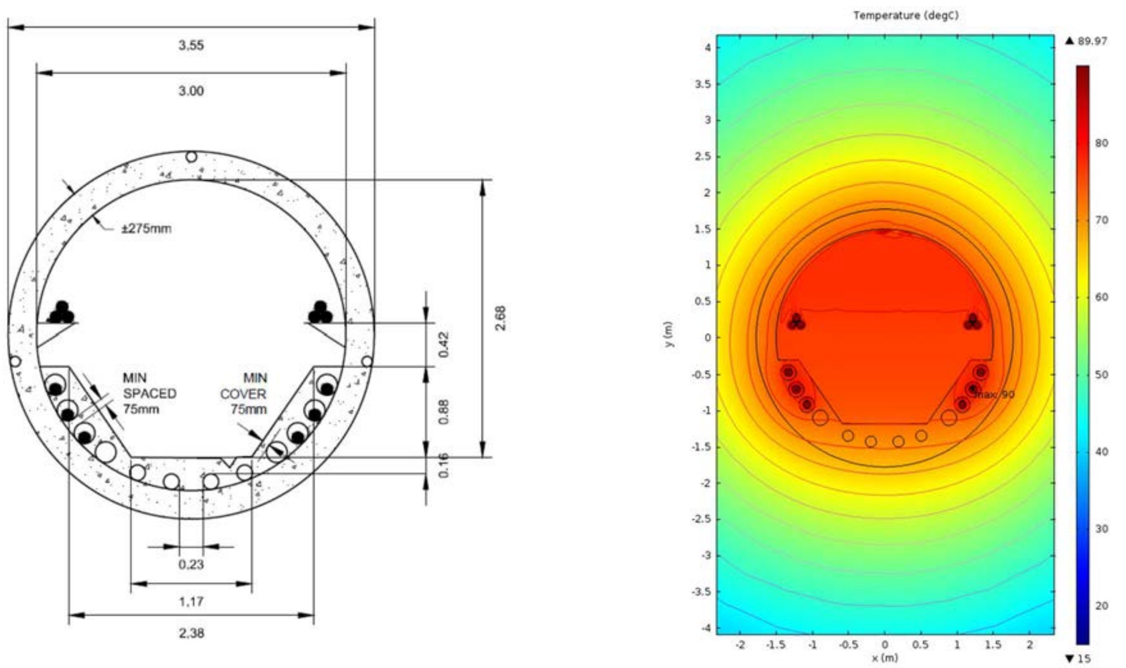

Fig. 1 Cross section of the tunnel installation and the results of the FE analysis

One of the contributions of the paper will be an introduction of a simplified model for the temperature calculations in a ventilated tunnel. The proposed model is shown below.

Figure 2 shows heat balance at distance z in the tunnel. The heat dissipated from the cable is transported by the air flow along the tunnel and conducted through the tunnel wall.

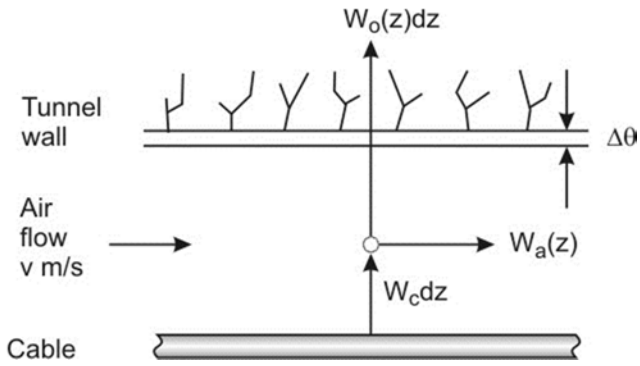

Fig. 2 Model of a fragment of the cable tunnel

The equation for heat balance in the tunnel is:

$$W_o \cdot dz = \frac{\theta(z) - \Delta\theta - \theta_o}{T_o} \cdot dz + \frac{d\theta}{dt} \cdot c_{pa} \cdot v \cdot \pi \cdot \frac{D^2}{4}$$

The heat transfer coefficient h at the tunnel wall gives rise to a temperature drop $\Delta\theta$ over a transition layer. The temperature drop may be eliminated through introduction of an equivalent thermal resistance T_{oe}. Calculations of this resistance as well as analytical solution to the heat balance equation are discussed in the proposed paper.