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

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ABSTRACT

This paper addresses several issues related to the calculation of rating of cables located in deep tunnels. It shows the results for ventilated and unventilated tunnel 3 m in diameter 30 m deep. The paper also introduces of a simplified model for the temperature calculations in a ventilated tunnel.

KEYWORDS

power cables, rating calculations, tunnel installations

INTRODUCTION

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 [1]. 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 230 kV cable circuits located in a new concrete tunnel, due to personnel safety of people entering the tunnel for maintenance and inspection, two of the 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. One of the contributions of the paper is an introduction of a simplified model for the temperature calculations in a ventilated tunnel. The paper discusses also how such installations can be rated and shows the results for ventilated and unventilated tunnel 3 m in diameter 30 m deep.

SIMPLIFIED MODEL FOR RATING OF CABLES IN A VENTILATED TUNNEL

Rating of cables installed in a deep ventilated tunnel was discussed in detail in [1]. A comprehensive model shown there is fairly complex. Therefore, the authors of this paper decided to introduce a simplified set of equations that can be used in a first approximation of current rating calculations for such installations.

List of symbols

D	m	Tunnel diameter
H	m	Tunnel depth to centre
L	m	Tunnel length
z_0	m	Characteristic length of the tunnel
v	m/s	air velocity in the tunnel
T_0	K×m/W	Thermal resistance of the tunnel
T_{0e}	K×m/W	Equivalent thermal resistance of the tunnel
W_c	W/m	Cable losses
$W_a(z)$	W	Heat transported by air flow
$W_o(z)$	W/m	Heat transferred through tunnel wall
$\theta(z)$	°C	Temperature of air in the tunnel at distance z.
θ_i	°C	Temperature of air at the inlet
θ_0	°C	Temperature of the ground level
$\Delta\theta$	K	Temperature drop in the transition layer at the tunnel wall
c_{pa}	Ws/K·m^3	Specific heat of air
h	W/K·m^2	Heat transfer coefficient at the tunnel wall.

Heat balance equation

Figure 1 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.