CURRENT RATING OF CABLES INSTALLED IN DEEP OR VENTILATED TUNNELS

Éric **DORISON** - EDF R&D, Moret-sur-Loing (France), eric.dorison@edf.fr
George **ANDERS** - Technical University of Lodz, george.anders@attglobal.net

ABSTRACT

The series of IEC 60287 standards provides methods for calculating the permissible current rating of cables.

This paper deals with the present work carried out within the IEC TC 20 WG 19, intending to extend the scope of these standards to groups of cables installed in deep or ventilated tunnels.

INTRODUCTION

The IEC 60287-1-1 [1] and 2-1 [2] standards address the thermal rating of a cable circuit installed in still air with given temperature, the IEC 60287-2-2 [3] providing an extension to some homogeneous groups of cables. The same calculations can be used to rate cables in tunnels, however, the external thermal resistance of the tunnel itself requires special considerations.

The paper deals with the work carried out by WG19 of the Technical Committee 20 of the IEC intended to extend the scope of these standards to cables installed in ventilated deep tunnels.

The IEC standards combine the effect of heat transfer by radiation and convection into one coefficient. In order to properly model the effect of air movement inside the tunnel, the convective and radiative heat transfers must be treated separately. Hence, first, the IEC method for rating cables installed in still air is reviewed and considerations are given to the modeling of heat transfer by radiation. In particular, the radiative heat transfer for a group of cables is addressed and the extension of the IEC method to the groups of cables with different designs is proposed considering the effect of dielectric losses.

Next, a rating method for cables in ventilated tunnels is presented, based on an analytical approach, originally developed by CIGRE and published in Electra [4,5].

Finally, for deep tunnels, a fictitious equivalent depth is introduced, to optimize cable rating, taking into account the soil thermal inertia, without performing transient analysis.

BASIC MODEL FOR CABLES IN AIR

According to the IEC 60287 standards, the rating of air installed cables is based on a relationship that links the total heat loss of a cable W_t with the temperature rise of its surface θ_s above the ambient θ_a by:

$$W_t = \pi.D_e.h.(\theta_s - \theta_a)^q \qquad [1]$$

where D_e is the cable diameter, h is a heat dissipation coefficient depending on the installation and q is a constant, set equal to 1,25.

Generally, the thermal resistance T_4 of the surroundings of a cable is defined by:

$$T_4 = \frac{\theta_s - \theta_a}{W_t} \qquad [2]$$

So that the thermal resistance T_4 for a cable in air is:

$$T_4 = \frac{1}{\pi.D_e.h.\Delta\theta_s^{0,25}} \qquad \Delta\theta_s = \theta_s - \theta_a \qquad [3]$$

The heat dissipation coefficient h is given as:

$$h = \frac{Z}{D_e^g} + E \qquad [4]$$

where Z, E, g are constants, whose values depend on the type of installation.

As T_4 is a function of θ_s, an iterative process has to be conducted, taking into account the temperature drop between the cable conductor(s) and its surface:

$$\theta_c - \theta_s = n.W_d.[T_d - T_{\text{int}}] + W_t.T_{\text{int}} \qquad [5]$$

θ_c is the conductor(s) temperature, n is the number of conductors, W_d represents the dielectric losses per conductor and T_d and T_{int} are the equivalent thermal resistances used in expressing the transfer of dielectric losses and Joule losses within the cable, respectively:

$$\begin{aligned} T_d &= \frac{T_1}{2.n} + T_2 + T_3 \\ T_{\text{int}} &= \frac{1}{1+\lambda_1+\lambda_2}.\left[\frac{T_1}{n} + (1+\lambda_1).T_2 + (1+\lambda_1+\lambda_2).T_3\right] \end{aligned} \qquad [6]$$

The permissible current I is obtained from W_t as follows:

$$W_t = n.[W_c.(1+\lambda_1+\lambda_2) + W_d] \qquad [7]$$

$$W_c = R.I^2 \qquad [8]$$

The thermal resistances T_1,T_2,T_3 and loss factors λ_1, λ_2 are as in IEC 60287. R is the conductor resistance at θ_c.

For installations involving several circuits, the value of the heat dissipation coefficient is defined in IEC 60287-2-2 from the value for a single circuit given in IEC 60287-2-1.

This approach is based on modelling of the heat transfers by radiation and convection, using Ohm's thermal law, linking temperature drop and heat rate through a thermal resistance, with the following assumptions :

- The construction of all cables in the tunnel is the same. This means that the surface temperatures of the cables are similar; and, therefore, the radiative heat transfers between the cables may be ignored.