New issues in current rating of power cables installed in tunnels

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ABSTRACT

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

This paper deals with possible extension to the scope of these standards to groups of cables installed in unventilated tunnels.

KEYWORDS

Rating, cable in tunnels, convection, radiation

INTRODUCTION

The current rating of power cables installed in still air is addressed by IEC standards.

The IEC 60287-2-1 standard provides a method for calculating the external thermal resistance of an isolated cable and considers the rating of some groups of cables. The IEC 60287-2-2 standard extends the scope to some larger groups.

In these standards, the cables are assumed of equal diameter, emitting same losses and the ambient temperature is supposed to be known. Moreover, in IEC 60287-2-2, dielectric losses are always neglected.

In the first part of this paper, the IEC method for rating cables installed in still air is reviewed and modelling of heat transfer is discussed.

Special attention is paid to the derating factors for groups of cables. The paper gives a method to take into account dielectric losses when deriving reduction factors and introduces derating factors for some homogeneous groups of cables which are not considered in the IEC standards particularly large groups of touching cables side by side.

Then, a way to take into account the variation of the ambient temperature when increasing the number of cables is proposed, considering the external thermal resistance of the tunnel.

Finally, the ratings calculated using this approach are compared with the FEM calculations on several examples.

BASIC MODEL FOR CABLES IN AIR

Current rating formula

The current rating is given by a general formula which may be written as:

$$I = \left[\frac{\theta_c - \theta_a - W_d.n.(T_d + T_4)}{n.R_t.(T_{\text{int}} + T_4)}\right]^{0,5} \quad [1]$$

θ_c is the temperature of the conductor(s) set equal to the maximum operating temperature and θ_a *is* the ambient temperature.

n is the number of conductors. W_d represents the dielectric losses per conductor.

R_t is the apparent conductor resistance, incorporating losses in the metal screen(s) and the armour; *R* is the conductor resistance at θ_c.

T_d and T_{int} are the equivalent thermal resistances used in expressing the transfer of dielectric losses and Joule losses within the cable.

$$R_t = R.(1+\lambda_1+\lambda_2) \qquad T_d = \frac{T_1}{2.n} + T_2 + T_3$$
$$T_{int} = \frac{1}{1+\lambda_1+\lambda_2}.\left[\frac{T_1}{n} + (1+\lambda_1).T_2 + (1+\lambda_1+\lambda_2).T_3\right] \quad [2]$$

The thermal resistances T_1, T_2, T_3 and loss factors λ_1, λ_2 are as in IEC 60287.

The thermal resistance of the surrounding medium T_4 is discussed below.

Derivation of the thermal resistance T_4

The rating of cables installed in air is based on a formula by Whitehead and Hutchings [1] 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:

$$W_t = \pi.D_e.h.(\theta_s - \theta_a)^q \quad [3]$$

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.

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

$$T_4 = \frac{\theta_s - \theta_a}{W_t} = \frac{1}{\pi.D_e.h.(\theta_s - \theta_a)^{0,25}} \quad [4]$$

The heat dissipation coefficient *h* is given as:

$$h = \frac{Z}{D_e^g} + E \quad [5]$$

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:

$$\theta_c - \theta_s = n.W_d.[T_d - T_{int}] + W_t.T_{int}$$
$$W_t = n.[W_c.(1+\lambda_1+\lambda_2) + W_d] \quad [6]$$
$$W_c = R.I^2$$