New issues in current rating of power cables installed in tunnels

Eric DORISON, Wilfried FRELIN; EDF R&D, France, wilfried.frelin@edf.fr, dorison.eric@orange.fr
George J. ANDERS; Lodz University of Technology, Poland, george.anders@bell.net
Olivier MOREAU, EDF CIST, Dubai, olivier.moreau@edfgroup.ae

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:

\[ I = \left[ \frac{\theta_c - \theta_a - W_d n (T_d + T_a)}{n R_t (T_{int} + T_a)} \right]^{0.5} \]  

[1]

\( \theta_c \) is the temperature of the conductor(s) set equal to the maximum operating temperature and \( \theta_a \) 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 the dielectric losses and Joule losses within the cable.

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

\[ R_t = R_c \left(1 + \lambda_1 + \lambda_2 \right) \]  

[2]

\[ T_d = \frac{T_{int}}{1 + \lambda_1 + \lambda_2} + T_a \]  

[2]

The thermal resistances \( T_1, T_2, T_3 \) and loss factors \( \lambda_1, \lambda_2 \) 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 \( \theta_s \) above the ambient \( \theta_a \) by:

\[ W_t = \pi D_c h (\theta_s - \theta_a)^q \]  

[3]

where \( D_c \) 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:

\[ T_4 = \frac{\theta_s - \theta_a}{W_t} = \frac{1}{\pi D_c h (\theta_s - \theta_a)^{0.25}} \]  

[4]

The heat dissipation coefficient \( h \) is given as:

\[ h = \frac{Z + E}{D_c^2} \]  

[5]

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

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

\[ \theta_c - \theta_a = n W_d \left[ T_d - T_{int} \right] + W_t T_{int} \]  

[6]

\[ W_t = n W_c \left[ (1 + \lambda_1 + \lambda_2) + W_d \right] \]  

\[ W_c = R_c I^2 \]