Calculation of cable thermal rating using a hybrid method based on IEC 60287 and finite element method

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ABSTRACT

The article discusses the challenges of calculating the current-carrying capacity of power cables in complex arrangements using the IEC 60287 standard and finite element methods. To address this, a hybrid method combining both methods was developed, using pyGIMLi software, resulting in a faster and more flexible approach.

The method has been integrated into a commercially available web-based cable rating software tool.

KEYWORDS

Cable rating, finite element method, IEC 60287

INTRODUCTION

The IEC 60287 standard [1] is an effective method for accurately calculating the current-carrying capacity of power cables in most practical arrangements using analytical methods based on Kennelly's hypothesis and the method of images. However, for complex arrangements that involve multilayer backfills, multiple parallel backfills, insulation barriers, and non-homogenous soil conditions, the proposed analytical method is not applicable, and finite element methods (FEM) are commonly used. A drawback of using finite element methods is that the specialized software required is powerful but also expensive and requires proper training and experience for effective use.

Using a simplification as proposed in IEC TR 62095 [2], a hybrid approach for calculating the ampacity of cables in non-homogenous soil was developed. The finite element technique is used to calculate the external thermal resistance for each heat source (cable, gas insulate lines or GIL, heat pipe etc.), taking into account all non-homogeneities in the soil. The obtained values are then used with the analytical equation from IEC 60287 to calculate the ampacity for each system.

This blend of finite element and analytical techniques provides the advantage of shorter calculation time in comparison to fully finite element methods, while also allowing for more flexibility in addressing complex arrangements not covered by the IEC method.

IEC 60287

The method from IEC 60287 considers a conduction shape factor *S* of a horizontal isothermal cylinder of length *L* buried in a semi-infinite medium as shown in **Fig. 1**. As such, the temperatures to be considered are the isothermal cylinder (or cable) surface temperature T_1 and the isothermal ground surface temperature T_2.

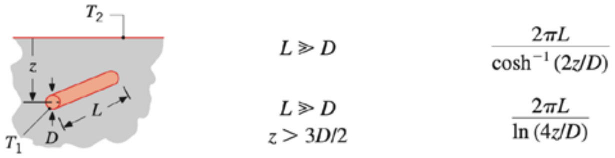

Fig. 1 Conduction shape factor Case 2, Table 4.1 of [3]

The shape factor is defined in [3] such that:

$$q = Sk\Delta T_{1-2} \quad [1]$$

where q is the steady-state conduction heat rate, k the thermal conductivity, and ΔT_{1-2} is the temperature difference between boundaries.

According to [3], it also follows that a two-dimensional conduction resistance may be expressed as:

$$R_{t,cond(2D)} = \frac{1}{Sk} \quad [2]$$

and therefore:

$$R_{t,cond(2D)} = \frac{1}{q}\Delta T_{1-2} \quad [3]$$

or written in the terminology of IEC 60287-2-1 for the temperature difference between surface and ambient:

$$T_4 = \frac{1}{W_p}(\theta_s - \theta_a) \quad [4]$$

where θ_s [°C] is the objects surface temperature and θ_a [°C] the ambient temperature, being the temperature of the soil surface. T_4 [K.m/W] is the thermal resistance of surrounding medium. W_p [W/m] is the total heat loss from object p.

IEC TR 62095

The technical report [2] presents in example A5 a procedure to obtain the geometric factor for cables located in backfills. The procedure described was proposed by El-Kady and Horrocks [4] where an extended table of geometric factors for backfills is given.

Essentially, the procedure considers the surface of the backfill to be an isothermal being set at $\theta_s = 1$ and the soil surface to be an isothermal at $\theta_a = 0$ (**Fig. 2**).

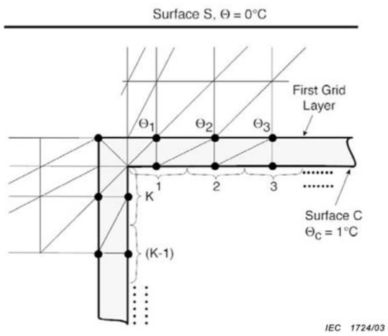

Fig. 2 Thermal circuit configuration from [2]