MODERN FEM TOOLS – AN EXAMPLE OF CABLES INSTALLED IN DUCT-BANKS

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ABSTRACT

In many places around the world cables are installed in duct-banks. The duct-bank has in all practical cases normally a lower thermal resistivity than the surrounding soil.
With modern FEM-tools it has in this paper been shown that the external thermal resistance and the effect of backfilling in some cases can increase the rating of the system compared to analytical tools according to standards. That is, the IEC and Neher McGrath formulas are not in perfect agreement with the results obtained from FEM.
In very extreme cases, for example a rectangular duct-bank with dimensions 1x0,33 m and large difference in thermal resistivities between soil and duct-bank, the rating may be increased by up to 30% compared to IEC and N-M if incorporating both rectangular shape of duct-bank and backfill. For more common conditions, one may however ask if backfill is necessary at all.

KEYWORDS

FEM, cable ampacity, duct-bank, backfill, soil drying out

INTRODUCTION

The aim of this paper is to address some contributions of modern FEM-tools, which may give a better understanding of thermal phenomena attributed to cables installed in duct-banks.
The modeling of the duct itself is not described here. Rather the agreement with IEC 60287 and Neher McGrath formulae for the external thermal resistance of the duct-bank is discussed. In IEC and N-M an equivalent diameter is introduced to make a transformation from rectangular to circular shape of the duct-bank possible. It will be shown that this transformation is not perfect.
Furthermore, the effect of thermal backfill is introduced and some corrective factors are given in the form of a diagram in order to give some rule of thumbs.
It is in this paper, however, not the aim to give any contribution to IEC or N-M, i.e. to suggest any modification therein. It is instead meant to show the possibilities of using modern FEM-tools and to make checks and comparisons possible with analytical solutions.
Maybe, modern FEM-tools, which give very exact solutions and which become more sophisticated, will be introduced as a standard calculation tool in the future. For example, IEC and N-M does not take into account the air inside adjacent ducts into account, i.e. the complete duct-bank is in fact not filled with concrete. Such a configuration, taking adjacent air-filled ducts into account, can easily be modeled in a modern FEM-tool.

CALCULATION OF T_4 IN IEC AND N-M

According to IEC 60287 [1] and Neher-McGrath [2] analytical models, the external thermal resistance of a buried cable, duct or duct-bank must satisfy the following two important conditions:

- The ground surface is treated as an isothermal surface, thus enabling the cable to be mirrored in this plane
- The thermal resistivity is constant versus space and time

Following these pre-conditions, any isotherm (harmonic circle) in the soil is calculated according to equation 1:

$$T_4 = \frac{\rho_e}{2\pi} ln\left(u + \sqrt{u^2 - 1} \right) = \frac{\rho_e}{2\pi} G \qquad [1]$$

ρ_e is the thermal resistivity of soil
$u = L/r_b$
L is the distance from the surface of the ground to the cable axis
r_b is the external radius of the isotherm

The isothermal circles from a single isolated buried cable are shown in Figure 1. It can be noticed that the bigger the isotherm is, the bigger is the offset between the center of the circle and the heat source generating the isotherm. This offset is taken into account and is included in the ln-expression, G, in equation 1.

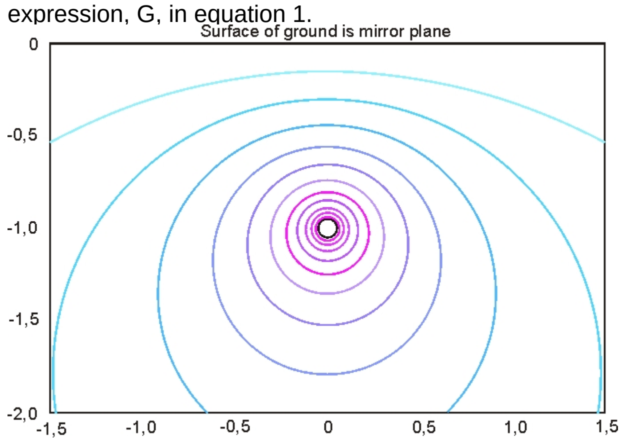

Figure 1. Isothermal harmonic circles for a single isolated buried cable.