Comparison of Quickfield™ simulation of three single core XLPE cables, in flat formation, with complex loading, between not taking drying- out and taking drying- out of soil into account.

Joubert **LE ROUX,** Vaal University of Technology, South Africa, joleroux45@gmail.com,
Jerry **WALKER**, Vaal University of Technology, South Africa, jerrywalker@walmet.co.za

ABSTRACT

Current rating calculations for power cables require a solution of the heat transfer equations which define a functional relationship between the conductor current and the temperature within the cable and its surroundings. Normally in such calculations the drying out of soil is not considered. This however, may have a very negative effect on the emergency rating of the cable. The thermal conductivity changes with moisture content. In this paper the effect of drying out of soil will be discussed.

KEYWORDS

Ampacity, full-load current, temperature-rise, soil thermal conductivity, soil moisture content, dry density.

INTRODUCTION

Current rating calculations for power cables require a solution of the heat transfer equations which define a functional relationship between the conductor current and the temperature within the cable and its surroundings. The challenge in solving these equations analytically often stems from the difficulty of computing the temperature distribution in the soil surrounding the cable. The ambient temperature in summer will be taken as 25º C. The burial depth of the cables is in the order of 10 times their external diameter and for the usual temperature range reached by such cables this is a reasonable assumption, but for large cable diameters and cables located close to the ground surface a correction to the solution has to be used or numerical methods should be applied. Normally in such calculations the drying out of soil is not considered. This however, may have a very negative effect on the emergency rating of the cable. This paper will show the difference between taking drying out into account and when this is not taken into account. The soil thermal conductivity is very much dependent on the saturation and dry density. Saturation is defined as the amount of moisture contained in the soil. Dry density is defined as the mass of soil particles per unit volume. An increase in either one of these factors will result in an increase in soil thermal resistance. Other factors influencing the soil thermal resistance indirectly includes mineral composition, texture, temperature and time.

DEVELOPMENT OF THE FORMULAE

It is possible to quantify the heat transfer process in terms of the appropriate heat transfer equation:

$$\frac{\partial^2\theta}{\partial x^2}+\frac{\partial^2\theta}{\partial y^2}+W_{int}\rho=\frac{1}{\delta}\frac{\partial\theta}{\partial t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(0.1)}$$

Where:

θ = unknown temperature

$\delta=\frac{1}{\rho c}$ thermal diffusivity of the medium (m^2/s)

c = volumetric specific heat of the material (J/m^3)

ρ = thermal resistivity of the material (K.m/W)

W_{int} = heat generation rate in cable (W/m)

Current rating calculations for power cables require a solution of the heat transfer equations which define a functional relationship between the conductor current and the temperature within the cable and its surroundings. The challenge in solving these equations analytically often stems from the difficulty of computing the temperature distribution in the soil surrounding the cable. An analytical solution can be obtained when a cable is represented as a line source placed in an infinite homogenous surrounding medium. Since this is not a practical assumption for cable installations another assumption is often used; namely, that the earth surface is an isotherm. With the isothermal boundary, the steady-state heat conduction equations can be solved assuming that the cable is located in a uniform semi-finite medium. Methods of solving the heat conduction equations for steady state conditions are described in [1] and for transient (cyclic) conditions in [2] for most practical applications. When these methods cannot be applied as for many non-standard installation conditions the heat conduction equations can be solved using numerical approaches [3]. One such approach, particularly suitable for the analysis of underground cables, is the finite element method presented in this paper. Quickfield™ is the program used in this paper.

The boundary conditions associated with equation 1.1 can be expressed in two different forms. If the temperature is known along a portion of the boundary then

$\theta=\theta_B(s)$ ………………………………….. (0.2) where

θ_B is the boundary temperature that may be a function of the surface length s. If heat is gained or lost at the boundary due to convection