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The influence of Earth thermal conductivity on temperature profile of 110 kV electric power cable system

Abstract. *The paper presents the conductivity of the ground effect on the distribution of temperature field in three-phasehigh-voltage cables, 64/110 kV, depending on the depth of their arrangement in the ground. The simulation uses the finite element method FEM.*

Streszczenie. *W pracy przedstawiono wpływ przewodności gruntu na rozkładu pola temperatury w kablach trójfazowych wysokiego napięcia 64/110 kV, w zależności od głębokości ich ułożenia w ziemi. W symulacji zastosowano metodę elementów skończonych MES.* (***Wpływ przewodności cieplnej gruntu na rozkład pola temperatury w układach kablowych 110 kV).***

Keywords: temperature field, the temperature limit, the cables of 110 kV, FEM.
Słowa kluczowe: pole temperatury, temperatura dopuszczalna, kable 110 kV, MES.

Introduction

Redistribution of electrical energy more and more often requires high voltage cable lines being used and laid underground. These requirements are forced by urbanization and environmental protection, energy transfer within the areas of national nature reserves, watersheds, military territories, airports and the like.

The amount of transferred energy is determined by the temperature of the core of the cable. The major impact on the temperature profile in the core, apart from the temperature above the surface and its profile underground, is dependent on the depth of the cable installation, construction and interconnection in three-phase systems. The thermal conductivity is dependent on the type of soil and its moisture. The aim of the article is to discuss the temperature profile in high voltage cables 64/110kV: 2XS (FL) with a copper conductor. In the present simulation the professional programme NISA/Heat Transfer is used, which uses for calculations finite element method.

Equation of thermal conductivity.

Stationary temperature field T (x, y) of high voltage cables laid directly in the ground for a homogeneous environment, two-dimensional system In steady state is described by the equation [1] :

$$\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} = -\frac{g(M)}{\lambda} \tag{1}$$

where: $g(M) = j^2 \rho \ [W/m^3]$ the performance of spatial heat sources, $j[A/m^2]$ current density, $[\Omega m]$ conductor resistivity (copper), $\lambda[W/mK]$ pipe thermal conductivity, insulating layers and the ground

Construction of High Voltage Cables.

Cables with cross-linking polyethylene insulation XLPE have been used since the beginning of the 1960s for the range of medium voltages and since 1971 they have been commonly used for the voltage of 123 kV. Currently, the cables for the voltage of 500 kV are being built and successfully exploited. Having approximately stable electric and dielectric characteristics of the cables and their increased resistance to the heat emission means higher permissible load in the mode of continuous work and in the case of short-circuit.

There are other following advantages of currently produced high voltage cables:

- Lower loss coefficient tan δ = 4x10^{-4}
- Relative permittivity ε_r = 2,4 (which allows lower working capacity)
- Lower mass
- Lesser bend radius
- Easy assembly
- Easy accessory attachment
- Unnecessary maintenance of the cable system

Numerical model of the cable

The selection of the electric power cable as well as other parameters is made on the basis of technical specification of the company *Tele-Fonika Kable S.A:* A2XS (FL) 2Y2Y-GC-FR 1x2000RMS/210 64/110 (123) kV IEC 60840

Table 1.

Current in the main conductor	Air temperature	Ground temperature	Distance from the ground surface
[A]	[^{0}C]	[^{0}C]	[m]
940	+35	+8	+8

Figure 1 presents the numerical model of the analyzed system, and in Figure 2 − the temperature profile for the typical boundary conditions of the system Table 1 where assumed thermal conductivity is λ=1[W /mK].

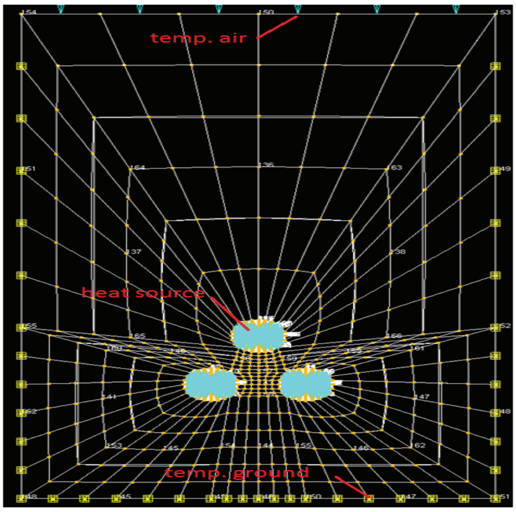

Fig. 1 FEM model of the analyzed system

There are substantial visible differences in temperature in the core of the cable for the earth thermal conductivity $\lambda_z \in 0,2 \div 0,8$[W /mK] Fig.4, additionally assumed boundary conditions for 40^{0}C.

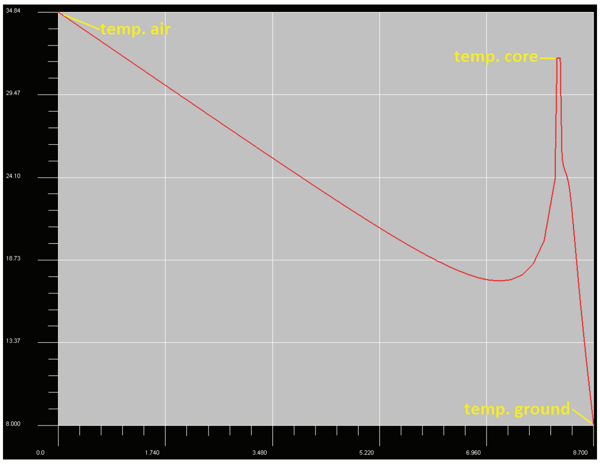

Fig.2 The temperature distribution in the ground and the maximum temperature of the core (for boundary conditions of Chart 1)

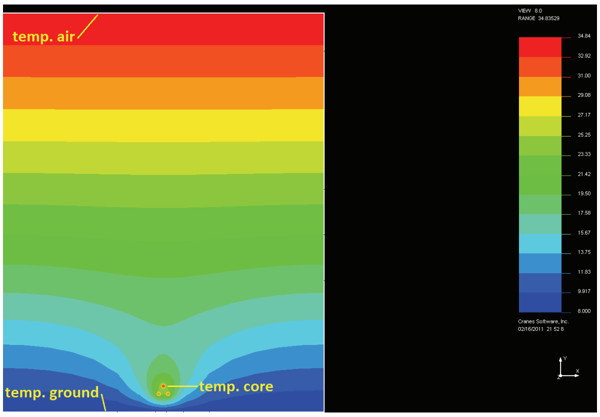

Fig.3 The temperature distribution in the ground, and analyzed the system (for boundary conditions of Chart 1)

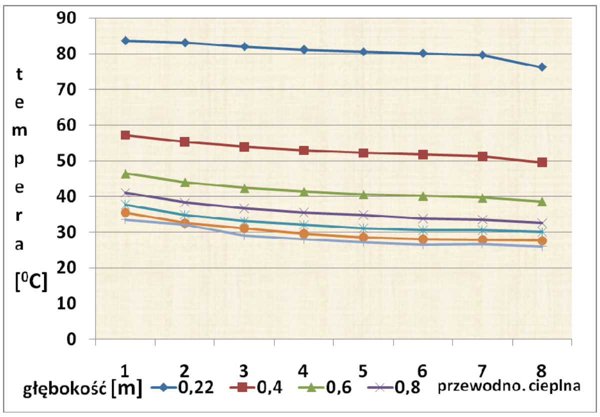

Fig.4. Temperature changes in the core of the cable at different depths (from 1 to 8 m) for different values of thermal conductivity (from 0,22 to 1,2).

Figure 5. presents the temperature profile in the core, screen and surface of the cable at different depths.

The temperature profile stabilizes starting at 10m and temperature differences between its individual layers are constant at different depths.

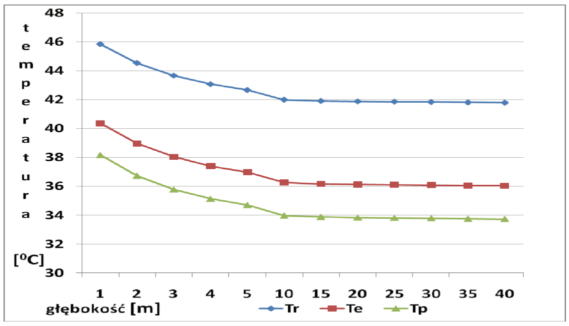

Fig.5. The analysis of temperature profile in the core of the cable for different depths *(1-40m)*.

Conclusions

As a result of the conducted computer simulation and the analysis of the temperature profile in the system depending on its distance from the surface of the earth and its thermal conductivity which is affected by different temperatures on the surface it is necessary to state the following:

- the thermal conductivity of earth has substantial influence on the temperature of the core of the cable – up to the value of 0,8[W /mK]
- the temperature in the core of the cable is determined starting at depth of 10 m
- the differences in temperatures between the core of the cable, its screen and the surface are constant for the defined boundary conditions and average between 6^0C and 2^0C, as well as can be defined after exceeding the depth of 10m
- the influence of the outer temperatures on the temperature profile inside the cable stabilizes below 10 m from the surface

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