The Influence of Overhead Lines on Buried Cables

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Abstract **This paper deals with electromagnetic fields of three-phase overhead power lines and the effects their interference has on buried cables. The work analyzes electric and magnetic fields of power transmission lines and simulates their field's influence on buried cables. Furthermore, this paper investigates the situation in the cables and shows changes of monitored values in cable covering according to different input data.**

Keywords **electric and magnetic field, three-phase overhead power lines, buried cables.**

I. Introduction

In recent years, there has been a tendency to build power corridors common for more transmission systems. Lots of aspects, such as difficulties in getting sites, high cost of land, the environment protection and better exploitation of land resources forces the industry to place transmission lines in parallel, i.e. to install electric lines and buried linear installations in the same transmission corridor.

II. The Model and the Area of Computation

The following model example shows a buried cable in parallel with a power overhead line (Fig. 1). Specific computations were carried out for various types of towers. The following text deals with a Donau type tower with two parallel 400 kV overhead lines.

With the overhead lines, the following nominal values are considered and used in the computations: $U_1 = U_2 = 400$ kV, $I_1 = I_2 = 790$ A.

The boundary condition problem is set for a magnetic vector potential. The area of air and soil was determined as semi-circles of 500 m radius. In the air area the relative permeability μ_r equals 1 and the conductivity γ is 0.

In practice, there is a change in soil type both vertically and horizontally; therefore, there is also a change in conductivity γ. Moreover, the changes in conductivity of soil depend not only on soil type, but also on pH of soil, yearly rainfall and the level of ground water. The expected values range from 0.0005 S/m to 0.5 S/m. The assumed relative permeability of soil μ_r is 1.

Fig. 2 depicts a buried three-phase power cable. In order to make a comparison, there is also considered another cable which is under the outer insulation equipped with copper concentric wire functioning as a shielding. There are given geometric dimensions of the cable, material properties of individual areas of the cable, effective value of the nominal current 100 A and voltage with frequency f = 50 Hz. The definition area Ω consists of five subareas. The steel covering, which is the subject of this study, is marked bold.

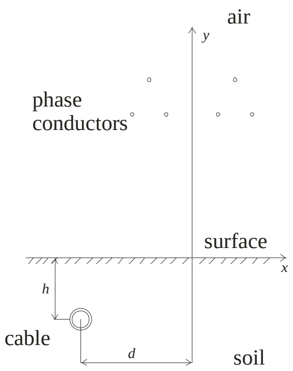

Fig. 1 Geometric Layout

The electromagnetic harmonic field was solved by using symbolic-complex method by means of Helmholtz equation

$$\Delta \underline{\boldsymbol{A}} - j\omega\gamma\mu\, \underline{\boldsymbol{A}} = \mu\, \underline{\boldsymbol{J}} \qquad (1)$$

for individual subareas $\Omega_{1\text{-}5}$.

The physical properties of copper are $\gamma = 5.8\cdot10^7$ S/m, $\mu_r = 0.99999$; the conductivity of steel roughly ranges from 10^4 S/m to 10^6 S/m and $\mu_r = 8000$. In insulation materials, the considered values are $\gamma = 0$, $\mu_r = 1$. The nominal voltage of the cable is 10 kV.

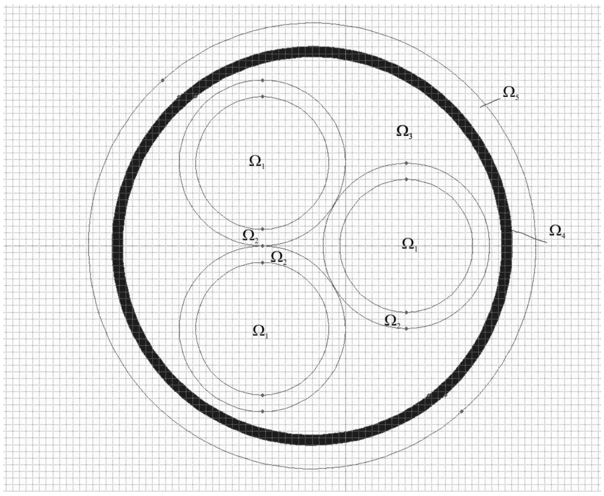

Fig. 2 Cable – Definition Area
Ω_1 – copper conductors, Ω_2 – PVC insulation, Ω_3 – rubber, Ω_4 – steel covering (flat steel bands), Ω_5 – outer PVC covering

III. Numerical Solution

As the problem was geometrically incommensurable (there is the field surrounding the outer electrical line and the field in the buried cable), first was solved the distribution of electromagnetic field generated from currents of the line wires. The rough mesh initially applied in the solution was subsequently locally softened in places where the buried cable occurred. Then a smaller area was selected, in which the field in the cable was solved in a soft mesh with re-calculated boundary conditions discovered by solving the same system in a rough mesh first. The solution is demonstrated for the Donau tower with two parallel electric overhead lines 400 kV. The arrangement of the phase conductors is as follows: $\overset{\times}{\bullet}\circ \quad \bullet\overset{\times}{\circ}$, (phase marked with symbols) [1]. The cable is buried in the depth of 1 m; the considered conductivity of soil is 0.01 S/m.

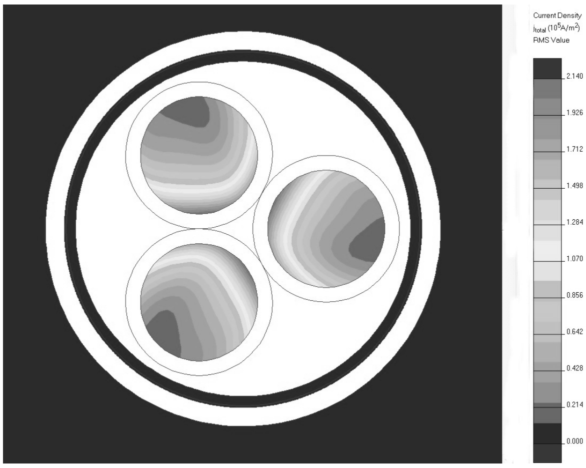

Fig. 3 Current Density Distribution

In this specific model problem, the buried cable is located 30 m from the axis of the tower. The current density solution and the magnetic flux density solution are depicted in Fig. 3 and Fig. 4.

The magnetic flux density distribution demonstrated in Fig. 4 shows that the conditions in the steel covering are significantly influenced by the magnetic field of the cable. If the buried cable is influenced by the 400 kV overhead power line on the Donau tower, the value of current density increases approximately by 25%.

Fig. 5 shows the dependence of current density and magnetic flux density emitted by a buried 3-phase cable on the distance from the cable. The cable is placed in soil in the depth of 1 m and is armoured with steel bands. The comparative cable is shielded with a copper concentric conductor.

Furthermore, Fig. 5 shows the dependence of monitored quantities on the distance from the three one-phase cables, each of which has its own copper shielding. The placement of the one-phase cables in ground is considered to be triangular without any gaps.

Fig. 5 clearly indicates that the current density around the cable is lower than 100 μA/m^2; therefore the soil surrounding the cable can be considered as the environment with a middle aggressivity from the point of view of corrosion probability [2]. In case of three one-phase cables, the middle aggressivity occurs up to the distance of 2.5 m. Up to this distance the soil surrounding the cables can be considered as the environment with higher aggressivity.

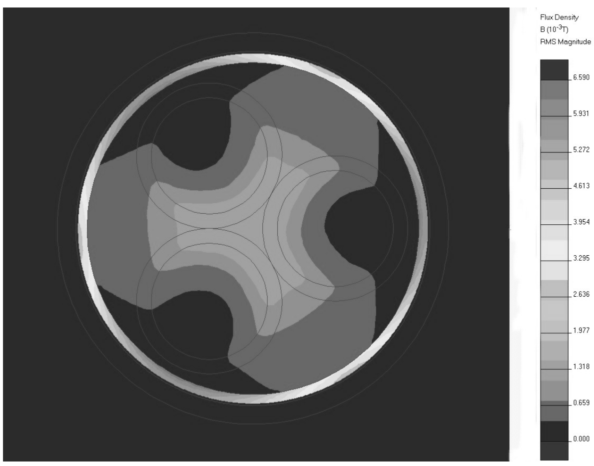

Fig. 4 Magnetic Flux Density Distribution

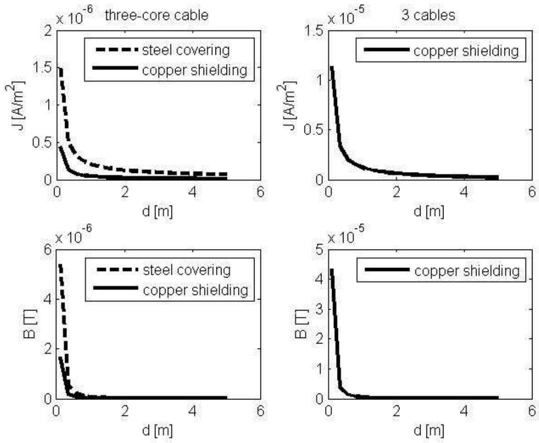

Fig. 5 Dependence of Current Density and Magnetic Flux Density on the Distance from the 3-phase Cable and from 3 One-phase Cables

IV. Conclusion

The value of current density and magnetic flux density in a cable covering is influenced by the magnetic field of the cable itself, by the distance of the cable from an overhead line, and by conductivity of soil, which is variable both vertically and horizontally depending on the soil composition. Values of investigated quantities are significantly influenced by the arrangement of phases in two parallel lines. The research shows that it is possible to find an optimal transposition of phase conductors, so that the values of current density and magnetic flux density in the cable covering are minimized. The concerned values are also nonnegligibly influenced by conductor sags. The decrease in current density as well as magnetic flux density in a cable covering is also possible to achieve by a steel pipeline placed in parallel with the cable; if need be by placing a shielding band along the cable. In such a case, it is necessary to consider the economic point of view.

Buried cables can induce a field which may influence technical installations placed in the same corridor. Therefore, it is necessary to choose an appropriate shielding. However, shielded cable lines are several times more expensive than commonly used overhead lines.

V. Acknowledgements

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VI. References

[1] Benešová, Z., Šroubová, L., Mühlbacher, J. Reduction of electric and magnetic field of double-circuit overhead lines. In *Komunalna energetika – Power engineering*, Maribor: Univerza v Mariboru, 2007. s. 1–7.

[2] ČSN P CEN/TS 15280 (03 8369)
Hodnocení pravděpodobnosti koroze střídavými proudy u potrubí uloženýchv půdě - Aplikace na katodicky chráněná potrubí.