Electromagnetic Field along the Power Overhead Line at Point Where the Line Route Changes Direction

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***Abstract*—Numerical analysis of electromagnetic field occurring along a high-voltage overhead line at the place where the line route changes its direction is carried out. The computation is performed by means of an integral method in the 3D arrangement, taking into account the location of the tower. The results obtained are compared with the exposure limits for low-frequency electric and magnetic fields in order to assess their effects on living organisms.**

Keywords—electromagnetic field; power overhead line; integral equations; maximum permissible exposure

I. Introduction

High-voltage overhead lines produce low-frequency electric and magnetic fields around them. These fields are easy to compute wherever the overhead line route is straight, as opposed to places where it changes its direction. Such cases require application of integral methods, making it possible to compute both components of an electromagnetic field at any point outside the lines, including the places where the presence of people or animals is expected.

II. Formulation of the Problem

Continuous urban expansion may eventually result in a situation when new development areas intended for residential, recreational and planting purposes can accidently be located in the vicinity of a high-voltage overhead line. Although the safety clearances are set out by electrical safety regulations, sometimes overhead lines pass almost immediately above a garden surrounding a detached house. Moreover, even the towers are sometimes adjacent to gardens. Such a case is depicted in Fig. 1 showing the 2 x 110 kV line route changing its direction at the angle of 36°. To the right of the power line, there is an area intended for gardening. The line generates an electromagnetic field whose effect on the health of people residing beneath depends on the values of the relevant electric field strength E and magnetic flux density B. Figure 2 shows a rectangular area of dimensions 15 x 11 m selected for the computation of the electromagnetic field. This area is coplanar to the ground plane at the height of 1.8 m above the ground. The computations were carried out for the maximum possible value of the current passing though the individual conductors, i.e. 1240 A.

III. Mathematical Model

This time-depended problem was solved three-dimensionally, in the Cartesian coordinate system x, y, z. The magnetic field strength $\boldsymbol{B}$ produced by the line at point Q is determined by means of an integral equation (Biot-Savart law)

$$\boldsymbol{B}(Q) = \frac{\mu_0 I}{4\pi} \int_c \frac{\mathrm{d}\boldsymbol{l} \times \boldsymbol{r}_{PQ}}{r_{PQ}^3}, \tag{1}$$

where μ_0 is the permeability of air, $\mathrm{d}\boldsymbol{l}$ is an element of the length of the conductor at general point P, and $\boldsymbol{r}_{PQ}$ is a radius vector that begins at point P and ends at point Q. The symbol I denotes the current passing through the conductor.

Fig. 1: Deviation tower with two parallel 110 kV overhead lines

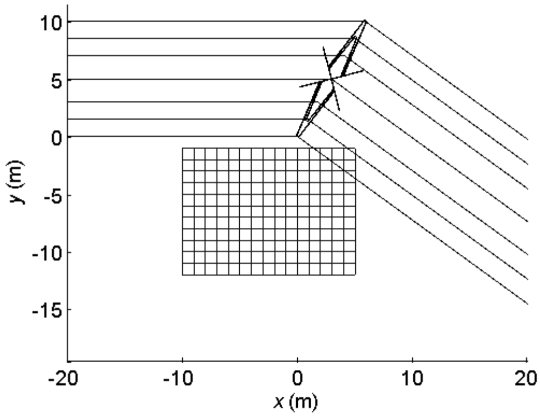

Fig. 2: Electromagnetic field computation area

The electric field strength $\boldsymbol{E}$ is determined by means of the integral equation

$$\boldsymbol{E}(Q) = \frac{1}{4\pi\varepsilon_0} \int_S \frac{\sigma(P) \cdot \boldsymbol{r}_{PQ}}{r_{PQ}^3} \mathrm{d}S \,, \qquad (2)$$

where σ is the surface charge density.

Unlike the computation of the magnetic flux density $\boldsymbol{B}$, the computation of the electric field intensity $\boldsymbol{E}$ requires taking into consideration the radius of the wire necessary for calculating the charge density σ along the conductor surface. The surface charge density is computed based on the known values of potentials of the involved conductors. The calculation of the surface charge density in several configurations including the solution to the problem with singularities is described in [1].

After obtaining the distributions of $\boldsymbol{B}$ and $\boldsymbol{E}$ of the electromagnetic field, the distribution of the Poynting vector $\boldsymbol{N}$ was calculated using the expression

$$\boldsymbol{N} = (\boldsymbol{E} \times \boldsymbol{B}) / \mu_0 \,. \qquad (3)$$

As all the field variables in this problem were time-dependent, they were first computed separately for each selected time instant t within one period, which was then followed by the calculation of their effective values.

IV. Results Obtained

Figures 3, 4 and 5 show the distributions of the effective values of the modules of vectors $\boldsymbol{E}$, $\boldsymbol{B}$ and $\boldsymbol{N}$ over the selected rectangular area.

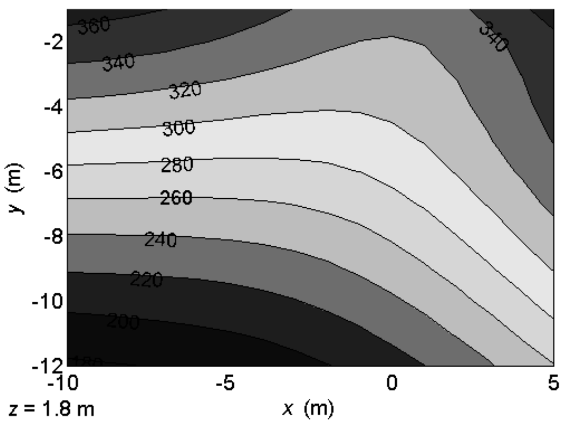

Fig. 3: Electric field strength distribution (V/m)

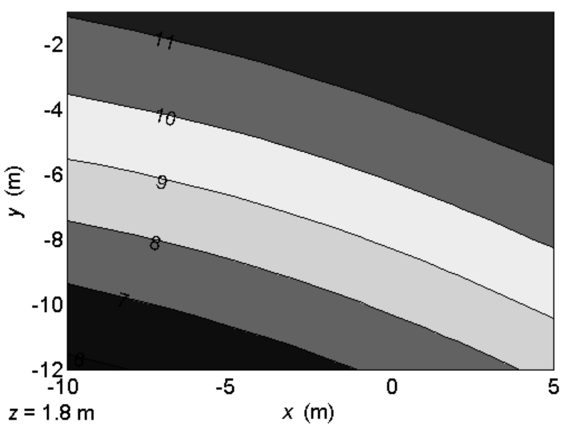

Fig. 4: Magnetic flux density distribution (μT)

Figure 6 demonstrates a 3D configuration of the Poynting vector in the selected rectangular area. The figure shows its distribution for the time $t = 0$.

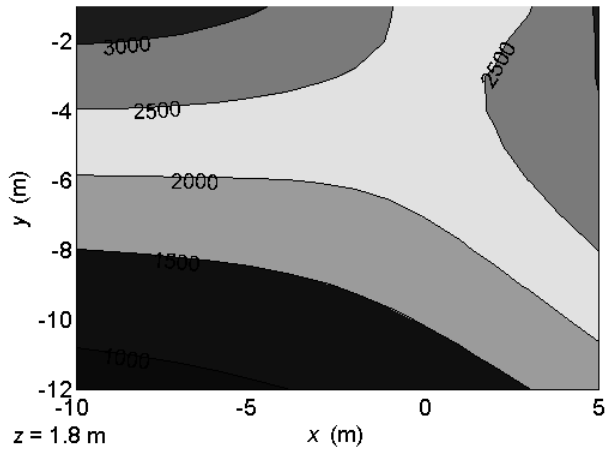

Fig. 5: Poynting vector distribution (W/m^2)

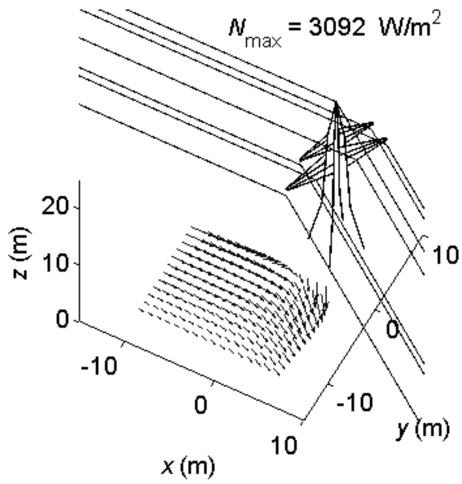

Fig. 6: Poynting vector in the selected rectangular area

V. Conclusion

The Regulation no. 1/2008 Coll., concerning protection of health against non-ionized radiation, stipulates 100 μT to be the maximum safe value of magnetic flux density in case of an uninterrupted exposure and frequency of 50 Hz. The investigated area did not exhibit values exceeding this statutory limit. The same was true for the maximum permissible level of electric field strength being specified at 5000 V/m.

Acknowledgment

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