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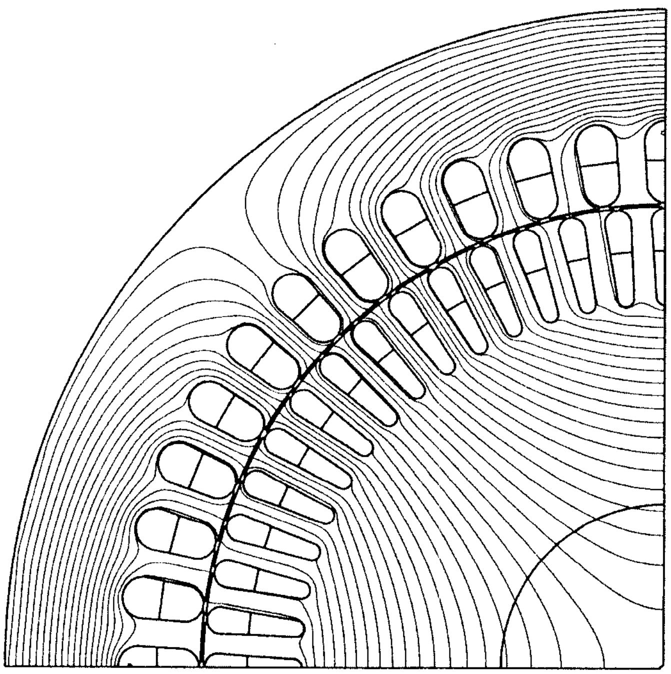
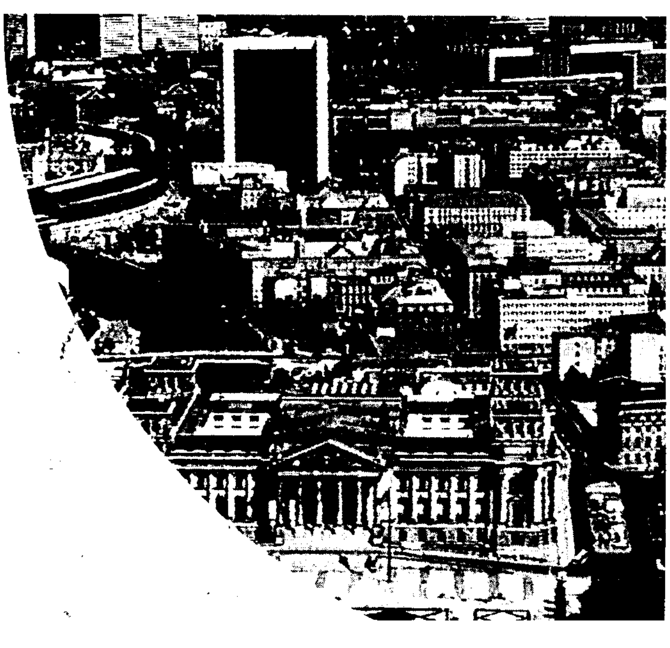
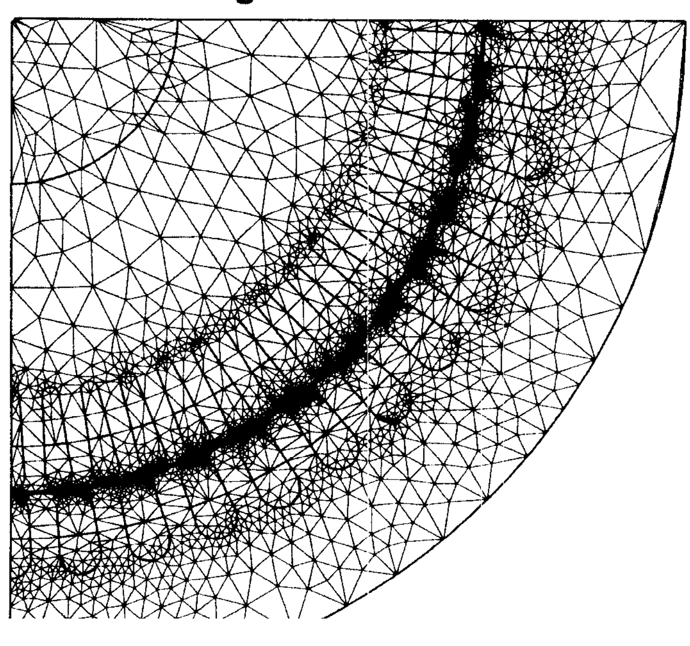


10th Conference on the Computation of Electromagnetic Fields





Computation of the field quantities excited by high-voltage lines

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Abstract- An increasing sensibility to ecological problems is seen. In the phase of planning high-voltage lines, the magnetic and electric field quantities have to be examined in order to avoid EMC problems with the surroundings of the power line. This request even gets more important with the trend towards higher transmission line voltages. In this paper, the computation of the three dimensional field distribution below high-voltage lines is demonstrated. The electric field is approximated with the point matching method and the magnetic field by a BIOT' SAVART solution.

INTRODUCTION

High-voltage lines generate electric and magnetic fields in their neighbourhood. The source of the magnetic fields are the currents in the phase cables. The electric field is caused by the high potential of the conductors. Due to the geometry of electrical energy transmission lines a wide expansion of the field is obvious. To evaluate the influence of the energy line, it is not sufficient to calculate the coupling impedance's or capacitance's of the line. It is necessary to analyse the generated field itself. The simulation of the line during planning has the advantage to know about possible risks and disturbing influences.

PREPARATION OF THE FIELD PROBLEM

Due to the slack of the phase cables the field problem turns out to be 3-dimensional. The problem specifies conductors with a small diameter above a large flat conducting ground plane. Those conductors have a specified time-depending electrical potential. The numerical analysis with the finite element method is expensive and computer time consuming.

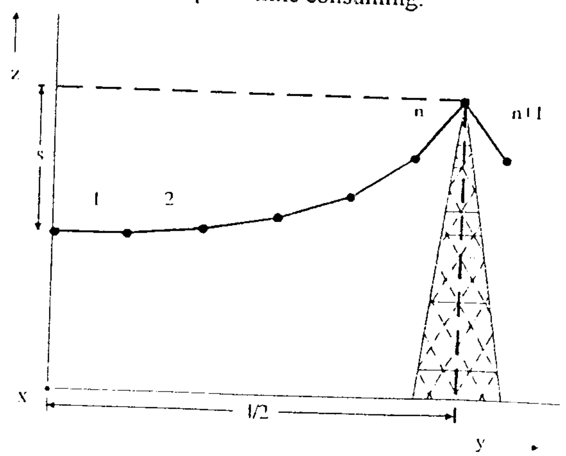

Fig. 1: Geometric modelling of a conductor.

Because of the very large wavelength of the field problem, it has to be considered being quasistatic. Therefore the solution can be determined by electrostatic and magnetostatic techniques. Hence, the field computation is done with a semi numerical method, the point matching method.

The geometry of the single transmission lines is approximated by a polygon. Due to the symmetry between two poles one half of the arrangement is drawn in fig. 1 only. The value of s indicates the slack and l is the distance between the two high voltage poles.

ELECTROSTATIC FIELD

To compute the electric field with the point matching method, each element of the polygon represents a line-charge. A constant line-charge at any position in the original co-ordinate system (x, y, z) is drawn in fig. 2. To evaluate the field quantities of the line-charge, this co-ordinate system has to be transformed into a system $(\tilde{x}, \tilde{y}, \tilde{z})$. This transformation is performed in two steps. The first step consists of a parallel shift of the origin into the starting point of the line-charge. In a second step a rotation of this temporary co-ordinate system (x°, y°, z°) around the x°-axis is carried out in the way that the line charge lies in the x°-y° plane. The last rotation in this step is around the z°-axis so that the line-charge lies in the x°-axis. In this co-ordinate system the potential φ of the line-charge in the point $P(\tilde{x}, \tilde{y}, \tilde{z})$ is given by

$$\varphi(\tilde{x}, \tilde{y}, \tilde{z}) = \frac{q}{4\pi l \varepsilon} \ln\left[\frac{l - \tilde{x} + \sqrt{\tilde{y}^2 + \tilde{z}^2 + (l - \tilde{x})^2}}{-\tilde{x} + \sqrt{\tilde{x}^2 + \tilde{y}^2 + \tilde{z}^2}}\right] \qquad (1)$$

It is assumed, that the ground potential below the voltage line is set to $\varphi = 0$. To evaluate the field quantities with respect to this boundary condition, the line-charge has to be mirrored at the plane x-y. The superposition of line-charge q and mirror-charge $-q$, indicated in fig. 2, gives the potential φ in the point $P(x, y, z)$ inside the global co-ordinate system.

To consider the before mentioned slack of the conductors a quadratic approximation is used. To refer to fig. 1 it can be written that

$$f(y) = s \cdot \left(1 - \frac{4}{l^2} y^2\right) \qquad (2)$$

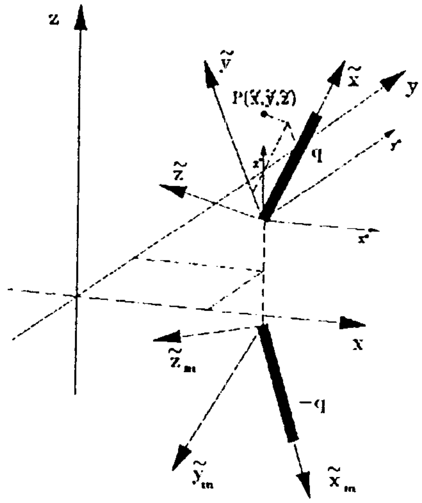

Fig. 2: Co-ordinate transformation.

With the known complex potentials $\underline{\varphi}_i$ of the i conductors and transformed (1) to compute the coefficient matrix **A**, a linear set of equations can be formulated.

$$\mathbf{A} \cdot \underline{\mathbf{q}} = \underline{\varphi} \tag{3}$$

The solution determines the charge $\underline{q}_i$ of each element of the conductors. With this value the components of the electro static field strength in the point $P(x, y, z)$ can be computed.

$$\mathbf{E} = -grad\varphi = -\left(\frac{\partial\varphi}{\partial x}\mathbf{a}_x + \frac{\partial\varphi}{\partial y}\mathbf{a}_y + \frac{\partial\varphi}{\partial z}\mathbf{a}_z\right) \tag{4}$$

Figure 3 shows the computed distribution of the electric field strength below a transmission line consisting out of two 400 *kV* systems. The field strength is computed 1 *m* above the ground. The high-voltage pole is located in the drawing at the position x=0 *m* and y=160 *m*.

Bundle conductors are taken into account with an equivalent radius. More details can be found in [1].

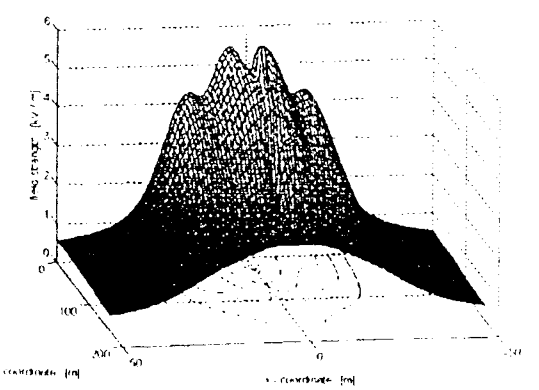

Fig. 3: Electric field distribution below a high-voltage line with two 400 *kV* systems.

Magnetic Field

The magnetic field problem is considered to be linear. Therefore, the field quantities can be computed and superposed with the help of the Biot' Savart law. Each element of the polygon from fig. 1 carries now a current *i(t)*. The generated flux density of this part of the conductor is given by

$$|d\mathbf{B}| = \frac{\mu_0}{4\pi r^2} \cdot i(t) \cdot dl \cdot \sin\alpha \tag{5}$$

The point where the flux density has to be calculated has to be transformed into the co-ordinate system $(\tilde{x}, \tilde{y}, \tilde{z})$. After integrating (5), the flux density is calculated with

$$|\mathbf{B}_i| = \frac{\mu_0}{4\pi r} \cdot i(t) \cdot \left(\frac{l - \tilde{x}}{\sqrt{(l-\tilde{x})^2 + r^2}} + \frac{\tilde{x}}{\sqrt{\tilde{x}^2 + r^2}}\right) \tag{6}$$

If n is the number of current leading conductors, the superposition of the partial flux densities results in the overall flux density.

$$\mathbf{B} = \sum_{i=1}^{n} \mathbf{B}_i \tag{7}$$

In fig. 4 the flux density distribution of a system carrying 1000 *A* and 1200 *A* is drawn.

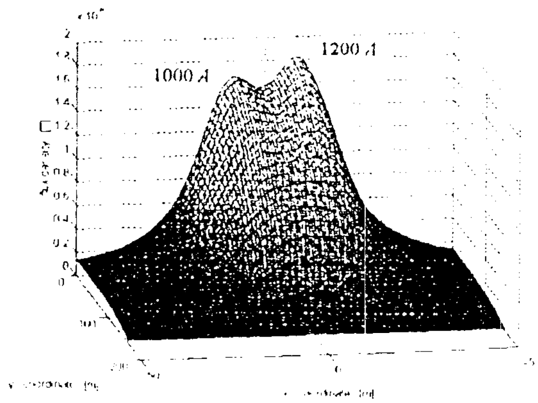

Fig. 4: Magnetic field distribution below a high-voltage line with two systems carrying 100 *A* and 1200 *A*.

Conclusions

Efficient methods to compute the three dimensional distribution of the electric and magnetic field below high-voltage lines has been demonstrated. The slack of the transmission line is approximated by a polygon. The computational costs are depending on the number of polygon elements.

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References

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