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Modeling of Electromagnetic Fields Close to the Very High Voltage and Extra High Voltage Poles

This paper deals with the solution of distribution of electromagnetic fields around the poles of very high and extra high voltage.

Keywords: electromagnetic fields, FEM, ANSYS, overhead lines

I. INTRODUCTION

For the mechanical mounting of the external overhead lines there are used poles, i.e. construction part for "carrying" of lines, mounted by insulator strings, because lines have different electric potential than the potential of the Earth. The shape and dimensions of the poles depend on the voltage, the type and number of lines and grounding cables, length of span, terrains, bearing capacity, material, functions and tensions, that pole have to resist. The pole height is determined on the location. It depends on terrain, cable arrangement on the pole head, cable sag, the length of insulator strings, the distance from the earth cable and lines from the prescribed height of the lower line from the ground or crossing-through objects.

For the double 110 kV overhead line it is mostly used one-tige narrow pole with a split basis (foot-stone, wall bearer). For a single 220 kV and 400 kV there were used double trunk pole. Currently, the double trunk and multi-tige poles should not be used in SR. Double trunk poles were replaced by the poles of shape of letter "Y". For the double 220 kV and 400 kV overhead lines there are used poles of type "Donau".

Through the overhead lines flow significant high currents and around them and also close the poles there is electromagnetic field (EMF) dangerous to life, eventually it could cause adverse effects. To eliminate the influence of electromagnetic fields it is necessary to know the correct and accurate distribution of the electromagnetic field. In the next section of this paper there will be described the results of solution of EMF distribution in the vicinity of 110 kV and 400 kV poles in more detail.

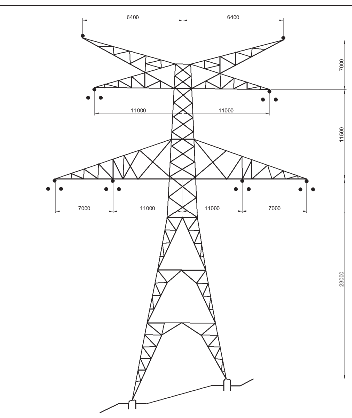
II. MODELING OF ELECTROMAGNETIC FIELD CLOSE TO ELECTRIC POWER EQUIPMENTS

For the numerical calculation of the electromagnetic field distribution there are used Maxwell's equations that are supplemented by the material equations. For their solution it is appropriate to use some numerical methods (finite element method (FEM), finite-difference method (FDM) and boundary element method (BEM)). Professional computer programs that use the FEM for solving electromagnetic fields are suitable for their versatility and also for this type of task. The presented model of poles was simplified into 2D space, so the calculation time was shorten compared to the 3D model. Geometric and material parameters of the poles, mounting and type of strand are listed in Tables 1 and 2.

III. MODELING OF ELECTROMAGNETIC FIELD CLOSE TO 400 KV OVERHEAD LINE

TABLE I
Specifications of 2×400 kV overhead line of type DONAU

Pole type	Donau
Number of 3-phase systems	2
Number of ground lines	2
Voltage level	400 kV
Phase current	$\leq 3\times835$ A
Frequency	50 Hz
Type of phase line	AlFe 450/52
Type of earthing line	AlFe 180/59
Number of lines in a bundle	3



Type of pole „Donau"

A. Results

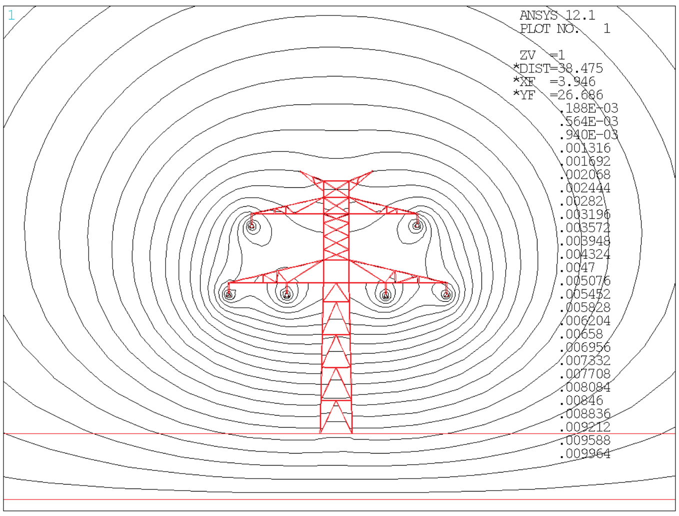
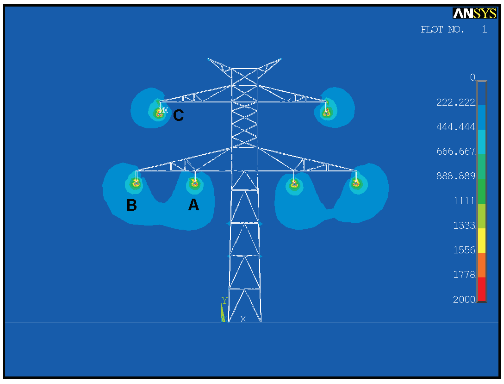
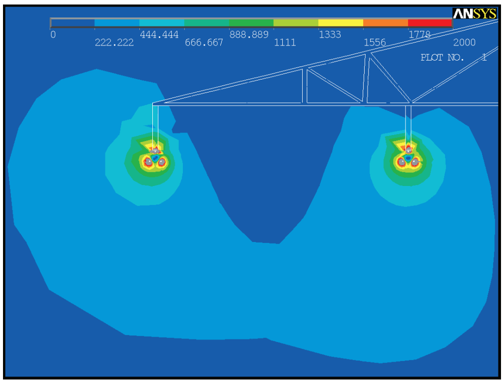


Figure 1. Distribution of magnetic field lines around the 400 kV line



a)



b)

Figure 2. a) Distribution of magnetic intensity around the 400 kV lines, b) Detail of magnetic intensity distribution around the conductor bundle 400 kV lines (A and B)

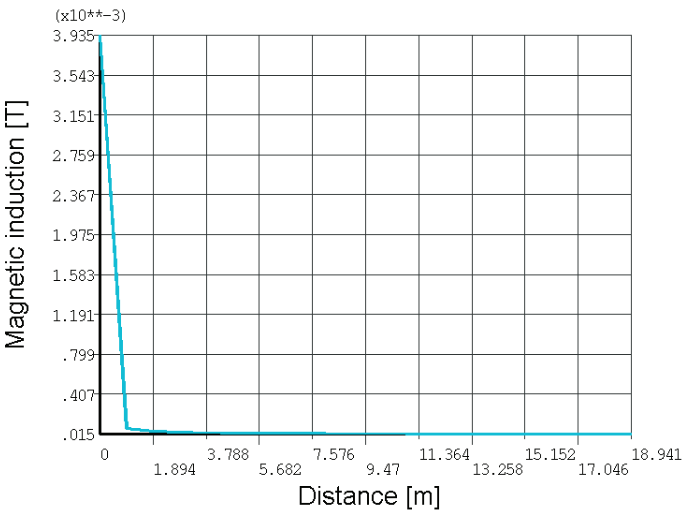
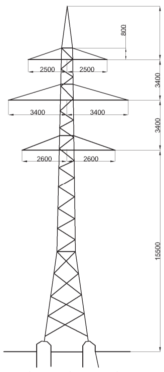


Figure 3. Graphical dependence of magnetic induction on the distance (between point A and ground (Fig. 2a))

There is in Fig. 3 presented graphical characteristics of the magnetic induction ***B*** [T] in dependence on the distance *d* [m] between the phase line “A” (Fig. 2a) and the ground. As one can see from the graph, the size of magnetic field in direction from the phase line “A” to the ground suddenly decrease and at a distance of approximately 20 m from the line the value of magnetic induction is 15 μT. This value represents the real value of magnetic induction, which can be measured directly under extra high voltage lines. Law No. 355/2007 collection of laws regularizes the exposure action values for the density of magnetic field of frequency 50 Hz, which is for the population to the limit of 100 nT. In this case the action value would exceed the value of magnetic field exposure and there must be done some precautions to avoid the adverse effects on the population. It should be noted that this increased value is measured directly under the 400 kV line. At a distance of 90 m from the phase line “B” the magnetic induction has negligible value. From this simulation is also evident that the presences directly below the overhead lines may cause affect the human body and can seriously endanger human health.

IV. MODELING OF ELECTROMAGNETIC FIELD CLOSE TO 110 KV OVERHEAD LINE

TABLE II
Specifications of 2 × 110 kV overhead line of type “Barrel”

Pole type	One-tige narrow	 Type of 110 kV pole “Barrel”
Number of 3-phase systems	2	
Number of ground lines	1	
Voltage level	110 kV	
Phase current	535 A	
Frequency	50 Hz	
Type of phase line	AlFe 240/39	
Type of earthing line	AlFe 180/59	

B. Results

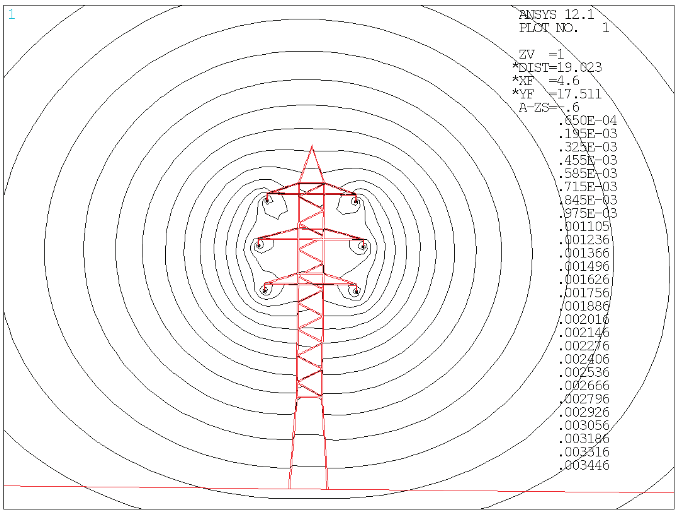
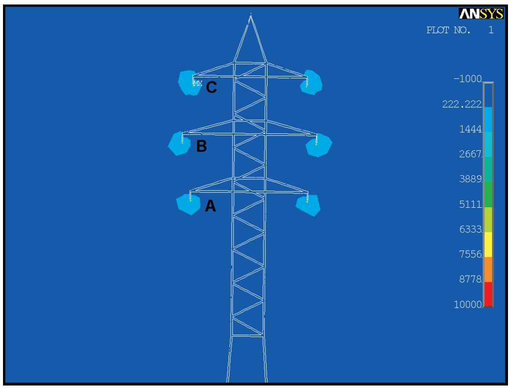
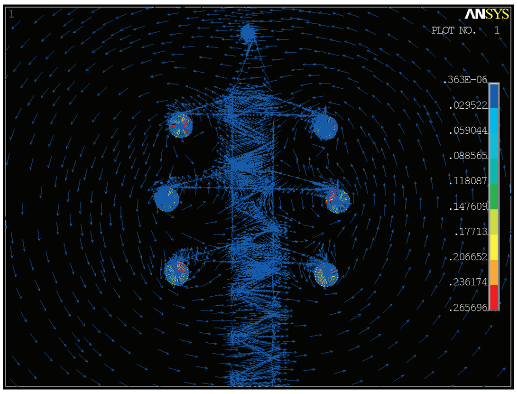


Figure 4. Distribution of magnetic field lines around the 110 kV line



a)



b)

Figure 5. a) Distribution of magnetic intensity around the 110 kV lines; b) Vector representation of the distribution of magnetic field around the 110 kV lines

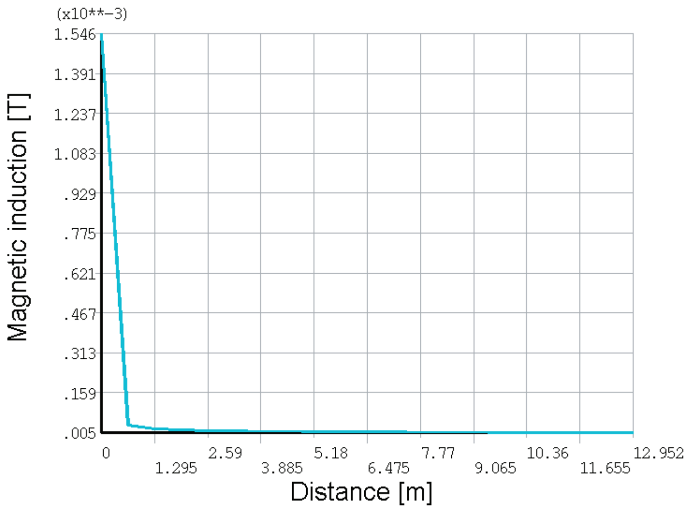


Figure 6. Graphical dependence of magnetic induction on the distance (between point A and ground (Fig. 5a))

There is in Fig. 6 the graphical characteristics of the magnetic induction $\boldsymbol{B}$ [T] in dependence on the distance d [m] between the phase line “A” (Fig. 5a) and the ground (perpendicular to the ground). As one can see from the graph, the size of magnetic field in direction from the phase line “A” to the ground suddenly decrease and at a distance of approximately 13 m from the phase line “A” the value of magnetic induction is approximately 5 µT. Even in this case, there is the excess of permitted magnetic induction values, as in an example above (400 kV lines). At a distance of approximately 100 m from the phase line “A” the magnetic induction has negligible values that do not endanger human health.

Electromagnetic fields in locations under the overhead lines could be eliminated, respectively reduced by the number of ways, e.g.:

- increasing the distance of phase lines from the earth,
- decreasing the operation voltage,
- ensuring the compactness of lines – control of line distances,
- changing the phase sequence of multi-system overhead lines,
- adding the shielding cables.

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