Investigation of Electromagnetic Field in 110 kV Substation

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***Abstract*—This article deals with the investigation of electric and magnetic field distribution of an electric 110 kV substation. The chosen quantities, that were investigated were electric intensity E and magnetic induction B. Simulations, realized in ANSYS, were performed at three selected heights of 0.3 m; 1 m and 1.8 m above the ground, that consisted of 168 measuring points along the selected part of the power-line. The simulation results were analysed and compared with the action values set out in Decree 534/2007 Coll. and 209/2016 Coll.**

Keywords—electromagnetic field; simulation; ANSYS

I. Introduction

This article presents the results of electromagnetic field (EMF) distribution in a high voltage (HV) 110 kV substation. In Slovakia, there are often used for interpretation of EMP two documents that indicate the limits of harmful values of EMF. These documents are the Decree of the Ministry of Health of the Slovak Republic no. 534/2007 Coll. (for residents) and government regulation 209/2016 Coll. (for employees), that set exposure limit values and exposure action values for electromagnetic fields.

Because the power stations are sometimes close to human residences, the investigation of EMF of the HV 110 kV substation and its results will be presented in this paper.

II. Description of Investigated Electrical Substation

The simulation distribution of electromagnetic field was performed according to disposition and measured data of HV substation in eastern Slovakia of 110 kV level. The chosen part of the electric array on which the simulation was done is shown in the figure (Fig. 1). The chosen array of the electric substation, where the simulation was performed, consisted of 3-phase overhead lines, consoles, supports, voltage instrument transformers, grounding, and another common equipment of electric array.

Fig. 1. Disposition of electric devices of the selected part of the power substation where the simulation of EMF was performed

Description of investigated places for EMF analysis

The HV substation consisted of a various types and number of arrays, but specific one of 110 kV array was chosen, where the actual load of this array was doubled in comparison to normal load. The indication of the investigated points is shown on the plan view of the HV substation array (Fig. 2).

The dimensions of the selected array: length (x axis) 15 400 mm, width (y axis) 9 600 mm. The x-axis step 2.2 m and y-axis 1.6 m were chosen from the array dimensions. The 56 investigated points were created from this array size and the selected steps. In every investigated point, there were realized also another three measurements of EMF at a height of 0.3 m; 1 m; 1.8 m. 168 values of electric intensity ***E*** and 168 values of magnetic induction ***B*** were investigated at all.

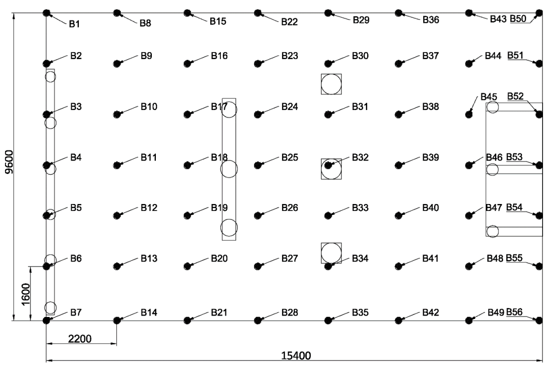


Fig. 2. Plan view of the chosen array in the HV substation, indicating the investigated points

These indicating measurement points corresponds to model created in ANSYS (Fig. 3).

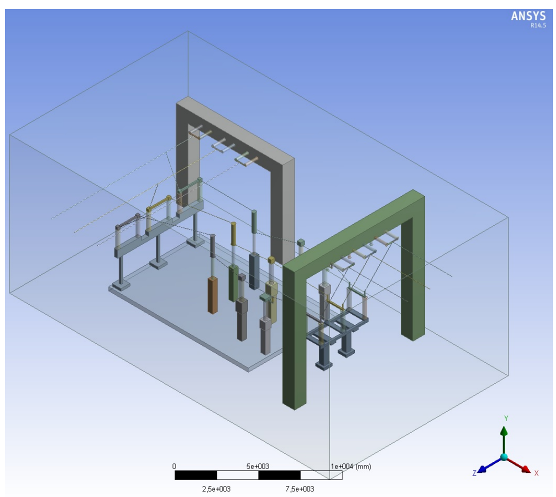


Fig. 3. Created 1:1 3D model of selected array of electrical substation in ANSYS

Within the investigation of ***E*** and ***B***, it was considered that almost all three phases are loaded symmetrically, where the mean effective current values in phases L_1, L_2, L_3 were $I_{L1} = 231.37$ A, $I_{L2} = 236.02$ A, $I_{L3} = 235.12$ A. The mean voltage at time of investigation was considered $U = 117,69$ kV.

III. Simulation of the Electromagnetic Field Distribution in ANSYS

The simulation of EMF distribution were realized in ANSYS Workbench environment, where the 3D 1:1 model of chosen array of 110 kV HV substation. According to computer configuration (12-core processor, 96 GB RAM), it was necessary to proceed the appropriate simplification (in geometry) to obtain valuable results in adequate time. Using of this computer simulation it was possible to obtain results after 9 days of calculation (created only mesh of mesh size of 10 cm and 21 276 196 elements), and subsequently circa 7 day for calculation of magnetic induction and 7 days for electric intensity.

Magnetic field distribution analysis

The material properties of the components used in HV substation (consoles, conductors, supports, …) were chosen according to datasheet provided by operator of HV substation. Table I. shows the electromagnetic properties of materials used in simulation. Note: these values were used also for magnetic and electric field analysis.

TABLE I. Electromagnetic Properties of Materials

Material	Resistivity [Ω·m]	Relative permeability
Air	$2 \cdot 10^{14}$	1.00000037
Aluminum	$8.21 \cdot 10^{-5}$	1.000022
Concrete	$1 \cdot 10^{8}$	2
Porcelain	$1 \cdot 10^{12}$	1
Iron	$1.7 \cdot 10^{-7}$	100

The placing of the probes for measuring of electric intensity ***E*** and magnetic induction ***B*** were according to Fig. 2, where in every investigated place were realized data reading in 3 heights (0.3 m, 1 m and 1.8 m above the ground).

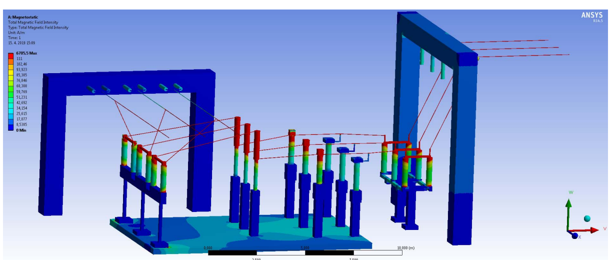


Fig. 4. Front view of distribution of magnetic field intensity ***H*** in the measurement array

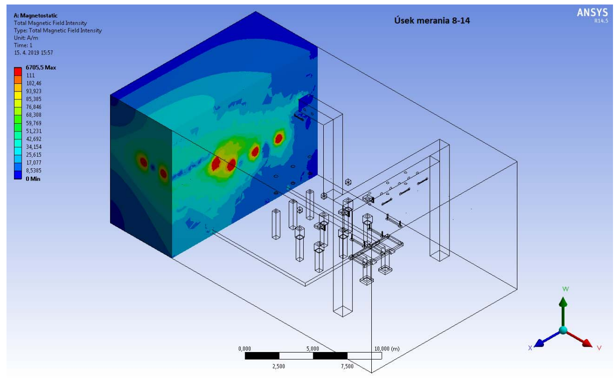


Fig. 5. Perspective view on the section 8-14, where the magnetic field intensity ***H*** distribution was investigated

The magnetic induction distribution ***B*** in the particular places is possible obtain in similar way (Fig. 6).

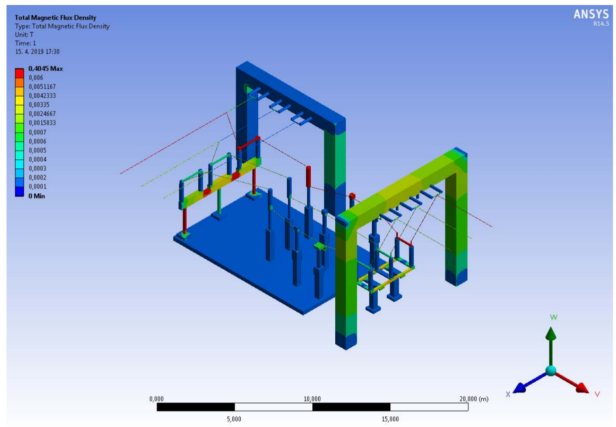


Fig. 6. Side view on the magnetic induction distribution ***B*** distribution of the investigated array

The distribution of magnetic induction ***B*** in the investigated array can be seen in Fig. 7 and Fig. 8. The magnitude of the magnetic induction at height of 1.8 m is similar to that of 1 m above the ground., were recorded In the last investigated section 50-56 were recorded the highest values of magnetic induction as well as at a height of 1 m above the ground and at this height of 1.8 m above the ground. Mean values in this section were in the range of 40÷55 µT. Primarily, the increased values could be seen at the beginning of the section at the point of investigation 2 and at the end of the section at the point of investigation 6. A steel structure console offers to hold the conductors out of the array at these points. Therefore, in these places, raised values arise due to the magnetic induction emitting from the phase conductors, (see Fig. 8). In the others sections, the values of magnetic induction are mostly evenly distributed and are of similar size. The range of these values is within 15÷45 µT.

Note: the magnetic induction at height of 0.3 m above the ground was considerably increased due to the grounding effect, which is made of steel and concrete. The material properties of this grounding and geometric simplification (considered as a full ground, not latticed and geometrically close to the consoles) had great influence to the simulation results.

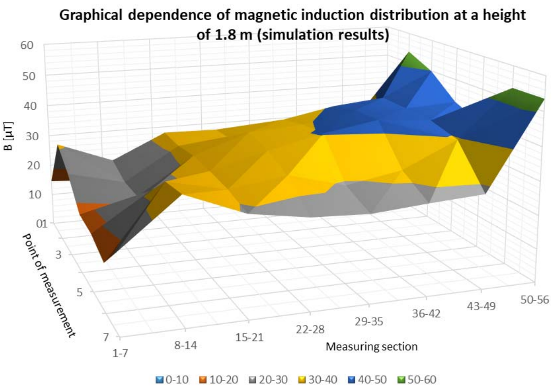


Fig. 7. Dependence of the magnetic induction distribution at height of 1.8 m above the ground

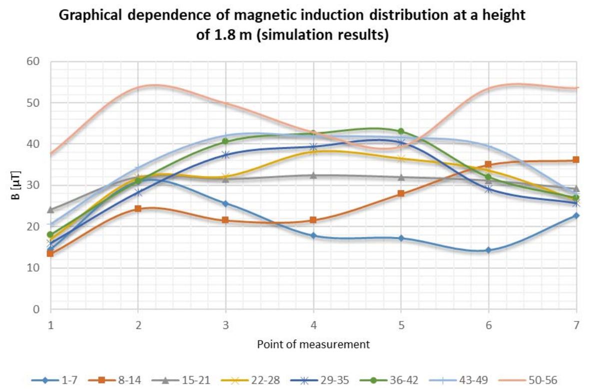


Fig. 8. Dependence of magnetic induction distribution in particular sections at a height of 1.8 m above the ground

Electric field distribution analysis

The same mesh model was used as in the case of magnetic field also for the purpose of simulation of the electric intensity distribution ***E***. The properties that influenced the electric field distribution were considered electric resistivity and relative permittivity.

The results of the distribution of electrical intensity ***E*** at the chosen locations (according to Fig. 2) and heights can be seen in the next graphs.

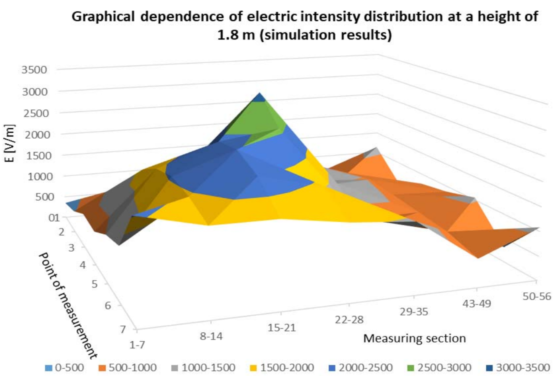


Fig. 9. Dependence of the electric intensity distribution at height of 1.8 m above the ground

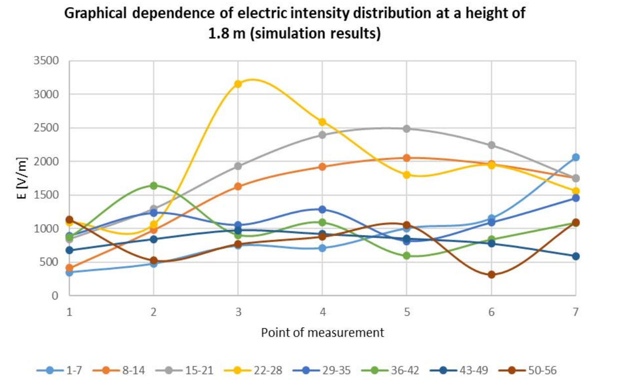


Fig. 10. Dependence of electric intensity distribution in particular sections at a height of 1.8 m above the ground

The dependencies presented in graphs of electric intensity ***E*** at height of 1.8 m above ground are in Fig. 9 and Fig. 10. One can see that in the most part of this array the electric intensity ***E*** is the range from 313.71 V/m to 1 282.5 V/m. However, in the investigated section 22-28, the value rapidly increased at the investigated point 3 to value of 3 152.4 V/m. Such an increase was caused due to an alternation in phase conductor height. The conductor (phase line) passes through the switcher that is placed vertically. Hence, the outgoing conductor from the switcher is located approximately 1.2 m lower than the input conductor. Such a lowering of conductor height and increasing of measurement height caused an increase of the electric field intensity ***E***. In the other two investigated sections, 8-14 and 15-21, a similar behavior of electric field intensity distribution can be seen. These increases were caused by crossing power-lines from the supplying power-line and conductors in the array. So, there are two power sources that are the source of the electric field and for this reason these values are as well higher than the remaining values.

IV. Results Evaluation from Simulation

It could be noted, that the results obtained from the simulation were compared to results obtained from the measurement from the identical HV substation and also with national legislation mentioned in Decree no. 534/2007 Coll. (for residents) and in regulation no. 209/2016 Coll. (for employees).

Magnetic field results

TABLE II. Evaluation of Magnetic Induction Value by Measurement/Simulation with National Legislation

	Maximum measured / simulated value	Action value for employees (209/2016 Coll.)	Action value for residents (534/2007 Coll.)
B (μT) (0,3 m above ground)	12.8 / 78.156	1 000	100
B (μT) (1 m above ground)	13 / 59.154	1 000	100
B (μT) (1,8 m above ground)	14.81 / 53.792	1 000	100

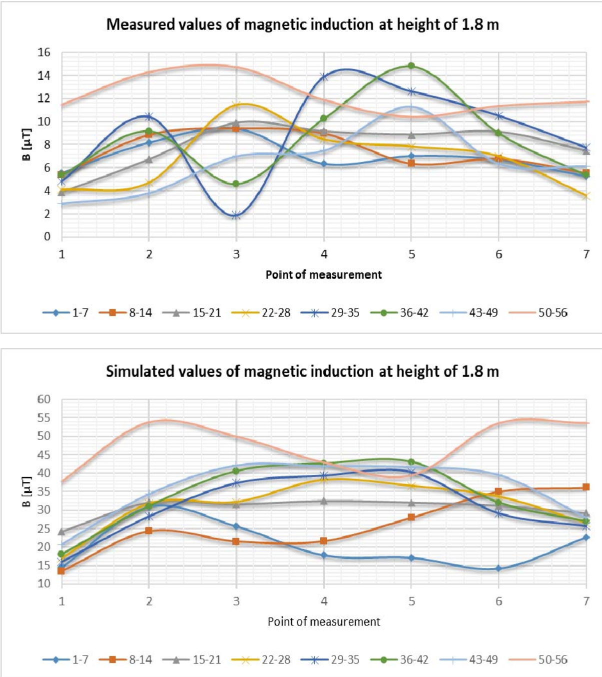
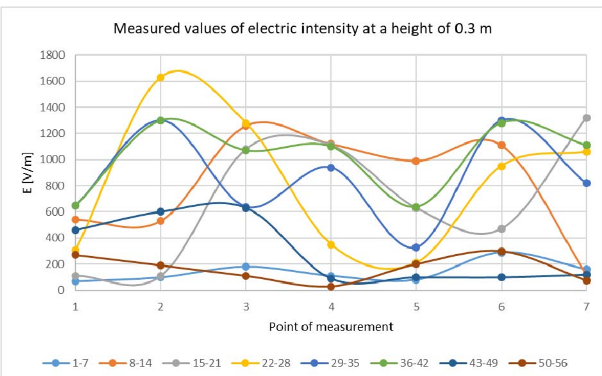


Fig. 11. Magnetic induction *B* obtained by measurement and simulation at a height of 1.8 m above the ground

Electric field results

TABLE III. Evaluation of Electric Intensity Value Obtained by Measurement/Simulation with National Legislation

	Maximum measured / simulated value	Action value for employees (209/2016 Coll.)	Action value for residents (534/2007 Coll.)
E (V/m) (0,3 m above ground)	1630 / 1 802.7	10 000	5 000
E (V/m) (1 m above ground)	NA / 2 214.2	10 000	5 000
E (V/m) (1,8 m above ground)	NA / 3 152.4	10 000	5 000



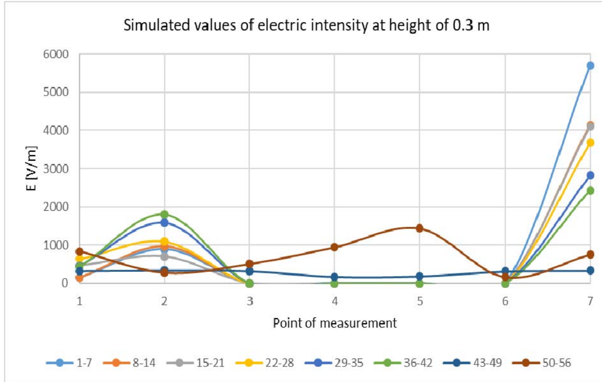


Fig. 12. Electric intensity *E* obtained by measurement and simulation at a height of 0.3 m above the ground

V. Conclusion

The purpose of this article was to present the results of the analysis of the distribution of the electromagnetic field inside the HV 110 kV substation. The results of computer simulation of electromagnetic field distribution in 110 kV electrical substation are described in this paper. The results of simulations and measurements were compared with the action values mentioned in Decree of the Ministry of Health of the Slovak Republic no. 534/2007 Coll. (for residents) and government regulation 209/2016 Coll. (lower electric field intensity action values (RMS) were considered and compared in this case. For employees.), where are introduced exposure limit values and exposure action values for electromagnetic fields. The results show, that the exposure limits were not excessed, but these limits could be examined again in particular human entering the place of EMF appearance. Other standards that are relevant for dealing with electromagnetic field are for example STN EN 50499; STN EN 50647; STN EN 62110.

Acknowledgment

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