ТЕСЛИНИ ИНОВАЦИОНИ ДАНИ
TESLA INNOVATION DAYS
Belgrade, Serbia, April 7 - 8, 2025

DOI: 10.5937/TID25033G

ANALYSIS OF MAGNETIC FIELD LEVELS IN THE VICINITY OF THE TRANSMISSION POWER LINE TOWER AT THE LOCATION OF TRANSITION FROM OVERHEAD TO CABLE SECTION

Maja Grbić*, Dejan Hrvić, Katarina Maksić, Dragana Tomašević

Nikola Tesla Institute of Electrical Engineering, University of Belgrade, Republic of Serbia
* *maja@ieent.org*

Abstract

The paper analyses the levels of electromagnetic field in the vicinity of a 110 kV mixed transmission line tower, at the transition point between the overhead and underground sections. The aim of the research is to quantify the electromagnetic field levels near this tower and to compare them with the field levels on the overhead and underground cable sections of the line. The research encompasses two complementary approaches – field measurements and numerical modelling. The measurements of electromagnetic field were conducted under real conditions in the vicinity of the aforementioned tower, using appropriate measuring equipment. In addition to measurements, electromagnetic field calculations, based on power line modelling, are performed using specialized software. Simulations will provide a detailed insight into the spatial distribution of the electromagnetic field and enable comparisons with experimentally obtained results. The obtained results will provide an understanding of the differences in electromagnetic field levels around the tower compared to the levels in the overhead and underground cable sections of the transmission line. These results will be analysed in the context of current regulations regarding the protection of the general public from non-ionizing radiation. Besides analysing electromagnetic field levels, the paper also proposes measures to reduce the field levels around such towers and emphasizes the importance of proper planning and design of transmission lines to minimize the negative impacts of the electromagnetic field on the environment. The conclusions of the paper provide specific information on the characteristics of the electromagnetic field in the particular conditions of transition from an overhead to an underground cable section of the transmission line. They contribute to further research and the development of methods for reducing electromagnetic field in the vicinity of power lines.

Keywords: electromagnetic field, non-ionizing radiation, magnetic flux density, mixed transmission line, transmission power line.

1 Introduction

The paper is related to the topic of the protection of general public from non-ionizing radiation, i.e. low frequency electromagnetic field originating from the mixed transmission power line. The topic related to the influence of electromagnetic fields originating from power facilities and lines as well as possible mitigation techniques was analysed by several working groups [1–4]. Due to their length and proximity to residential areas, transmission lines are one of the most important sources of low frequency electromagnetic field in the environment. Knowing the levels of electric and magnetic fields in the vicinity of power lines is of great importance for planning the construction of new power lines near residential areas as well as for the construction of residential and other buildings near existing power lines. The levels of electric field strength and magnetic flux density in the vicinity of power lines have to be in compliance with the reference levels prescribed by international [5–7] and national [8–10] legislation. The levels of electric and magnetic fields near power lines are obtained by measurements and calculations. Measurements are carried out in accordance with the relevant standards [10–13], while calculations can be based on various methods. Different methods for the calculations of electric field strength and magnetic flux density are presented in [13–19]. The calculations in this paper are carried out using specialized software [20, 21]. The model used for calculations has to be previously verified in order to obtain reliable results which will be used for the assessment of compliance with the prescribed reference levels. The model can be verified by comparing the results with the results obtained by another software or by measurements. In this paper the method based on comparison with the measurement results was used.

The analysis in this paper is focused on the field levels near the 110 kV mixed transmission power line tower at the location of transition from overhead to cable section. In order to compare the results, the following three areas are analysed: 1) location at the overhead section of the line, 2) location at the cable section of the line and 3) location next to the tower where the

cables are descending to the ground. Since the results of electric field strength are relevant only for the overhead section of the line, the analysis is focused on magnetic field.

2 Legislation on protection from non-ionizing radiation

On the international level the reference levels for the protection of the general public from non-ionizing radiation are prescribed by the Recommendation 1999/519/EC [6] and guidelines published by International Commission on Non-Ionizing Radiation Protection (ICNIRP). The reference levels of exposure of the general public to power frequency (50 Hz) magnetic flux density, prescribed by [6], is set to 100 μT. This reference level is equal to the reference prescribed by the ICNIRP guidelines from 1998 [5]. In the ICNIRP guidelines from 2010 [7] the reference levels for power frequency (50 Hz) magnetic flux density is 200 μT. The Republic of Serbia fulfilled the requirements of [6] in 2009 by adopting the Law on Protection from Non-Ionizing Radiation [8] and several rulebooks. According to the Rulebook on Limits of Exposure to Non-Ionizing Radiation from 2025 [9], the reference levels for power frequency magnetic flux density are 40 μT for increased sensitivity areas and 100 μT for public areas. The term "increased sensitivity area" refers to residential areas, schools, homes, preschools, hospitals, tourist facilities etc.

3 Analysed situation of the 110 kV mixed transmission power line

Figure 1 shows the tower of the 110 kV mixed transmission power line at the transition point between the overhead and underground sections. Figures 2 and 3 show part of the tower where cable enters the ground. From the front, the cable is covered with a protective sheet, while from the back, direct access is possible.



Figure 1. The tower at the transition point between the overhead and underground sections



a) b)

Figure 2. Cables descending into the ground, shown from the front side (a) and from the back (b)

Figure 3 shows the location of the tower as well as four profiles (P_1–P_4) along which the calculations were carried out. The locations of the profiles are as follows:
P_1 – 20 cm from the center of the cable, inside the tower;
P_2 – 20 cm from the center of the side conductor of the cable line;
P_3 – away from the tower, above the route of the underground section of the cable, approximately perpendicular to the cable line route;
P_4 – away from the tower, perpendicular to the axis of the transmission line.

The profiles P_1 and P_2 are positioned next to the tower in order to analyse the influence of the cable descending to the ground. The profile P_3 is positioned away from the tower, above the route of the underground section of the cable, in order to analyse the contribution of that section only. The profile P_4 is also positioned away from the tower, below the overhead section of the line, in order to determine the contribution of the overhead section only. The profiles P_1–P_4 are located at the 1 m height above the ground, in accordance with the requirements of the standards [12, 13].

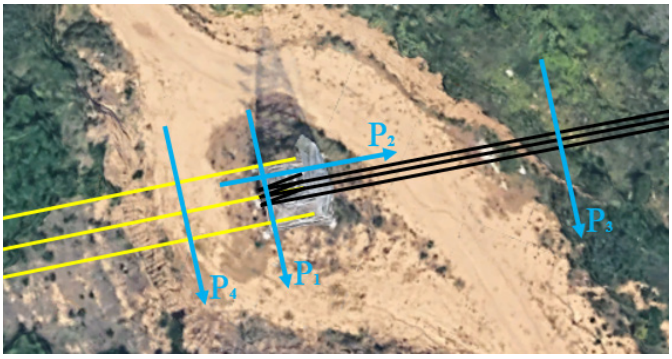


Figure 3. The location where the testing was conducted, showing the routes of the overhead and underground routes of the line, as well as the positions of the profiles

4 Results of magnetic field measurements and calculations

The analysis of the magnetic field levels is based on magnetic flux density measurements and calculations.

Measurements are carried out in accordance with the requirements of the standards [10–13]. During the testing, the rms values of magnetic flux density were measured isotropically, using magnetic field analyser connected to the isotropic probe for magnetic field measurements. The measuring system fulfils the requirements of the standard [11].

The calculations are carried out using specialized software [20, 21], based on Partial Element Equivalent Circuit (PEEC) method.

Figure 4 shows the geometry of the phase conductors and ground wire at the overhead section of the line next to the tower.

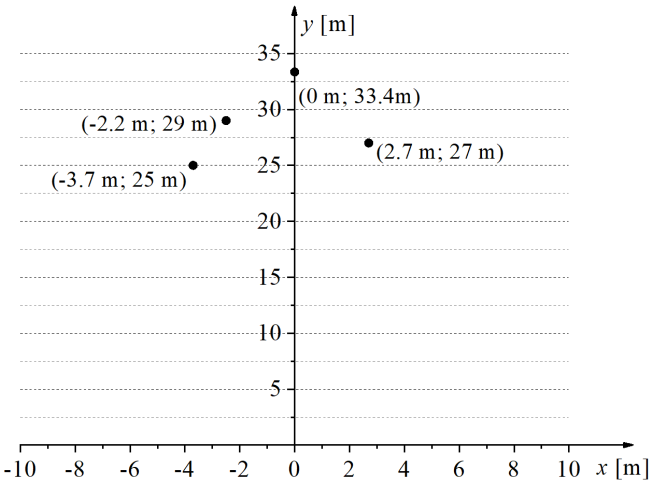


Figure 4. Geometry of the line near the tower

The type of the cable line is 3 x (XLPE 300/95 mm^2) and its maximum current is 481 A. The type of the phase conductors at the overhead section is ACSR 240/40 mm^2. Its maximum current in the winter period is 880 A. Since the maximum current of the entire power line is limited on 481 A the calculations are carried out for this value.

The magnetic flux density measurements are carried out at the profiles P_1 and P_4. During the measurements the power line current was I_m = 107 A. The magnetic flux density calculations are carried out along the profiles P_1–P_4 for the power line current at the time of measurements (I_m = 107 A) and for the maximum power line current (I_{max} = 481 A). The obtained results are presented in Figures 5–8.

Figures 9 and 10 show the magnetic flux density results obtained by calculations at the planes located near the tower at the height of 1 m above the ground. The dimensions of the planes are 2 m x 1 m. The calculations were made for the maximum current intensity.

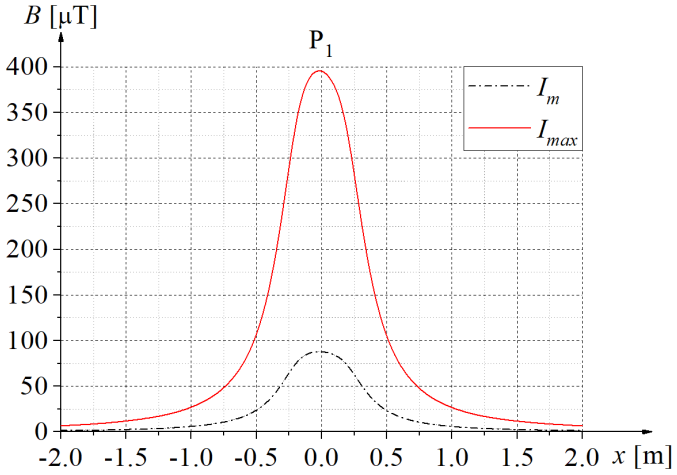


Figure 5. Magnetic flux density values obtained by calculations along the profile P_1 for maximum current (481 A) and the current during measurements (107 A)

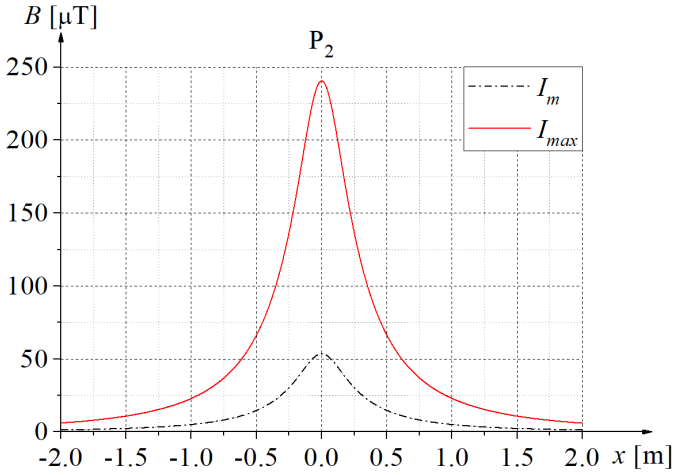


Figure 6. Magnetic flux density values obtained by calculations along the profile P_2 for maximum current (481 A) and the current during measurements (107 A)

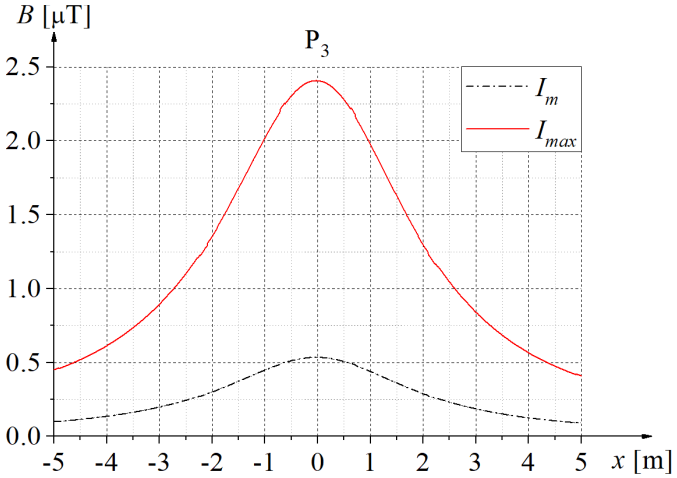


Figure 7. Magnetic flux density values obtained by calculations along the profile P_3 for maximum current (481 A) and the current during measurements (107 A)

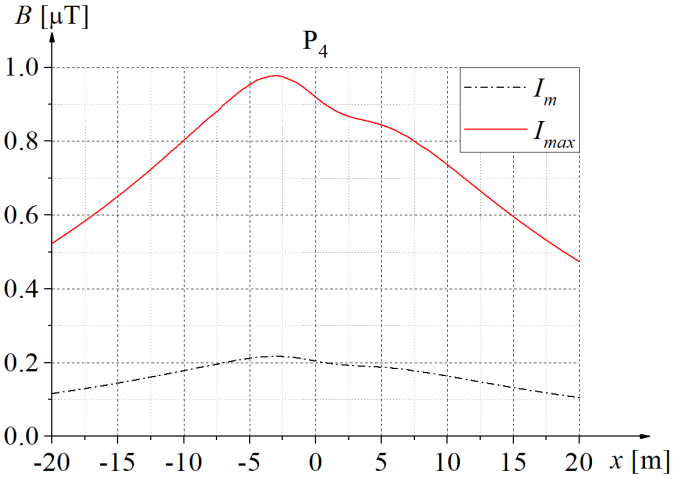


Figure 8. Magnetic flux density values obtained by calculations along the profile P_4 for maximum current (481 A) and the current during measurements (107 A)

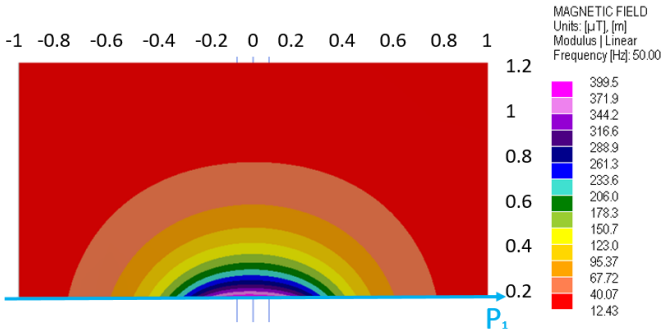


Figure 9. Values of magnetic flux density obtained by calculations on the plane located at the height of 1 m above the ground, on the back of the cable

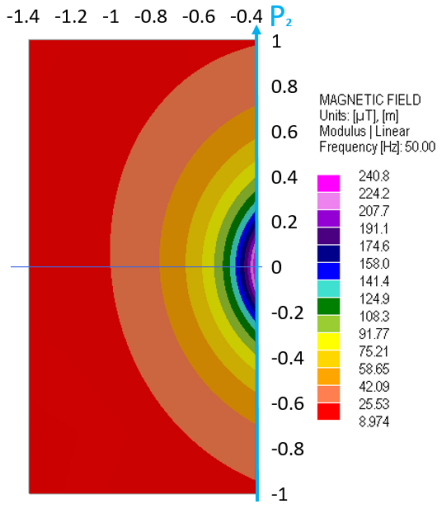


Figure 10. Values of magnetic flux density obtained by calculations on the plane located at the height of 1 m above the ground, on the side of the cable

Table 1 shows the maximum values of magnetic flux density along different profiles obtained by measurements and calculations for the current present at the time of measurements.

Table 1. Maximum magnetic flux density values (B_m) obtained for I_m = 107 A

I_m = 107 A	Maximum values of magnetic flux density [μT]			
	P_1	P_2	P_3	P_4
Measurements	88	/	/	0.26
Calculations	89	55	0.55	0.22

From the results given in Table 1 it can be concluded that there is an agreement between the results obtained by measurements and calculations along the profiles P_1 and P_4. Since the power line model used for calculations is verified it can be used for calculating maximum values of magnetic flux density which occur in the case when the power line current is equal to the maximum current.

Table 4 shows the maximum values of magnetic flux density along different profiles obtained by calculations for the power line maximum current.

Table 2. Maximum magnetic flux density values (B_{max}) obtained for I_{max} = 481 A

I_{max} = 481 A	Maximum values of magnetic flux density [μT]			
	P_1	P_2	P_3	P_4
Calculations	399.5	240.8	2.45	0.99

From the presented results it can be concluded that the highest values of magnetic flux density are obtained along the profiles P_1 and P_2, which are located near the tower, i.e. next to location where the cable enters the ground. These results are obtained due to the proximity of the profiles to the cable. The results obtained at profiles P_1 and P_2 for the maximum current exceed the reference level of 100 μT prescribed by [9] for public areas as well as by [5, 6]. These results also exceed the reference level of 200 μT prescribed by [7]. The results obtained along the profiles P_3 (underground cable section) and P_4 (overhead section) are significantly lower compared to the results along the profiles P_1 and P_2. The results obtained along the profiles P_3 and P_4 are significantly lower than the reference levels of 100 μT and 200 μT even in the case of the maximum power line current. The lowest values of magnetic flux density are obtained along the profile P_4 which correspond to the overhead section.

The levels of magnetic field in the vicinity of the tower, i.e. near the cable can be reduced by placing a conductive shield around it [22]. Another possibility is to place a fence around the tower at a certain distance in order to prevent the population from getting close to the cable and entering the area where the magnetic field values exceed the prescribed reference levels.

5 Conclusion

The levels of magnetic field which occur in the vicinity of the 110 kV mixed transmission power line are analysed in the paper. The results show that significantly higher values are obtained at the location next to the tower where the cables are

descending to the ground compared to the values obtained at the overhead section and underground cable section of the power line. The values obtained at the location where the cables enter the ground, at the distance of 20 cm from the cables, can exceed the reference levels prescribed by [5, 6, 9]. These magnetic field levels can be reduced by applying the shielding system, i.e. placing the conductive shield around the cables. Another possibility is to place a fence around the cable to prevent the population from entering the area with high magnetic field values.

6 Acknowledgements

This work was supported in part by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia under the Contract on the realization and financing of the scientific research work of research and innovation organizations in 2025.

7 References

[1] Technical guide for measurement of low frequency electric and magnetic fields near overhead power lines, CIGRE Working Group C4.203, 2009.

[2] Mitigation techniques of power frequency magnetic fields originated from electric power systems, CIGRE Working Group C4.204, 2009.

[3] Characterisation of ELF magnetic fields, CIGRE Working Group C4.205, 2007.

[4] Responsible management of electric and magnetic fields, CIGRE Working Group C3.19, 2020.

[5] International Commission on Non-Ionizing Radiation Protection, "ICNIRP guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz)", Health Phys., vol. 74, No. 4, 1998, pp. 494–522.

[6] 1999/519/EC: "Council Recommendation of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz)", OJ L, L 199, 1999, pp. 59–70.

[7] International Commission on Non-Ionizing Radiation Protection, "ICNIRP guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz – 100 kHz)", Health Phys., vol. 99, no. 6, 2010, pp. 818–836.

[8] "Law on protection from non-ionizing radiation", Official Gazette of Republic of Serbia No. 36/09, May 15, 2009.

[9] "Rulebook on limits of exposure to non-ionizing radiation", Official Gazette of Republic of Serbia No. 16, February 26, 2025.

[10] EN 50413: "Basic standard on measurement and calculation procedures for human exposure to electric, magnetic and electromagnetic fields (0 Hz – 300 GHz)", 2019.

[11] IEC 61786: "Measurement of DC magnetic, AC magnetic and AC electric fields from 1 Hz to 100 kHz with regard to exposure of human beings – Part 1: Requirements for measuring instruments", 2013.

[12] IEC 61786: "Measurement of DC magnetic, AC magnetic and AC electric fields from 1 Hz to 100 kHz with regard to exposure of human beings – Part 2: Basic standard for measurements", 2014.

[13] EN 62110: "Electric and magnetic field levels generated by AC power systems – Measurement procedures with regard to public exposure", 2009.

[14] Power lines: Demonstrating compliance with EMF public exposure guidelines: A voluntary code of practice. Government of the UK, Department of Energy & Climate Change, London, UK, 2012.

[15] Turajlić, E., Mujezinović, A., Alihodžić, A.: "A novel method based on PSO algorithm and ANN for magnetic flux density estimation near overhead transmission lines", J. Electr. Eng., 2024, vol. 74, pp. 399-410.

[16] Alihodžić, A., Mujezinović, A., Turajlić, E.: "Artificial neural network-based method for overhead lines magnetic flux density estimation", J. Electr. Eng., 2024, vol. 75, pp. 181-191.

[17] Grbić, M., Pavlović, A.: "Determining the zone of influence of transmission overhead power lines from the aspect of non-ionizing radiation", Proc. of the 6th International RAD Conference, 2018, vol. 3, pp. 52–57.

[18] Grbić, M., Mikulović, J., Salamon, D.: "Influence of measurement uncertainty of overhead power line conductor heights on electric and magnetic field calculation results", Int. J. Electr. Power Energy Syst., (2018), 2017, vol. 98, pp. 167–175.

[19] Grbić, M., Salamon, D., Mikulović, J.: "Analysis of influence of measuring voltage transformer ratio error on single-circuit overhead power line electric field calculation results", Electr. Power Syst. Res., 2018, vol. 166, pp. 232–240.

[20] XGSLab User's Guide, SINT Ingegneria Srl, 2025.

[21] XGSLab Tutorial XGSA_FD, SINT Ingegneria Srl, 2025.

[22] Grbić, M., Canova, A., Giaccone, L., Pavlović, A., Grasso, S.: "Mitigation of low frequency magnetic field emitted by 10/0.4 kV substation in the school", Int. J. Numer. Model.: Electron. Netw. Devices Fields.