sciendo

B&H Electrical Engineering, Volume 18, Issue 1, 2024:31-39
ISSN:2566-3143, eISSN:2566-3151, DOI: 10.2478/bhee-2024-0004

Original scientific paper

Submitted: May 20, 2024

Accepted: June 4, 2024

EVALUATION OF THE LONG-TERM EXPOSURE TO THE MAGNETIC FIELDS GENERATED BY OVERHEAD TRANSMISSION LINES USING ARTIFICIAL NEURAL NETWORKS – A CASE STUDY

Ajdin Alihodžić[1,2], Adnan Mujezinović[1], Emir Turajlić[1], Maja Muftić Dedović[1], Nedis Dautbašić[1], Irfan Turković[1]

Abstract: The methodology for the evaluation of long-term exposure to the overhead line magnetic field is presented, in this paper. The developed methodology is based on the ambient temperature measurements and phase conductors' height measurements to find a linear regression model to determine phase conductors' height changes for different ambient temperatures. Based on the overhead transmission line geometry, and datasets about historical overhead line phase current intensity values and ambient temperatures long-term magnetic field exposure can be determined. For magnetic flux density determination, a method based on artificial neural networks is used. The methodology is applied to the case study of overhead line that connect substations Sarajevo 10 and Sarajevo 20. A period of one year is analyzed and magnetic flux density values are determined. The obtained results indicate that during the analyzed period for significant amounts of time magnetic flux density values surpass the recommended values for long-term exposure.

Keywords: magnetic field, long-term exposure, overhead transmission lines, artificial neural networks

INTRODUCTION

In modern society, there are numerous magnetic field sources, that can generate magnetic fields with a huge variety of frequencies and amplitudes. Following technological, economic, and scientific advancements and also the availability of information to the wide population significant concerns have arisen about the adverse effects of magnetic field exposure on living beings [1 - 6].

During the previous decades, numerous studies have been conducted to find the effects of magnetic field exposure on human health, as well as an exact mechanism of influence. Following the scientific findings, and principle of increased caution the reference magnetic field values are defined by numerous countries and international bodies [7 - 12].

Nevertheless, the exact mechanism of influence between the exposure to extremely low-frequency magnetic fields and the occurrence of health issues in human beings is not established, the scientific findings led to the classification of the extremely low frequency as possibly carcinogenic by The International Agency for Research on Cancer (IARC) [13]. However, the investigation of the influence of extremely low-frequency magnetic field exposure on living beings is still a popular research topic that attracts numerous researchers worldwide [14, 15].

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz to 100 kHz) provide a detailed overview of the epidemiological studies. As noted in the ICNIRP guidelines, studies are consistent with the findings that constant long-term exposure to the magnetic field is associated with the increased risk of occurrence of leukemia for children. The magnetic flux density level noted in the ICNIRP guidelines as relevant for consideration regarding long-term exposure is above 0.3-0.4 μT [7].

Since the overhead transmission lines are one of the major sources of extremely low-frequency magnetic fields, different methods for determination of the magnetic fields that can occur in their vicinity, have been proposed [16 - 24].

Following the relevant legislation regarding exposure to low-frequency magnetic fields, scientific findings about possible adverse effects of that exposure, the number and geographically widespread of overhead transmission lines, as well as the number of residents in their vicinity, exposure to the magnetic fields in the vicinity of overhead transmission lines is topic that has particular attention [25, 26].

[1] Faculty of Electrical Engineering University of Sarajevo, Bosnia and Herzegovina
[2] Correspondence email: ajdin.alihodzic@etf.unsa.ba
© 2024 Author(s). This is an open access article licensed under the Creative Commons Attribution License 4.0. (http://creativecommons.org/licenses/by/4.0/).

In [27], the authors proposed a hybrid method for the estimation of magnetic flux density distribution, temporal and spatial, under the overhead transmission lines based on the correlation between the data obtained through a magnetic flux density survey for several hours and simultaneously performed spot magnetic flux density measurements.

In [28], the author emphasizes the importance of analysis of the continuous exposure to the magnetic field generated by the overhead transmission lines providing a review of the main concepts and possible errors associated with these analyses based on the data on the overhead transmission line phase current intensity values. The paper [28], provides continuous magnetic field exposure evaluation utilizing the mean and median magnetic field values based on the historical data of the overhead transmission line phase current intensity values.

In [29], the authors presented the analysis of long-term exposure to magnetic field near high voltage overhead transmission lines, and increased cancer risk analysis in Slovenia. The authors [29], proposed a method based on the terrain data and mean phase current intensity values to calculate average long-term magnetic fields near overhead transmission lines.

Although the mean and the median values can provide information about the dataset under consideration, they still do not contain all the information that the entire data set carries. Therefore, for analyses of long-term exposure to magnetic fields of overhead lines, it is desirable to use specific values of the magnetic field at each moment of the considered interval.

Carrying out long-term measurements to determine the level of magnetic field exposure can be problematic in a few ways. First, it requires the consent of the property owners to install measuring equipment on their properties or inside objects, it also requires the equipment to stand for a period of several months or years and collect data, which can create significant logistical problems, etc.

This paper presents a methodology for long-term exposure assessment to the magnetic fields generated by overhead transmission lines. The proposed methodology enables the determination of the magnetic flux density values based on the overhead transmission line phase current intensity values and phase conductors' heights during the considered period.

The rest of the paper is organized as follows. Section 1 presents the methodology for long-term magnetic field exposure. A case study is presented in Section 2. The concluding remarks are given in Section 3.

1. METHODOLOGY FOR EVALUATION OF THE LONG-TERM EXPOSURE TO THE MAGNETIC FIELDS IN THE VICINITY OF OVERHEAD TRANSMISSION LINES

The magnetic flux density near overhead lines depends on their geometry, the phase current intensities, and the distance to the locations where its evaluation is performed. When it comes to the phase current intensities, they are characterized by strong fluctuations and unpredictability over time. However, modern systems for electric power systems supervision and management enable to have available data on the historical phase current intensity values of all individual overhead transmission lines. Furthermore, when it comes to the overhead line geometry, it is described by the horizontal distances between the phase conductors and shield wires, and their heights. For the magnetic flux density analysis, shield wires don't have any special influence [30], so they will not be considered in the rest of the paper. The horizontal positions of the phase conductors are determined by the overhead line tower head geometry and their changes over time are insignificant for magnetic flux density distribution analysis. On the other hand, the heights of the phase conductors can experience significant changes over time, due to various effects, and their changes should be considered when long-term exposure to magnetic fields in the vicinity of overhead lines analysis is performed.

The height of the phase conductors is influenced by various parameters, such as temperature, mechanical characteristics of the conductor, the length of the span between two adjacent towers, etc [31]. The influence of the conductor's temperature on the change of its height is significant. So, the largest sag, that is, the smallest height of the conductor is expected at the maximum conductor's temperature, or at the maximum additional weight that can be caused by the ice, wind, and the like. Very often, overhead lines have phase current intensity values significantly less than their rated currents. Also, in such situations, cooling is significantly more efficient than in the case of maximum phase current intensity values. Considering the previously mentioned, in situations where the overhead line has for a long period significantly smaller phase current intensity values than its maximum values, the conductor's temperature can be considered approximately equal to the ambient temperature [32].

In this paper, a methodology for the evaluation of long-term exposure to the magnetic fields, that considers overhead line phase conductors' height and phase current intensity changes over time is proposed.

One of the characteristics of the 400 kV transmission network in Bosnia and Herzegovina is that it has been underloaded, with overhead lines' phase current intensities that are significantly lower than the rated ones, continuously for the last decade. The phase current intensity changes for the overhead line substation (SS)

B&H Electrical Engineering, Volume 18, Issue 1, 2024:31-39
ISSN:2566-3143, eISSN:2566-3151, DOI: 10.2478/bhee-2024-0004

Sarajevo 10 - SS Sarajevo 20 during 2020 are shown in Figure 1. From Figure 1 it can be observed that during the entire considered period, the values of the phase current intensity were less than 400 A.

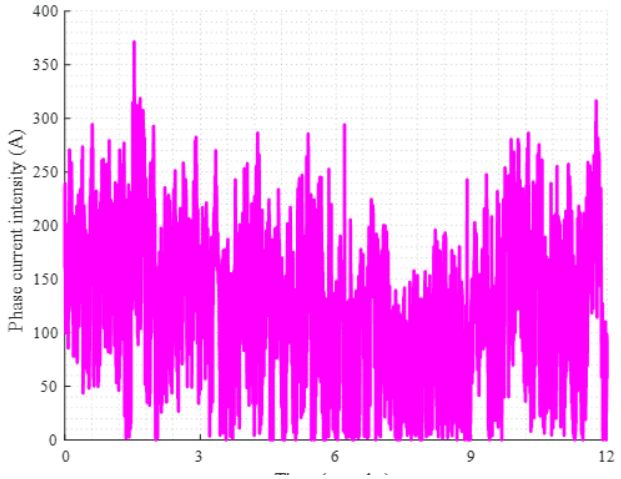


Figure 1: Phase current intensity changes during the year 2020 for SS Sarajevo 10 – SS Sarajevo 20 overhead transmission line [30]

To consider changes in the conductors' height over time, a linear regression model was implemented, that gives the relationship between the ambient temperature and the height of the phase conductor. This model was developed based on actual measurements of the phase conductors' heights and the ambient temperature for one 400 kV overhead transmission line. Although such a model introduces certain errors, it nevertheless allows one to consider the phase conductor's height change over time.

The phase conductors' height change measurements are made for overhead transmission line SS Sarajevo 10 - SS Sarajevo 20. The transmission network of a rated voltage of 400 kV in Bosnia and Herzegovina consists of 15 overhead lines with horizontal configuration of phase conductors. The tower head geometry of all transmission lines is designed so that all three phase conductors are at the same height as each other. All phase conductors are made as conductors in a bundle with two sub-conductors. A typical sub-conductor used in the 400 kV transmission network in Bosnia and Herzegovina is the ACSR Al/Fe 490/65 mm^2 conductor. Measurements of the phase conductors' heights were made at the center of the span between two adjacent towers, at the point where the sag is the largest, i.e. the conductors are closest to the ground. To measure the height of the phase conductors, an instrument that uses ultrasound, Suparule model 600, was utilized. Measurements were made during one day with hourly time intervals. Simultaneously with the measurement of the phase conductors' heights, measurements of the ambient temperature were also performed. Although there are certain deviations between the measured heights of individual phase conductors in the middle of the span, they will be considered identical in further consideration. Phase conductors' height changes in dependence on the ambient temperature obtained, by measurements, are shown in Figure 2.

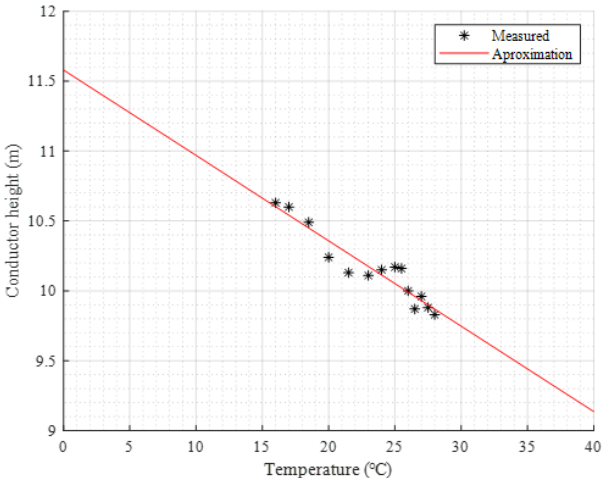


Figure 2: Conductor height changes in dependence on ambient temperature

Based on the measured values of conductor height and ambient temperature, a linear regression model was developed, and the change in conductor height in dependence on temperature can be described by the following equation:

$$h(T) = -0.0611 \cdot T + 11.5799 \quad (1)$$

where h is phase conductor height (m), and T is ambient temperature (°C).

When the data on the phase current intensities during the considered period are known, the calculation of the magnetic flux density can be done. The method proposed in [33] was used to determine the magnetic flux density distribution. The applied method uses artificial neural networks to estimate the magnetic flux density in the vicinity of multi-circuit overhead lines. Since single-circuit overhead lines are a simpler case, the method [33] provides accurate results when applied to them. The used method [33], enables a simple and fast determination of the magnetic flux density at points of the lateral profile up to 100 m away from the overhead line axis on both sides. As input data, the horizontal coordinates of the phase conductors, taken from the towers' design documentation, and the phase conductors' height values determined based on historical ambient temperature data, are used. Also, phase current intensity changes during the considered period are used as input parameters. As a result, the magnetic flux density values are obtained, at points at a height of 1 m above the ground surface, and a specified

distance from the overhead line axis. The height of the calculation points was chosen in accordance with the provisions of the relevant standards that regulate this topic [34 - 36].

Once the magnetic flux density calculation at the locations of interest is made, the evaluation of long-term exposure to the extremely low-frequency magnetic field can be undertaken.



Figure 3: One part of the SS Sarajevo 10 – SS Sarajevo 20 overhead transmission line route

As it can be noted from Figure 3 a significant number of residential and business facilities are built in the vicinity of the considered overhead transmission line's route. Furthermore, a popular recreation area is also in its immediate vicinity.

However, the problem of objects in the vicinity of the overhead transmission line is much more significant than it seems at first glance. Not only the objects are in the vicinity of the overhead transmission line route, but many of them are built inside the overhead transmission line's right-of-way. The rulebook on safety zones of overhead power lines with a nominal voltage of 110 kV to 400 kV (issued by the State Electricity Regulatory Commission of Bosnia and Herzegovina) prescribes that right-of-way for 400 kV overhead lines is 40 m, on both sides starting from overhead line's axis [38].



Figure 4: Objects in the considered overhead transmission line right-of-way – case I



Figure 5: Objects in the considered overhead transmission line right-of-way – case II

The information presented in Figures 3, 4, and 5 speaks in favor of the importance of long-term exposure analysis to magnetic fields for the SS Sarajevo 10 - SS Sarajevo 20 overhead line, considered here.

B&H Electrical Engineering, Volume 18, Issue 1, 2024:31-39
ISSN:2566-3143, eISSN:2566-3151, DOI: 10.2478/bhee-2024-0004

One location near the overhead line was considered, specifically the location where the measurements of the phase conductors' height were made, and the magnetic flux density was calculated. The calculations are made based on the data on the overhead line phase current intensity values and the change of phase conductors' height during 2020. The overhead line phase current intensity values were obtained based on the information recorded on the SCADA system and shown in Figure 1. The authors had available data on the phase current intensity values for each hour during 2020. In the case of the availability of phase current intensity values for smaller time intervals than one hour, the proposed methodology can be applied analogously.

For the case of the highest phase current intensity value during the analyzed period, magnetic flux density distribution during the lateral profile over the entire right-of-way is calculated. For the analyzed period, the highest recorded phase current intensity value was 371.35 A. Furthermore, for the exact hour, the phase conductor heights are determined based on the ambient temperature. The positions of phase conductors in the considered case are shown in Figure 6.

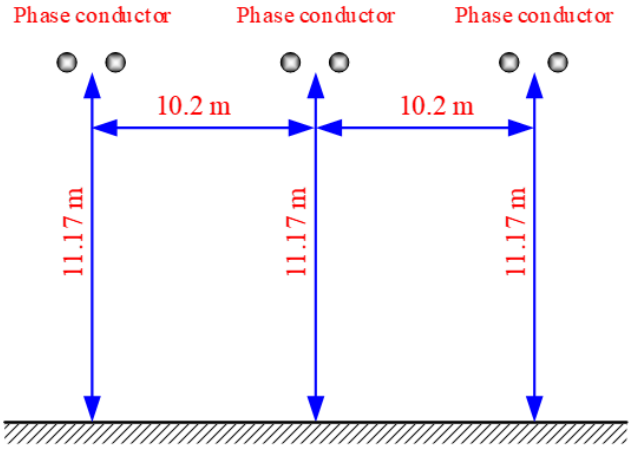


Figure 6: Overhead line phase conductor positions

The obtained magnetic flux density distribution over the right-of-way is shown in Figure 7.

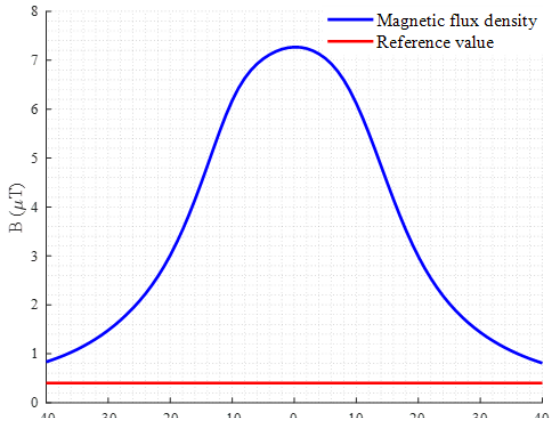


Figure 7: Magnetic flux density distribution over the right-of-way

Based on the results shown in Figure 7, it can be concluded that the magnetic flux density values over the entire right-of-way are higher than the recommended reference value relevant for the magnetic flux density long-term exposure, indicated by the red line in Figure 7. However, on the other hand, these values are significantly lower than the values recommended by ICNIRP for cases when the effects of long-term exposure are not considered (200 μT for general public exposure). Based on such considerations, conducting several individual analyses without taking long-term exposure into account, it could be concluded that the magnetic flux density values are satisfactory, while the analysis of long-term exposure could lead to the opposite conclusion.

Temperature changes during a period of 12 months, during the year 2020, were obtained from a meteorological station, which is located not far away from the considered location near the overhead transmission line. The meteorological station performs continuous automated measurement and storage of temperature values in time intervals of 10 minutes. Obtained temperature changes are averaged for every hour, to be compatible with current intensity changes, as shown in Figure 8.

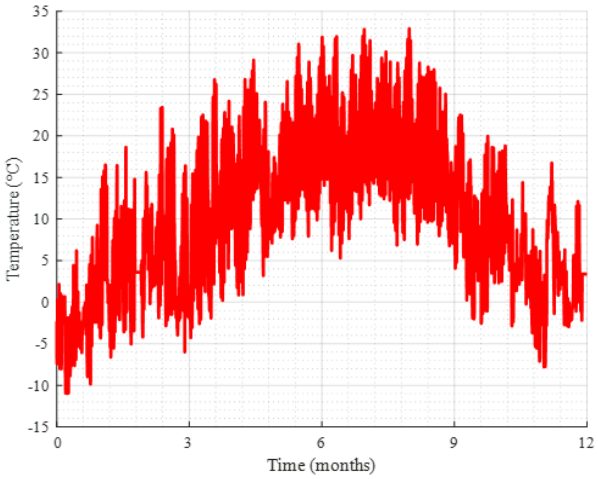
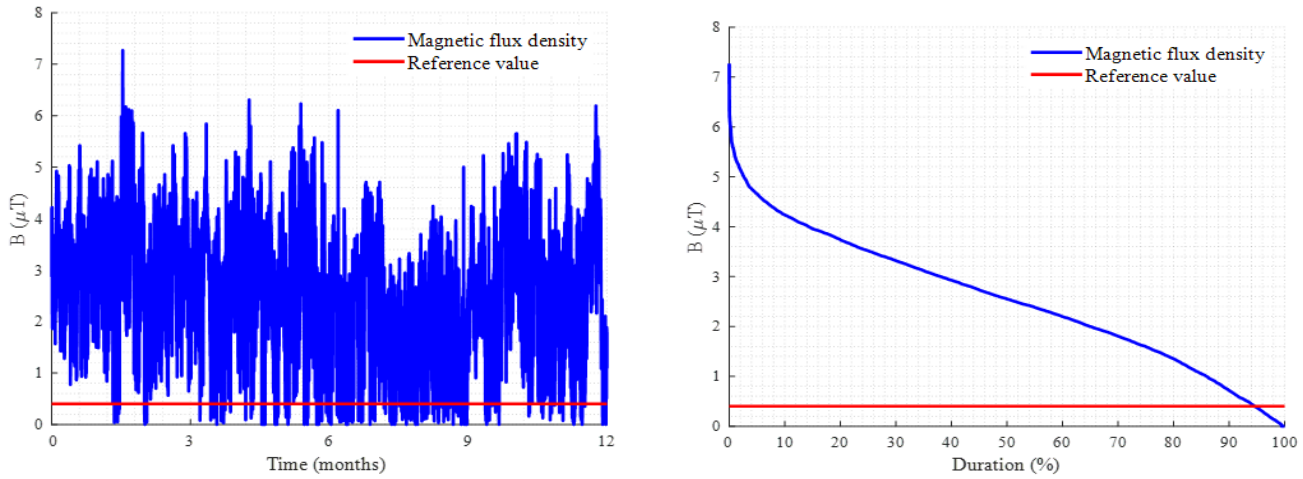


Figure 8: Temperature changes during the considered year at the location of interest

Based on the temperature changes shown in Figure 8, by applying equation (1), the phase conductors' heights for each hour in the considered period of 12 months were determined. Furthermore, using the thus determined phase conductors' heights, and the data on the phase current intensities during the considered period, calculations of the magnetic flux density were made.

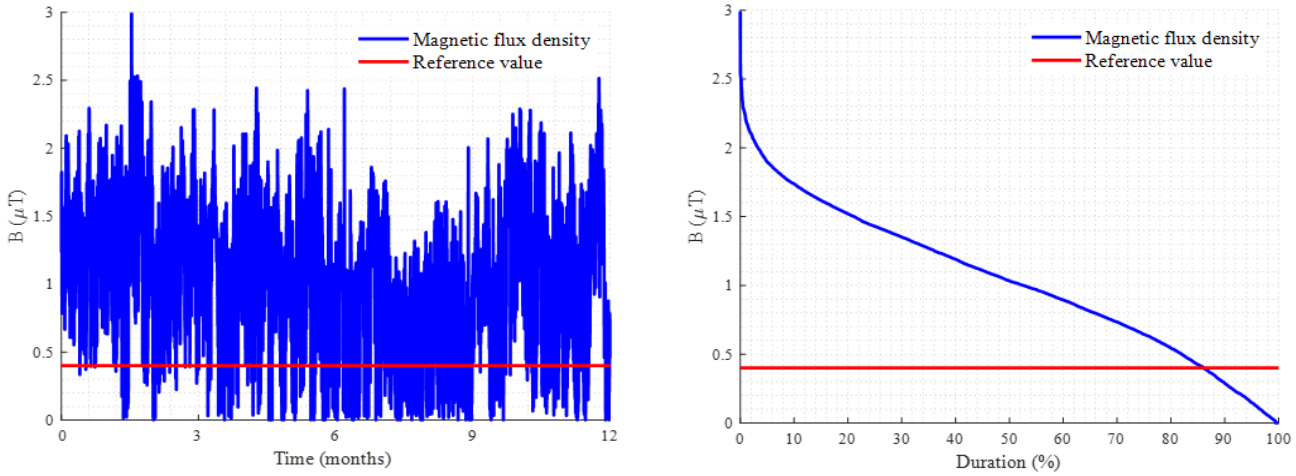
Magnetic flux density is determined for points within the right-of-way at different distances from its center, and the results are shown in Figures 9, 10, and 11. Figures 9a, 10a, and 11a show the magnetic flux density variations over time at the points immediately below the overhead line axis (right-of-way center) and points 20 m and 40 m away from it (right-of-way end), respectively



a) Magnetic flux density variations during time

b) Magnetic flux density duration

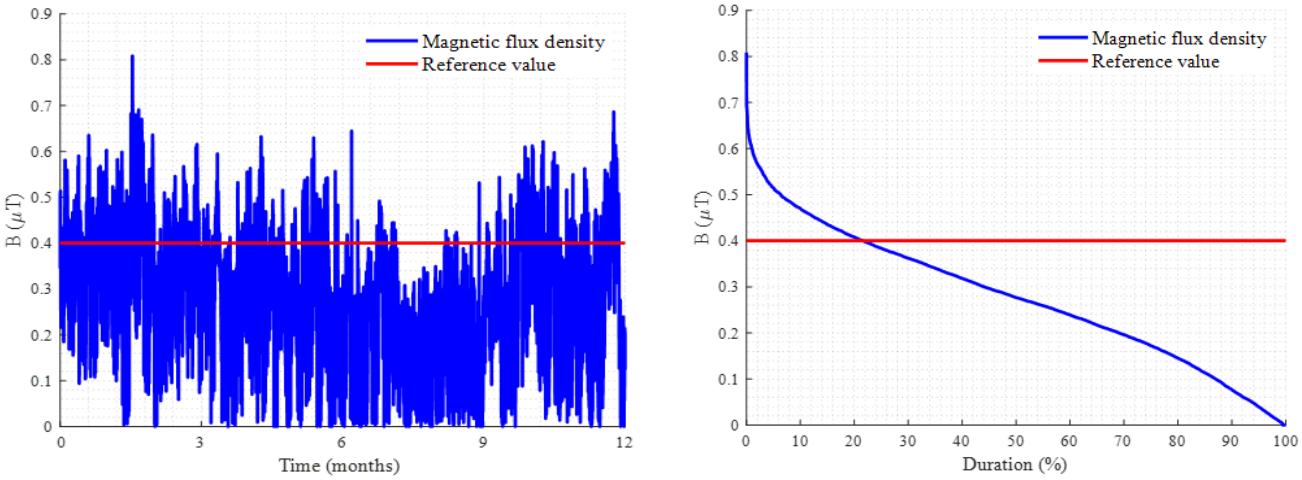
Figure 9: Magnetic flux density at the center of the right-of-way during the analyzed period



a) Magnetic flux density variations during time

b) Magnetic flux density duration

Figure 10: Magnetic flux density at the distance 20 m from the right-of-way center during the analyzed period



a) Magnetic flux density variations during time

b) Magnetic flux density duration

Figure 11: Magnetic flux density at the distance 40 m from the right-of-way center during the analyzed period

B&H Electrical Engineering, Volume 18, Issue 1, 2024:31-39
ISSN:2566-3143, eISSN:2566-3151, DOI: 10.2478/bhee-2024-0004

Furthermore, Figures 9b, 10b, and 11b show the duration curves for the magnetic flux density during the year 2020 at the considered points. In all considered Figures, the magnetic flux density reference value for long-term exposure analyses, according to ICNIRP [7], is marked in red.

As it can be noted from Figures 9b, 10b, and 11b more than 90%, 80%, and 20%, respectively, of time during the analyzed period the values of the magnetic flux density at the considered locations inside the right-of-way were higher than the reference value. The obtained results indicate that people with residence or professional activities within the objects inside the right-of-way are exposed to the significant risk of negative effects associated with long-term magnetic field exposure.

2. CONCLUSION

In this paper, a methodology for the analysis of long-term exposure to the magnetic fields generated by overhead lines is proposed. The presented methodology is based on the data on overhead line phase current intensity values during the considered periods. Measurements of the phase conductors' heights and the ambient temperature are also used to form a model for phase conductors' height estimation in dependence on the ambient temperature changes. For the case of the overhead line SS Sarajevo 10 - SS Sarajevo 20, a long-term exposure analysis was performed based on data on its phase current intensity values and ambient temperature recorded during 2020. To determine the magnetic flux density values at different points within the overhead line right-of-way, a method based on artificial neural networks was applied. The obtained results show that individuals who have resided for a long period of time either because of residence or work in objects within the right-of-way of the analyzed overhead line were exposed to magnetic flux density values higher than the reference value, for a long period of time. The analysis carried out within this paper indicates the importance of considering long-term exposure to magnetic fields generated by overhead lines. Considering the population that resides for a long time in the immediate vicinity of the considered overhead transmission line, it would be significant to conduct an epidemiological study on this topic in the future.

ACKNOWLEDGMENT

This research was supported by the Ministry of Education and Science of the Federation of Bosnia and Herzegovina under the grant: 05-35-2496-1/23.

REFERENCES

[1] M. Bonato, E. Chiaramello, M. Parazzini, P. Gajšek, and P. Ravazzani, "Extremely Low Frequency Electric and Magnetic Fields Exposure: Survey of Recent Findings," in IEEE Journal of Electromagnetics, RF and Microwaves in Medicine and Biology, vol. 7, no. 3, 2023, pp. 216-228.

[2] L. Kheifets, A. Ahlbom, C.M. Crespi, G. Draper, J. Hagihara, R.M. Lowenthal, G. Mezei, S. Oksuzyan, J. Schüz, J. Swanson, et al. "Pooled analysis of recent studies on magnetic fields and childhood leukaemia", British Journal of Cancer, 103, 2010, 1128–1135.

[3] Bunch, K.J.; Keegan, T.J.; Swanson, J.; Vincent, T.J.; Murphy, M.F.G. "Residential distance at birth from overhead high-voltage powerlines: Childhood cancer risk in Britain 1962–2008", British Journal of Cancer, 110, 2014, 1402–1408.

[4] S. Greenland, AR. Sheppard, WT. Kaune, C. Poole, MA. Kelsh, "A pooled analysis of magnetic fields, wire codes, and childhood leukemia", Childhood Leukemia-EMF Study Group. Epidemiology,11(6), 2000, 624-634.

[5] C.M. Crespi, X.P. Vergara, C. Hooper, S. Oksuzyan, S. Wu, M. Cockburn, L.; Kheifets, "Childhood leukaemia and distance from power lines in California: A population-based case-control study", British Journal of Cancer, 115, 2016, 122–128.

[6] G. Draper, T. Vincent, ME. Kroll, J. Swanson, "Childhood cancer in relation to distance from high voltage power lines in England and Wales: A case-control study", BMJ 2005, 330.

[7] J. Lin, R. Saunders, K. Schulmeister, P. Söderberg, B. Stuck, A. Swerdlow, et al., "ICNIRP guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz to 100 kHz)", 2010, Health Phys., vol. 99, no. 6, pp. 818-836.

[8] "IEEE Standard for Safety Levels with Respect to Human Exposure to Electric Magnetic and Electromagnetic Fields 0 Hz to 300 GHz", IEEE Std C95.1-2019 (Revision of IEEE Std C95.1-2005/ Incorporates IEEE Std C95.1-2019/Cor 1-2019), 2019, pp. 1-312.

[9] European Parliament, "Directive 2013/35/EU of the European Parliament and of the council of 26 june 2013 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields)(20th individual Directive within the meaning of Article 16 (1) of Directive 89/391/EEC) and repealing Directive 2004/40/EC," Official Journal of the European Union L, vol. 179, 2013.

[10] Directive European Council, "Council Recommendation of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz) 1999/519."

[11] R. Stam, "Comparison of international policies on electromagnetic fields:(power frequency and radiofrequency fields)," 2018.

[12] Z. Nadolny, "Impact of Changes in Limit Values of Electric and Magnetic Field on Personnel Performing Diagnostics of Transformers." Energies 15, no. 19, 2022, 7230.
[13] IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, World Health Organization, & International Agency for Research on Cancer, Non-ionizing radiation. Part 1, Static and extremely low-frequency (ELF) electric and magnetic fields, ser. IARC monographs on the evaluation of carcinogenic risks to humans, vol. 80. Lyon, France: IARC Press, 2002.
[14] H. Nguyen, S. Segers, M. Ledent, R. Anthonissen, L. Verschaeve, M. Hinsenkamp, J.F. Collard, V. Feipel, and B. Mertens, "Effects of long-term exposure to 50 Hz magnetic fields on cell viability, genetic damage, and sensitivity to mutagen-induced damage", Heliyon, 9(3), 2023.
[15] C. Malagoli, M. Malavolti, L. A. Wise, E. Balboni, S. Fabbi, S. Teggi, G. Palazzi et al. "Residential exposure to magnetic fields from high-voltage power lines and risk of childhood leukemia," Environmental Research 232, 2023, 116320.
[16] T. Modric, S. Vujević, and D. Lovrić. "3D computation of the power lines magnetic field." Progress In Electromagnetics Research M 41, , 2015 1-9.
[17] J. Bendík, M. Cenký, Ž. Eleschová, et al. Comparison of electromagnetic fields emitted by typical overhead power line towers. Electrical Engineering 103, 1019–1030, 2021.
[18] A. Alihodzic, A. Mujezinovic, E. Turajlic, and M. Muftic Dedovic. "Determination of electric and magnetic field calculation uncertainty in the vicinity of overhead transmission lines." Journal of Microwaves, Optoelectronics and Electromagnetic Applications 21 392-413, 2022.
[19] R. Djekidel, S-A. Bessedik, and A. Samar. "Accurate computation of magnetic induction generated by HV overhead power lines." Facta Universitatis, Series: Electronics and Energetics 32, no. 2, 267-285, 2019.
[20] V. David, I. Pavel and E. Lunca, "A Method for Estimating the Magnetic Fields Generated by the Overhead Power Lines," 2020 International Conference and Exposition on Electrical And Power Engineering (EPE), Iasi, Romania, 2020, pp. 662-667.
[21] S. Vujević, D. Lovrić, and T. Modrić. "2D computation and measurement of electric and magnetic fields of overhead electric power lines." In Proceedings of the Joint INDS'11 & ISTET'11, 2011, pp. 1-6.
[22] R. Djekidel, and S-A. Bessedik, "ASA Algorithm Combined with Current Simulation Method (CSM) for the Magnetic Induction under HV Power Lines in 3D Analysis Model." Advanced Electromagnetics 9, no. 2 (2020): 7-18.
[23] J. Bendik, M. Cenky, Z. Eleschova, A. Belan, and B. Cintula, "Influence of the harmonic content on the root mean square value of the electromagnetic field produced by overhead power lines," in 14th International Scientific Conference on Energy Ecology Economy (EEE) Conference Location SLOVAKIA, 2018, pp. 116–119
[24] A. Mujezinović, E. Turajlić, A. Alihodžić, M. Muftić Dedović, and N. Dautbašić. "Calculation of magnetic flux density harmonics in the vicinity of overhead lines." Electronics 11, no. 4 (2022): 512.
[25] F. Deshayes-Pinçon, F. Morlais, O. Roth-Delgado, O. Merckel, B. Lacour, G. Launoy, L. Launay, and O. Dejardin, "Estimation of the general population and children under five years of age in France exposed to magnetic field from high or very high voltage power line using geographic information system and extrapolated field data", Environmental Research, 232, , 2023, p.116425.
[26] F. Deschamps, and V. Deambrogio. "Calculated residential exposure to power frequency magnetic fields for an epidemiological study in France and comparison to measurements." Journal of Radiological Protection 43, no. 2 (2023): 021507.
[27] I. Pavel, C. Petrescu, V. David, and E. Lunca, "Estimation of the Spatial and Temporal Distribution of Magnetic Fields around Overhead Power Lines—A Case Study" Mathematics 11, no. 10:2292, 2023.
[28] G. Mazzanti, "Evaluation of Continuous Exposure to Magnetic Field From AC Overhead Transmission Lines Via Historical Load Databases: Common Procedures and Innovative Heuristic Formulas," in IEEE Transactions on Power Delivery, vol. 25, no. 1, pp. 238-247, Jan. 2010.
[29] T. Zagar, B. Valic, T. Kotnik, S. Korat, S. Tomsic, V. Zadnik, and P. Gajsek. "Estimating exposure to extremely low frequency magnetic fields near high-voltage power lines and assessment of possible increased cancer risk among Slovenian children and adolescents." Radiology and Oncology 57, no. 1 (2023): 59-69.
[30] A. Alihodzic, A. Mujezinovic, and E. Turajlic, "Electric and Magnetic Field Estimation Under Overhead Transmission Lines Using Artificial Neural Networks," IEEE Access, vol. 9, pp. 105 876–105 891, 2021.
[31] L. Huang, N. Shengsuo, H. Yueyan, and Z. Jingping. "Study on the influence of meteorological conditions on transmission line parameters." In IOP Conference Series: Earth and Environmental Science, vol. 218, no. 1, p. 012103. IOP Publishing, 2019.
[32] A. Bürgi, S. Sagar, B. Struchen, S. Joss, and M. Röösli. "Exposure modelling of extremely low-frequency magnetic fields from overhead power lines and its validation by measurements." International journal of environmental research and public health 14, no. 9 (2017): 949.
[33] A. Mujezinovic, E. Turajlic, A. Alihodzic, N. Dautbasic, and M. M. Dedovic, "Novel method for magnetic flux density estimation in the vicinity of multi-circuit overhead transmission lines," IEEE Access, vol. 10, pp. 18 169–18 181, 2022.
[34] "IEC 62110:2009 Electric and magnetic field levels generated by AC power systems - Measurement

B&H Electrical Engineering, Volume 18, Issue 1, 2024:31-39
ISSN:2566-3143, eISSN:2566-3151, DOI: 10.2478/bhee-2024-0004

procedures with regard to public expo- sure," International Electrotechnical Commission, 2009.
[35] "IEEE Standard Procedures for Measurement of Power Frequency Electric and Magnetic Fields from AC Power Lines," IEEE Std 644- 2019 (Revision of IEEE Std 644-2008), pp. 1–40, 2020.
[36] IEEE Standard Procedures for Measurement of Power Frequency Electric and Magnetic Fields from AC Power Lines, IEEE Std 644-2019 (Revision of IEEE Std 644-2008) (2020) 1–40
[37] https://www.google.com/maps
[38] Rulebook on safety zones of overhead power lines with a nominal voltage of 110 kV to 400 kV" (Official Gazette of Bosnia and Herzegovina No. 23/08)

BIOGRAPHY

Ajdin Alihodžić received the B.S. and M.S. degrees (Hons.) from the Department for Electric Power Engineering, Faculty of Electrical Engineering, University of Sarajevo, in 2015 and 2017, respectively, where he is currently pursuing the Ph.D. degree. From 2017 to 2020, he was an Investment Associate Engineer in the Executive Directorate for Investments at Joint Stock Company BH Telecom. Since 2020, he has been a Teaching Assistant/a Research Assistant with the University of Sarajevo. His research interests include numerical techniques in electromagnetics, transmission lines, and artificial intelligence.

Adnan Mujezinović received his M.Sc. and Ph.D. degrees in electrical engineering from the Faculty of Electrical Engineering, University of Sarajevo (Bosnia and Herzegovina), in 2011 and 2017, respectively. From 2012 he has been with the same faculty as a teaching assistant, and currently, as an Associate Professor. He has authored numerous conference and journal papers. His research interest includes numerical calculations of electromagnetic fields, cathodic protection and transmission lines.

Emir Turajić received the Ph.D. degree from Brunel, University, U.K., in 2007. He is currently an Associate Professor with the Department of Telecommunications, Faculty of Electrical Engineering, University of Sarajevo, Bosnia and Herzegovina. He has authored numerous conference and journal papers. He has written books on artificial neural networks, and image and video compression. His primary research interests are in the fields of digital signal processing, speech processing, artificial intelligence and machine learning. He has expanded his research to include image processing, data compression and metaheuristic algorithms.

Maja Muftić Dedović was born in Sarajevo, Bosnia and Herzegovina. She received the Ph.D. degree in electrical engineering from the Faculty of Electrical Engineering, University of Sarajevo. She works at the Faculty of Electrical Engineering, University of Sarajevo as a teaching and research assistant. Her research interests are in power system analysis, power system dynamics and stability, WAMPCS and signal processing.

Nedis Dautbašić was born in Srebrenica, Bosnia and Herzegovina. He received the Ph.D. degree in electrical engineering from International Burch University. He works at the Faculty of Electrical Engineering, University of Sarajevo as a teaching assistant. His research interests are in power system analysis, electromagnetic transients, grounding systems and signal processing.

Irfan Turković received his M.Sc. and Ph.D. degrees in electrical engineering from the University of Sarajevo, Bosnia and Herzegovina, in 2003 and 2010, respectively. Currently, he is an Full Professor at the University of Sarajevo – Faculty of Electrical Engineering. His topics of interest include cathodic protection, electrical measurements, safety in low voltage network and EMC in power systems.