

ENVIRONMENTAL POLLUTION BY MAGNETIC FIELD AROUND POWER LINES

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Abstract: According to the contemporary epidemiological researches, there are some indications that extremely low frequency electromagnetic fields harm human health which has been proved through numerous scientific studies published in recent years. Today, most countries use the ICNIRP guidelines and Council Recommendation as the scientific basis for their recommended levels of exposure. Magnetic fields from high voltage transmission power lines have been discussed in this paper. The field profiles and their contribution to environmental pollution are studied. The obtained results are found to be useful for discussing the comparison of the field densities on the human body at the ground level under or near the lines.

Key words: Electromagnetic fields, Power line, Environmental pollution

1. INTRODUCTION

In 1974, the International Radiation Protection Association (IRPA) formed a working group on non-ionizing radiation (NIR). This working group became the International Non-Ionizing Radiation

Committee (INIRC) in 1977 and examined the problems arising in the field of protection against the various types of NIR.

The IRPA/INIRC developed a number of health criteria documents on NIR as part of WHO's (World Health Organization) Environmental Health Criteria Programme. These health criteria have provided the scientific database.

In 1992, independent scientific organization—the International Commission on Non-Ionizing Radiation Protection (ICNIRP) was established as a successor to the IRPA/INIRC. The functions of the Commission are to investigate the hazards that may be associated with the different forms of NIR, develop international guidelines on NIR exposure limits, and deal with all aspects of NIR protection, [1].

Today, most countries use the ICNIRP, [1], guidelines and Council Recommendation [2] as the scientific basis for their recommended levels of exposure. Belgium, Italy, Estonia and Switzerland have implemented stricter legislation making reference to the precautionary principle.

The first report suggesting an association between residential electric and magnetic fields and childhood leukaemia was published in 1979. There have been numerous comprehensive reviews, meta-analyses, and two recent pooled analyses. Based on epidemiologic studies and two

pooled analyses [3, 4] extremely-low frequency magnetic field (ELF-MF) has been classified as a possible human carcinogen by the International Agency for Research on Cancer (IARC). An ELF-MF exposure of greater than 0.4 micro-Tesla (μT) is considered as a possible cause of childhood leukemia in [5]. In recent years many states have taken regulatory actions to limit the intensity of electric and magnetic fields on the edge of the transmission line right-of-way (ROW). In Serbia overhead high-voltage power lines have three voltage levels: 400 kV, 220 kV and 110 kV, and an extreme attention should be paid to investigation of the electromagnetic fields surrounding power lines as well as of definition of ROW corridor.

Related to this, there is a necessity for calculation of electromagnetic (EM) field in the surround of an electric power transmission lines, and a number of analytical and numerical methods are suggested, [6-10].

Artificial intelligence techniques such as fuzzy logic, neural networks and genetic programming, have been successfully applied to a number of power systems problems during recent years, [11].

Artificial neural networks also are used for estimating electromagnetic field, [12,13].

The purpose of the present work is the investigate whether ANFIS (adaptive network-based fuzzy inference systems) may be also used for the estimation magnetic field. ANFIS was trained using data derived from magnetic field calculations based on [14]. After the training, ANFIS has been used to calculate the magnetic field in a new geometry differing from the geometries used for training. The software for

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simulation and training of the ANFIS is written in the Matlab. Also, routines wrote in Matlab are used for visualization of magnetic field distribution around an overhead power transmission lines. The obtained results for magnetic field near by considered power lines (around 50 m) are grater than $0.4 \mu\text{T}$, which indicates to the possible health risk within this zone.

2. ADAPTIVE NETWORK-BASED FUZZY INFERENCE SYSTEMS (ANFIS)

The Adaptive-Network-based Fuzzy Inference System (ANFIS) was proposed by [15]. It combines the features of fuzzy logic and neural networks.

It is supposed that there is two input linguistic variables x and y and each variable has two fuzzy sets A_1, A_2, B_1, B_2 . Fig. 1 shows a Sugeno fuzzy system with two inputs, one output and four rules, [16].

Takagi-Sugeno-type fuzzy *if-then* rule could be set up as:

Rule 1: If (x is A_1) and (y is B_1) then

$$(f_1 = p_1x + q_1y + r_1)$$

Rule 2: If (x is A_1) and (y is B_2) then

$$(f_2 = p_2x + q_2y + r_2)$$

Rule 3: If (x is A_2) and (y is B_1) then

$$(f_3 = p_3x + q_3y + r_3)$$

Rule 4: If (x is A_2) and (y is B_2) then

$$(f_4 = p_4x + q_4y + r_4)$$

$p_i, q_i, r_i, i=1,2,3,4$ are the parameters set,

referred to as the consequent parameters.

The node function in the same layer are of same function described as follows, [15]:

Layer 1

Every node in this layer is an adaptive node with node function as:

$$O_i^1 = \mu_{A_i}(x), i = 1, 2$$

$$O_i^1 = \mu_{B_{i-2}}(x), i = 3, 4$$

where x (or y) is the input of the node, A_i (or B_{i-2}) is a fuzzy set associated with this node.

Usually it is chosen $\mu_{A_i}(x)$ and $\mu_{B_{i-2}}(x)$ to be bell-shaped such as:

$$\mu_{A_i}(x) = \frac{1}{1 + \left[\frac{(x - c_i)^2}{a_i} \right]^{b_i}} \quad (1)$$

or:

$$\mu_{A_i}(x) = e^{-\left\{ \left[\frac{(x - c_i)^2}{a_i} \right]^{b_i} \right\}} \quad (2)$$

where a_i, b_i , and c_i are the parameter set.

Layer 2

The nodes in this layer are fixed. The outputs of these nodes are given by:

$$O_1^2 = u_1 = \mu_{A_1}(x) * \mu_{B_1}(y)$$

$$O_2^2 = u_2 = \mu_{A_1}(x) * \mu_{B_2}(y)$$

$$O_3^2 = u_3 = \mu_{A_2}(x) * \mu_{B_1}(y)$$

$$O_4^2 = u_4 = \mu_{A_2}(x) * \mu_{B_2}(y)$$

where $*$ denotes t-norm.

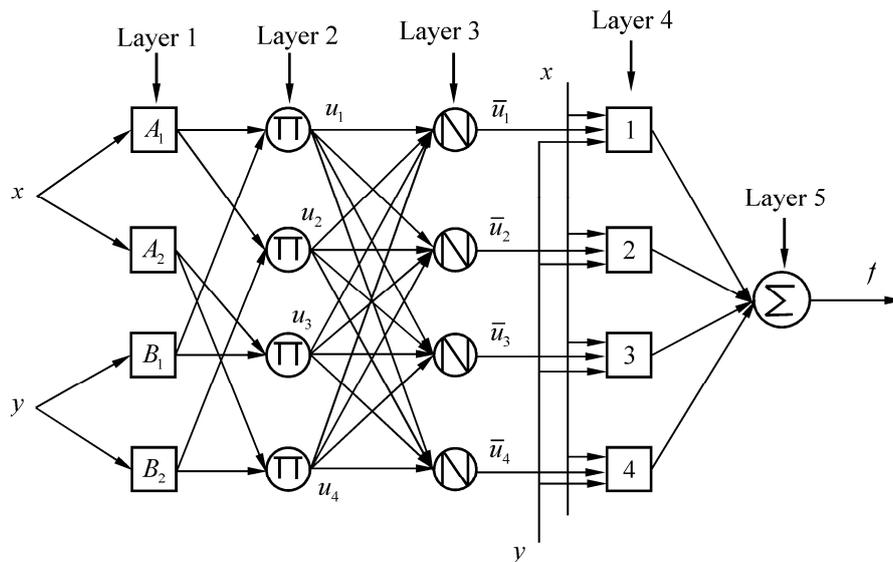


Figure 1 - 2-input ANFIS with 4 rules

Layer 3

Each node in this layer is a circle node. The outputs of this layer can be represented as:

$$O_i^3 = \bar{u}_i = \frac{u_i}{\sum_{k=1}^4 u_k}, \quad i = 1, 2, 3, 4 \quad (4)$$

Layer 4

Every node in this layer is an adaptive node, with node function:

$$O_i^4 = \bar{u}_i f_i, \quad i = 1, 2, 3, 4. \quad (5)$$

Layer 5

The node in this layer is a circle node that computes the overall output as the summation of all incoming signals:

$$O_i^5 = \sum_{i=1}^4 \bar{u}_i f_i \quad (6)$$

In [15] the hybrid learning algorithm is used for updating the parameters. For adapting premise parameters a_i , b_i , c_i gradient descent method is used. The least squares method is used for updating the consequent parameters.

3. SIMULATION RESULTS

ANFIS neural network has been used to determine the magnetic field in transmission line system shown in Fig. 2, where y - axis represents the ground surface.

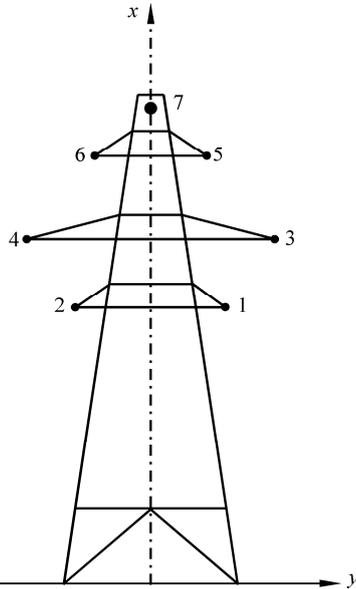


Figure 2 - Cross-section of the 110 kV power transmission lines

The values of voltage and currents flowing through the conductors are: $U_f = 110 \text{ kV} / \sqrt{3}$, $I_l = 50 \text{ A}$, $s = 2\pi/3$, current frequency is 50Hz, radius of conductor is $a_n = 15 \text{ mm}$ and coordinate

of protective rope are: $x_7 = 35 \text{ m}$, $y_7 = 0 \text{ m}$. Parameters of the ground are: relative permittivity $\epsilon_r = 3$, relative permeability $\mu_r = 1$, and conductivity $\sigma = 0.01 \text{ S/m}$. Coordinates of the power lines are shown in Table 1.

The inputs of the ANFIS are the coordinates (x, y) where intensity of magnetic field is calculated. In this paper two input variables are chosen. It is possible to add more variables, such as, for example, ground conductivity, position and dimensions of the phase conductors, etc. The number of the input variables is restricted, in order to show in a simple way the effectiveness of the proposed method.

The training data set is shown in Table 2.

Table 3 summarize test results where magnetic field calculations by the ANFIS network ($H_{e(ANFIS)}$), and the method proposed in [14] H_e have been compared.

The absolute errors have been computed as:

$$e_H = \left| \frac{H_e - H_{e(ANFIS)}}{H_e} 100 \right| \quad (7)$$

Magnetic fields distribution in surrounding of 110 kV power transmission lines obtained by the ANFIS is shown in Fig. 3.

The obtained values for magnetic field near by typical power lines in Serbia (around 50 m) are greater than $0.4 \mu\text{T}$ (0.32 A/m), Fig. 3.

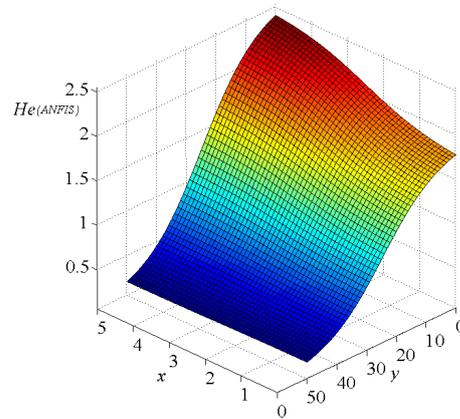


Figure 3 - Magnetic field distribution in surrounding of 110 kV power transmission lines

4. CONCLUSIONS

This paper describes in detail the design of ANFIS models in order to evaluate magnetic field of power transmission lines. The ANFIS is developed using MATLAB software.

	phase I		phase II		phase III	
n	1	2	3	4	5	6
x_n [m]	19	19	25	25	31	31
y_n [m]	-2.1	2.1	-4.2	4.2	-2.1	2.1

Table 1 - Coordinates of the power transmission lines

x [m]	0	2	5
0	1.831	2.11	2.608
1	1.831	2.098	2.597
2	1.831	2.075	2.585
4	1.785	2.052	2.515
5	1.773	2.017	2.469
8	1.669	1.889	2.272
10	1.588	1.785	2.121
13	1.46	1.634	1.901
15	1.368	1.518	1.75
17	1.263	1.402	1.6
19	1.182	1.298	1.472
20	1.136	1.252	1.414
21	1.089	1.194	1.344
24	0.973	1.055	1.182
25	0.927	0.997	1.124
27	0.834	0.904	1.02
29	0.765	0.834	0.927
30	0.742	0.788	0.881
32	0.672	0.718	0.8
33	0.637	0.695	0.753
35	0.579	0.626	0.672
38	0.486	0.521	0.579
40	0.452	0.475	0.51
41	0.417	0.44	0.486
43	0.371	0.394	0.44
44	0.347	0.371	0.417
46	0.301	0.336	0.359
47	0.301	0.324	0.347
49	0.243	0.266	0.289
50	0.231	0.255	0.266

Table 2 - Training data set

The results obtained according to the proposed ANFIS method are very close to those calculated by method based on [14], which clearly implies that the proposed method ensures acceptable accuracy and satisfying convergence. Maximal absolute error is less than 4% when ANFIS is used.

It can be concluded that developed method can be a very efficient tool for the study of magnetic

fields generated by various power line configurations and useful alternative for such investigations. Advantage of this method would be obvious when considering power lines with available measurement data set for network training.

The proposed expert system might also be adapted to similar studies for analysis and design of electric power systems.

x [m]	y [m]	H_e [A/m]	$H_{e(ANFIS)}$ [A/m]	e_H [%]
0.5	9.5	1.584	1.634	3.157
1.55	17.85	1.478	1.423	3.721
2	6.07	1.923	1.895	1.456
3.725	21.35	1.462	1.472	0.684
3.444	14.75	1.867	1.821	2.464
4.089	33.67	0.733	0.721	1.637
4.55	24.5	1.323	1.312	0.831
5	47.97	0.244	0.235	3.689

Table 3 - Magnetic field values for several new geometries of the examined problem, obtained by method based on [14] and by ANFIS, and proper absolute errors

REFERENCES

- [1] 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.* 74 (4), 494–522, 1998.
- [2] Council Recommendation of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz). *Official Journal of European Communities*, L 199, 59–71, 1999.
- [3] Ahlbom A., Day N., Feychting M. *et al.*: "A pooled analysis of magnetic fields and childhood leukaemia", *Br. J. Cancer* 83, 692–698, 2000.
- [4] Greenland S., Sheppard A. R., Kaune W. T., Poole C., Kelsh M.: "A pooled analysis of magnetic fields, wire codes, and childhood leukemia", *Epidemiology* 11, 624–34, 2000.
- [5] International Agency for Research on Cancer (IARC). IARC monographs on the evaluation of carcinogenic risks to humans, vol. 80. Lyon: IARC; 2001.
- [6] Abdel-Salam M., Abdallah H., El-Mohandes M. Th. and El-Kishky H.: "Calculation of magnetic fields from electric power transmission lines", *Electric Power Systems Research* 49, 99–105, 1999.
- [7] Filippopoulos G. and Tsanakas, D.: "Analytical calculation of the magnetic field produced by electric power lines", *IEEE Transactions on Power Delivery* 20(2), 1474 – 1482, 2005.
- [8] IEEE Magnetic Fields Task Force, "Magnetic Fields from Electric Power Lines: Theory and Comparison to Measurements", *IEEE Trans. on Power Delivery* 3(4), 219–228, 1988.
- [9] Geri A., Locatelli A. and Veca G.M.: "Magnetic Fields Generated by Power Lines", *IEEE Trans. on Magnetics*, 31(3), 1508–1511, 1995.
- [10] D. Veličković, J. Radulović: "Electromagnetic Field of Current Conductor Above Semi-Conducting Half-Space", *FACTA UNIVERSITATIS, Ser.: Electronics and Energetics*, vol. 15, pp. 217-225, 2002.
- [11] Warwick K., Aggarwal R. and Ekwue A.: "Artificial Intelligence Techniques in Power Systems", (Institution of Engineering and Technology (IET)). ISBN 0-85296-897-3, 1997.
- [12] Maris T. I., Ekonomou L., Fotis G. P., Nakulas A., Zoulias E.: "Electromagnetic field identification using artificial neural networks", *Proc. of the 8th Conference on 8th WSEAS International Conference on Neural Networks - Volume 8*, Canada, pp.84-89, 2007.
- [13] G. Capizzi, G., S. Coco, A. Laudani: "A Neural Network tool for the prediction of electromagnetic field in urban environment", *Proc. of the 12th Biennial IEEE Conference on Electromagnetic Field Computation*, pp. 60, 2006.
- [14] Radulović J.: "New approach for calculation of EM field of linear conductor above semiconducting half space", *Doctoral disertacion, faculty of Electronics, Niš, Serbia*, 2000. (in Serbian).
- [15] Jang J.-S. R. ANFIS: "Adaptive-Network-Based Fuzzy Inference Systems". *IEEE Transactions on Systems, Man, and Cybernetics*, 23(3), 665–685, 1993.
- [16] Ranković, V.: "Intelligent control", *Faculty of Mechanical Engineering, Kragujevac*, ISBN 978-86-86663-35-1, 2008. (in Serbian).