Technical Sciences
Academy of Romania
www.jesi.astr.ro

Journal of Engineering Sciences and Innovation
Volume 6, Issue 4 / 2021, pp. 419-430

D. Environmental Engineering and Energy

Received ***10 February 2021*** *Accepted* ***19 November 2021***
Received in revised form ***27 July 2021***

Study on the magnetic field influence around of the overhead power lines regarding the general public exposure level

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Abstract. This paper analyzes the distribution of the dimensions of the magnetic field in the vicinity of the high voltage overhead power lines (400 kV), in the context in which the effects of the electromagnetic field on living organisms and especially on humans are currently being analyzed. Electromagnetic fields of different frequencies interact with the human body in different ways, just as the effects of low frequency fields are not the same as those of the high frequency fields. Analysis of the electromagnetic field values near a high voltage overhead power line is very important for determining the degree of exposure to the electromagnetic field. The measurements are performed with the magnetic field tester, Hioki FT 3470-50 and the values obtained are compared with those indicated by current standards.

Keywords: electromagnetic field, magnetic flux density, exposure level occupational, exposure level general public, electromagnetic compatibility.

1. Introduction

Exposure to electromagnetic fields has distinct consequences depending on the frequency of the applied field. Exposure to high value electromagnetic fields and for long time' periods, may be a health hazard, [1 - 16]. The degree of exposure (occupational and public) is determined by analyzing the values of the electromagnetic field sizes, obtained by measurements in workspaces and in the public domain. In the exploitation activity, the operators from the electric networks, as well as other categories of employees from the electric power sector, are exposed to the action of the electromagnetic field. In addition, people that living in homes

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built in the immediate vicinity of overhead power lines may be affected by prolonged exposure to low-frequency electromagnetic fields.

Addressing the problem with electromagnetic fields, the magnetic field was measured in the vicinity of 400 kV overhead power lines. The data obtained from the measurements were compared with the limits imposed by the Directives: 1999/519 / EC, 2013/35 / EU, [8], [11].

2. Methodology

Magnetic field exposure analysis uses the following physical quantities: the intensity of the magnetic field (H), which together with the magnetic induction (B) defines a magnetic field at any point in space. Magnetic induction is a vector quantity, which is manifested by the force exerted on moving electric charges. In free space and in biological materials, the magnetic induction and the magnetic field strength can be used in place of each other. Considering a system of three-phase lines, the total magnetic field is obtained from the superposition of the fields, taking into account the phase shift between the currents that cross the lines, [17], [18]. In general situations, the magnetic field generated by three-phase power lines is elliptical.

Hioki FT3470-50 magnetic field tester measures the magnetic induction and the magnetic field strength in frequency ranges 10 Hz to 400 kHz / 10 Hz to 2 kHz / 2kHz to 400 kHz.

The Hioki FT3470-50 Magnetic Field Tester can be used to measure the conformance to Guidelines for Limiting Exposure to Time-varying Electric, Magnetic, and Electromagnetic Fields (ICNIRP 2010) [5], [6] and a standard for measuring fields of electrical house-hold appliances (IEC/EN 62233) [9].

The instrument and the magnetic field sensors are built mainly from nonmagnetic metals and contain hardly any magnetic materials. The magnetic field sensors have a plastic housing that may melt if brought into contact with a hot measurement object [9].

The tester can measure on each axis (X, Y, Z) separately or simultaneously on the three axes and calculates the resultant value (R), [9]. The values obtained when measuring a magnetic field vary depending on the direction of the field, so it is necessary to measure in all three directions, i.e. on each axis (X, Y, Z).

The instantaneous values obtained from X-axis, Y-axis and *Z*-axis sensors as time *t*, are referred to as, respectively, $x(t)$, $y(t)$ and $z(t)$ while the RMS values are respectively: $\hat{x}(t)$, $\hat{y}\ (t)$ and $\hat{z}\ (t)$, x, y and z, can be used to represent both magnetic flux density and exposure values.

The resultant value as time $t, R(t)$ is:

$$R(t) = \sqrt{\{\, x(t)\}^2 + \{y\ (t)\}^2 + \{z\ (t)\}^2} \tag{1}$$

The RMS values used by this tester represent the values shown below.

$$\hat{x}(t) = \sqrt{\frac{1}{T} \cdot \int_{t-T}^{t} \left((x(t)\right)^2 dt} \tag{2}$$

where *RMS* value per $\Delta\, t$ interval, is:

$$\hat{x}_n(1 \le n \le N, N \cdot \Delta t = T), \sqrt{\frac{1}{N} \cdot \sum_{n=1}^{N} \hat{x}_n^2}.$$

$$\hat{y}(t) = \sqrt{\frac{1}{T} \cdot \int_{t-T}^{t} \left((y(t)\right)^2 dt}, \quad (3)$$

where the *RMS* value per $\Delta\, t$ interval, is:

$$\hat{y}_n(1 \le n \le N, N \cdot \Delta t = T), \sqrt{\frac{1}{N} \cdot \sum_{n=1}^{N} \hat{y}_n^2}$$

$$\hat{z}(t) = \sqrt{\frac{1}{T} \cdot \int_{t-T}^{t} \left((z(t)\right)^2 dt}, \quad (4)$$

where the *RMS* value per $\Delta\, t$ interval, is:

$$\hat{z}_n(1 \le n \le N, N \cdot \Delta t = T), \sqrt{\frac{1}{N} \cdot \sum_{n=1}^{N} \hat{z}_n^2}$$

The resultant *RMS* value (T – integral time, interval [*t*-*T*, *t*]), $\widehat{R}\,(t)$ represents the following:

$$\hat{R}(t) = \sqrt{\{\hat{x}\,(t)\}^2 + \{\hat{y}\,(t)\}^2 + \{\hat{z}\,(t)\}^2} \quad (5)$$

On note here that *T* refers to the RMS integration time and is approximately 0.12 s when the slow function is turned off and about 1 s when the function is on.

The probe, Figure 1, consists of three orthogonal coils, so the displayed information is the sum of the fields being radiated at that particular point irrespective of their frequencies [19].

Fig. 1. Magnetic field tester measurement test Hioki FT3470-50, [22].

Fig. 2. The high voltage overhead 400 kV' power lines for which magnetic field measurements were performed.

3. Results and discussions

For the analysis of the magnetic field in the vicinity of some overhead power lines, several measurements were taken, performed with the magnetic field tester FT3470-50, in two areas (around Bucharest) crossed by high voltage overhead power 400 kV lines, with different distributions. Certain circuit portions of the studied overhead power lines were investigated and the recorded data were processed. To determine the spatial variability of the magnetic field, a circuit portion related to the 440 kV line was chosen (simple circuit horizontal crowning) and measurements were made at the worker's head, the distance between the measuring points being 10 m and maintaining the measurement sample along the analyzed line. Software HIOKI VIEWER for FT3470 Version 1.05, [9] was used to process the recorded data.
The Figure 3 indicates the Magnetic Flux Density at 20 m from the axis of the electricity pole along the line. The measurement conditions are: Sampling period: 0.25 s, [5 s/div]; for the frequencies between 10 Hz-400 kHz: Sampling Method: fixed interval.

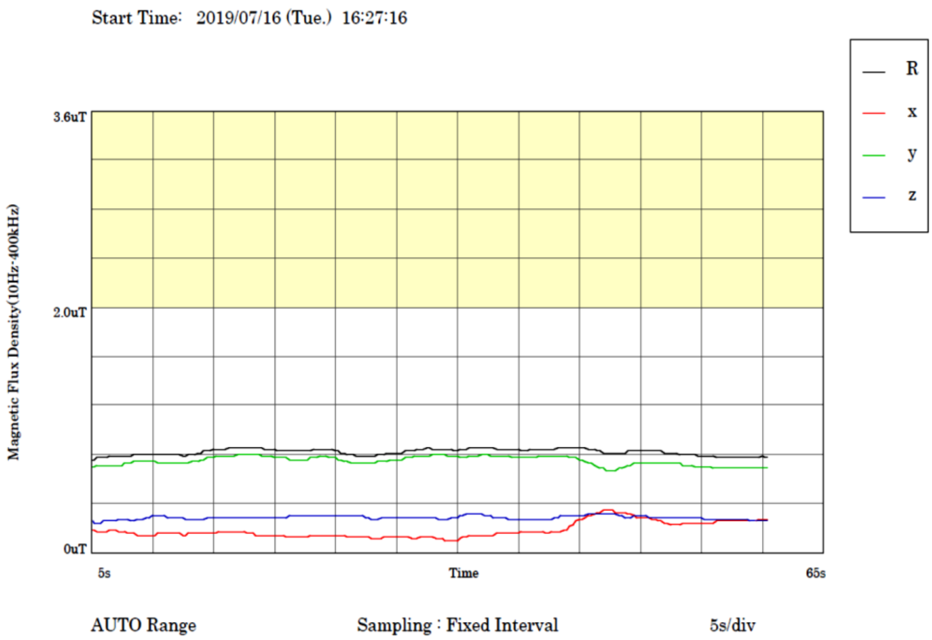

Fig. 3. The Magnetic Flux Density (10 Hz - 400 kHz) measured at 20 m from the axis of the electricity pole along the line.

The measured values of the magnetic field in the considered time interval do not exceed the values recommended by the norms (2 [μT]). The highest values of the magnetic induction are obtained on the axis of symmetry of the electricity pole, at the points located along the Y axis. Table 1 shows records of the magnetic flux density along the analyzed line (from the axis of the electricity pole, up to 35 m from it, at a time value, set at 32 s).

Table 1. Magnetic Flux Density (10 Hz – 400 kHz) [μT].

Distance $[m]$ from the axis of the electricity pole along the line	The Magnetic Flux Density (10 Hz – 400 kHz) $[\mu T]$			
	X – Axis Sensor	Y – Axis Sensor	Z – Axis Sensor	R – The Resultant Value
in axis of symmetry of the electricity pole	0.541	0.448	1.04	1.26
10 (1 from Fig. 4)	0.144	0.612	0.695	0.937
20 (2 from Fig. 4)	0.233	0.723	0.285	0.812
25 (3 from Fig. 4)	0.242	0.706	0.0835	0.747
30 (4 from Fig. 4)	0.192	0.572	0.0567	0.0606
35 (5 from Fig. 4)	0.209	0.509	0.124	0.564

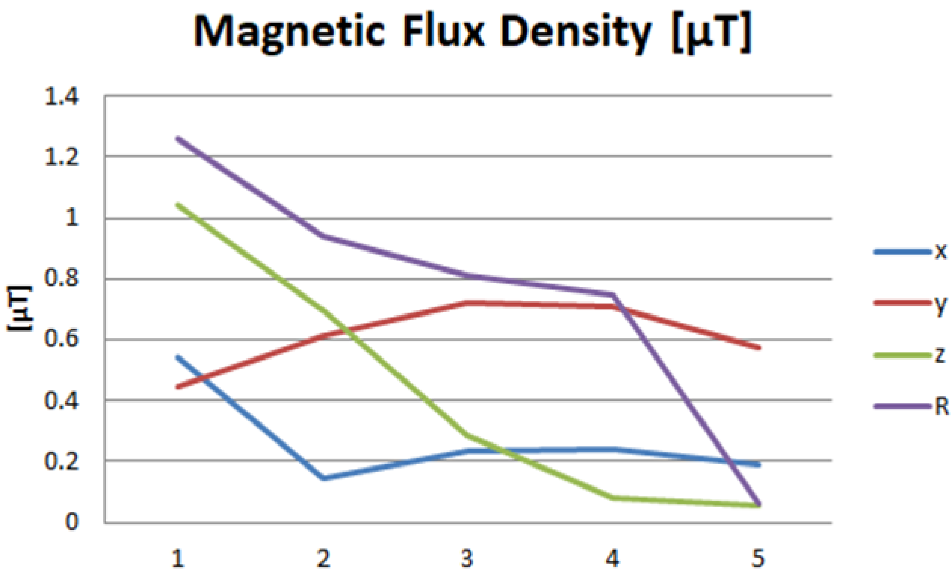

Fig. 4. Magnetic Flux Density (10 Hz-400 kHz) measured along the line from the axis of the electricity pole up to 35 m.

Figure 4 was constructed with the data of the records presented in Table 1.
The highest values of magnetic induction are obtained on the axis of symmetry of the electricity pole and then decrease as it moves away from the axis of the electricity pole. Although the magnetic field component on the Y axis has a slightly increasing behavior, the resulting value R of the magnetic field decreases as it moves away from the axis of the electricity pole.
Table 2 shows records of the Exposure Level along the analyzed line (from the axis of the electricity pole, up to 35 m from it, at a time value, fixed at 32 s).

Table 2. The Exposure Level [%]

Distance [m] from the axis of the electricity pole along the line	The Exposure Level [%]			
	X – Axis Sensor	Y – Axis Sensor	Z – Axis Sensor	R – The Resultant Value
in axis of symmetry of the electricity pole	0.1964	0.03944	0.4915	0.5308
10 (1 from Fig. 5)	0.04943	0.3125	0.3088	0.4421
20 (2 from Fig. 5)	0.06448	0.3692	0.09391	0.3864
25 (3 from Fig. 5)	0.06846	0.2259	0	0.236
30 (4 from Fig. 5)	0.1013	0.201	0	0.2251
35 (5 from Fig. 5)	0.05853	0.2006	0	0.209

Figure 5 shows the variation of the Exposure Level (General Public), along the analyzed line (from the axis of the column, up to 35 m from it, at a time value set at 32 s and constructed using the data from the records in the Table 2).
Exposure limit values for sensory and health effects are not exceeded (20 %).

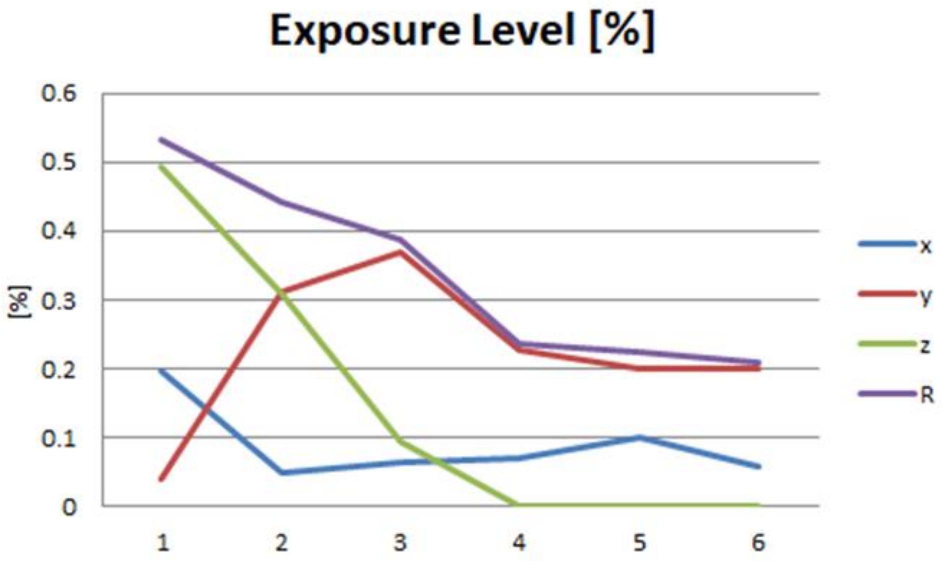

Fig. 5. Variation of the Exposure Level (General Public) measured along the X, Y, Z axes and R, along the line, from the axis of the electricity pole up to 35 m.

Also for determining the spatial variability of the magnetic field, in the second phase, a circuit portion related to the 440 kV line was chosen (vertical crowning two circuits) and measurements were made at the worker's head, the distance between the measuring points being 10 m and maintaining the measurement sample along the analyzed line.
The same software HIOKI VIEWER for FT3470 Version 1.05, [9] was used to process the recorded data.
Figure 6 indicates Magnetic Flux Density at 20 m from the axis of the electricity pole along the line. The measurement conditions are: Sampling period: 0.25 s, [5 s/div]: For frequencies between 10 Hz-400 kHz; Sampling Method: fixed interval.

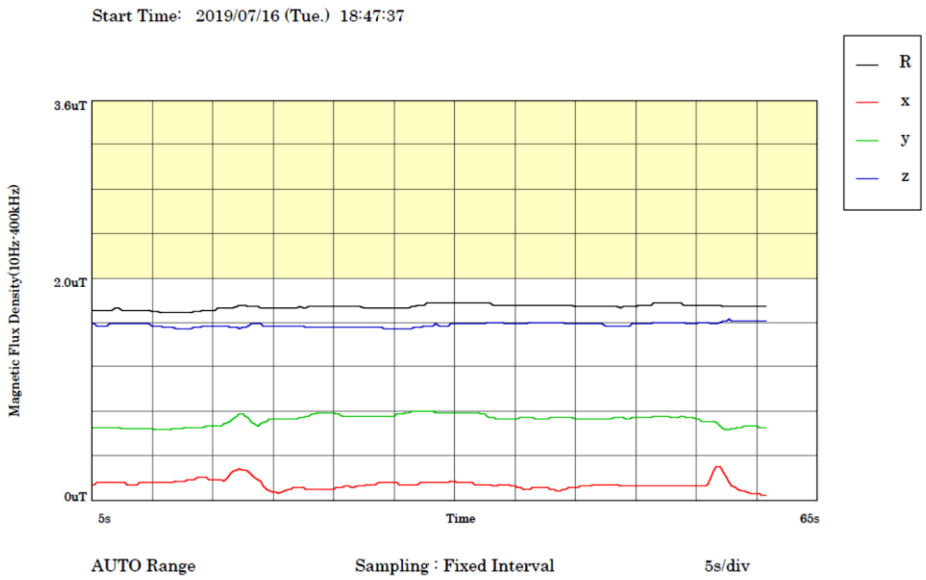

Fig. 6. The Magnetic Flux Density (10 Hz-400 kHz) measured at 20 m from the axis of the electricity pole along the line.

The measured values of the magnetic field, in the considered time interval, do not exceed the values recommended by the norms (2 [µT]). The highest values of the magnetic induction are obtained on the axis of symmetry of the electricity pole, at the points located along the Z axis, [20], [21].

Table 3 shows records of the magnetic flux density, along the analyzed line (from the axis of the electricity pole, up to 35 m from it, at a time value, set at 32 s).

Table 3. Magnetic Flux Density (10 Hz – 400 kHz) [µT].

Distance $[m]$ from the axis of electricity the pole along the line	The Magnetic Flux Density (10 Hz – 400 kHz) $[\mu T]$			
	X – Axis Sensor	Y – Axis Sensor	Z – Axis Sensor	R – The Resultant Value
in axis of symmetry of the electricity pole	0.985	0.347	0.534	3.64
10 (1 from figura 7)	0.147	1.78	2.12	2.77
20 (2 from figura 7)	0.2	0.612	1.56	1.69
25 (3 from figura 7)	0.0752	0.0508	1.33	1.43
30 (4 from figura 7)	0.181	0.378	1.06	1.14
35 (5 from figura 7)	0.122	0.399	0.866	0.961

Figure 7 was constructed with the data of the records presented in the Table 3.

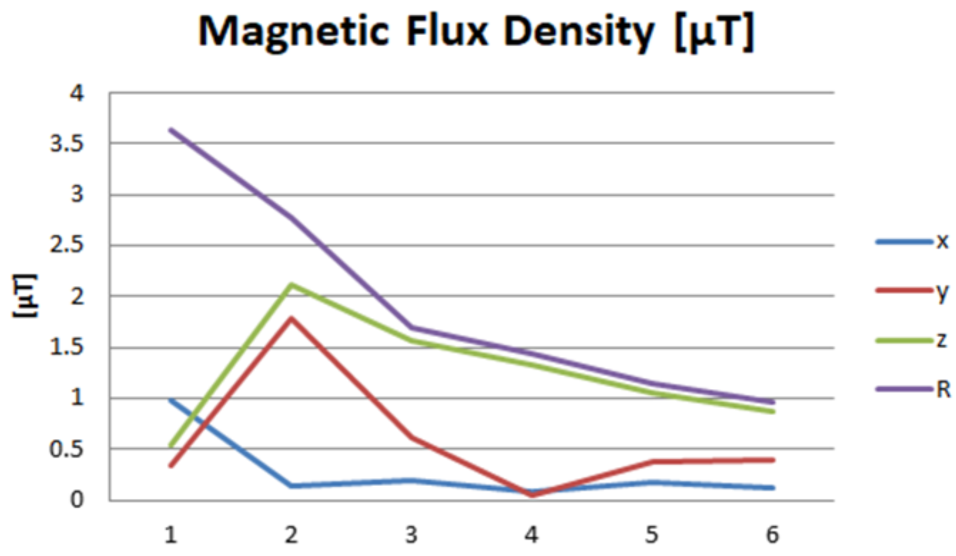

Fig. 7. Magnetic Flux Density (10 Hz-400 kHz) measured along the line, from the axis of the electricity pole up to 35 m.

The measured values of the magnetic field, in the considered time interval, do not exceed the values recommended by the norms (2 [µT]). Although the Y-axis and Z-axis magnetic field components have a slightly oscillating behavior, the resulting value R decreases as it moves away from the axis of the electricity pole.
Table 4 shows records of the Exposure Level along the analyzed line (from the axis of the electricity pole, up to 35 m from it, at a time value, fixed at 32 s).

Table 4. The Exposure Level [%]

Distance [m] from the axis of the electricity pole along the line	The Exposure Level [%]			
	X – Axis Sensor	Y – Axis Sensor	Z – Axis Sensor	R – The Resultant Value
in axis of symmetry of the electricity pole	0.04042	1.72	0.6988	1.857
10 (1 from Fig. 8)	0.06235	0.9701	0.8779	1.31
20 (2 from Fig. 8)	0	0.3234	0.7037	0.7745
25 (3 from Fig. 8)	0.05647	0.2137	0.5727	0.6139
30 (4 from Fig. 8)	0	0.1493	0.4652	0.4886
35 (5 from Fig. 8)	0.01493	0.1201	0.3824	0.4011

Figure 8 shows the variation of the Exposure Level (General Public) measured along the analyzed line (from the axis of the column, up to 35 m from it, at a time value, set at 32 s and constructed using the data from the records in Table 4).

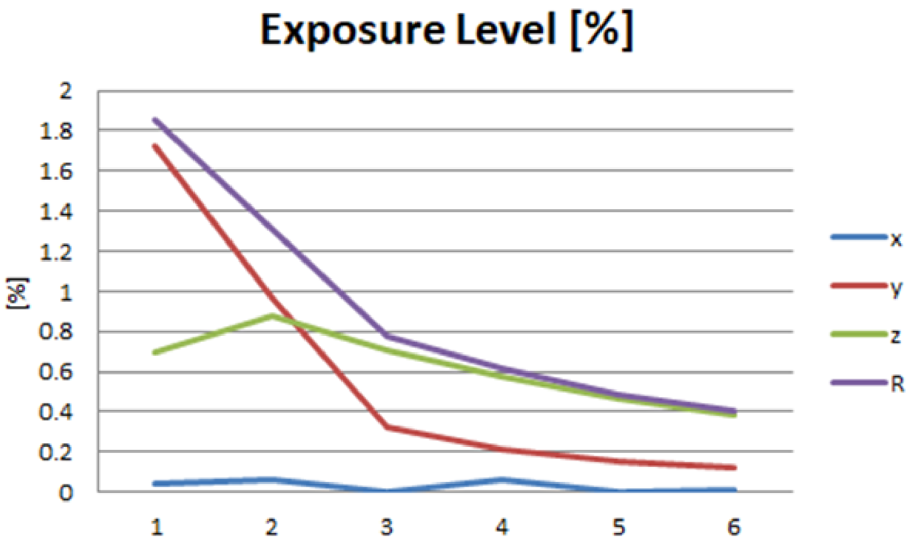

Fig. 8. Variation of the Exposure Level (General Public) measured along the X, Y, Z axes and R, along the line, from the axis of the electricity pole up to 35 m.

Analyzing all the recorded and the processed data, it can be seen that the exposure limit values for sensory and health effects are not exceeded (20 %).

4. Conclusions

The application of the measures to reduce low frequency electromagnetic fields is very important, due to the effects on living organisms and especially on humans.
The choice of the measurement areas and the application of the measurement methods specific to each area depend on the existing sources and the complexity of the studied space.
Occupational exposure occurs during the exercise of the profession is limited in time, and the fields acting on staff are larger than in the case of the residential exposure. However, in the case of dwellings built in the immediate vicinity of overhead power lines, it must be borne in mind that humans may be affected by prolonged exposure to low-frequency electromagnetic fields. For this purpose, the use of the metal reinforcement mesh for the housing construction materials may be considered as an easy-to-implement measure. The highest values of the magnetic induction are obtained on the axis of symmetry of the electricity pole at the points along the Y axis (400 kV overhead power lines - horizontal crowning, single circuit) and Z axis (400 kV overhead power lines - vertical crowning, two circuits).
As expected, both the magnetic flux density values and the Exposure Level (General Public) values decrease as we move away from the electricity pole axis and are larger in the case of 400 kV overhead power lines - vertical crowning, two circuits, than in the case of 400 kV overhead power lines - horizontal crowning, single circuit.

For the analyzed lines area, the measured values of the magnetic field strength (figures 3, 4, 6 and 7) and the degree of public exposure (figures 5 and 8) are lower than those accepted by the norms and actual standards, directives 1999/519/EC, 2013/35/UE, [8], [11].

Acknowledgements: *The research was conducted within the contract No. 30PFE/2018 signed between National R&D Institute for Electrical Engineering ICPE-CA and Romanian Ministry of Research and Innovation (MCI) and POSCCE-A2-O2.2.1-2013-1 – Operation 2.2.1: DEVELOPMENT OF EXISTING CD INFRASTRUCTURE AND CREATION OF NEW CD INFRASTRUCTURES (LABORATORIES, RESEARCH CENTERS), ID 1883, Code SMIS 49161, „DEVELOPMENT OF RDI CAPACITY OF THE ENERGY EFFICIENCY RESEARCH CENTER IN BUILDINGS (EEB) IN THE FACULTY OF BUILDING SERVICES, IN THE DIRECTION OF SURVEY SYSTEMS AND ENERGY TECHNOLOGIES SUSTAINABLE FOR SUSTAINABLE DEVELOPMENT OF THE ENVIRONMENT”.*

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