The Analysis of Magnetic Field Measurements in a Public Access Area

Georgiana Roşu *, Octavian Baltag †
* Military Technical Academy, Bucharest, Romania, georgianamarin01@gmail.com
† University "Gr. T. Popa" of Medicine and Pharmacy, Iasi, Romania, octavian.baltag@bioinginerie.ro

***Abstract* - This paper describes a case study referring to the magnetic field measurements performed in a public access area. Compared to the standard limits regarding the human exposure to electromagnetic fields, the measurement results were significantly higher. Based on these results and the scarce data regarding the magnetic field sources in the area, there are discussed several cases of power lines configurations and their corresponding magnetic field levels.**

Keywords: *electromagnetic exposure, electromagnetic pollution, magnetic field measurement, standards*

I. INTRODUCTION

The case study described in this paper is based on a set of magnetic field measurements performed in a market place area [1]. The paper aims to identify the magnetic fields sources that could generate such high levels registered in the measurement stage. Because the analyzed area is a public access area, determining the electromagnetic field exposure of the general public is highly important [2-9]. Based on an analytical model and the scarce data regarding the magnetic field sources in the area, there are discussed several cases of power lines configurations and their corresponding magnetic field levels.

II. DESCRIPTION OF THE ANALYZED CASE

The case presented herein refers to an area located North of Constanta, Romania, illustrated in Fig. 2, where a transformer substation 400/110/20 kV operates as part of the national power grid. Also, in the close vicinity of the substation, there is located a market place. People working and visiting this public access area are exposed to the electric and magnetic fields generated by the power lines converging to and from the substation, as the map in Fig. 2 shows clearly.

In the center of the market place there is situated one of the very high voltage (400 kV) power line towers, carrying electric power from the national grid to the transformer substation. Also, crossing above the southern side of the market area, there are three high voltage power line towers, each supporting a three-phase system of 110 kV. In Fig. 1 there is illustrated the 400 kV power line tower which is located in the north-eastern corner of the market place, and the inscription of the tower, stating that there should be maintained a protection area of 75 meters width from the power line axis.

Fig. 1. The 400 kV power line tower in the center of the market place

Fig. 2. The market place adjacent to the substation and converging power lines (Google Maps)

In order to determine the magnetic field levels affecting all exposed persons around, a set of measurements of magnetic flux density was performed on the contour of the market place. The measurement device was a gauss-meter with transversal Hall probe, which was calibrated before the measurements. The space coordinates corresponding to the magnetic field data were recorded with a GPS device. The measurements were performed at 1 meter above ground; there was measured the vertical component of the magnetic field. Magnetic flux density ranging from a few μT to several hundred μT, was measured on the boundary of the selected area. Fig. 3 outlines the measurement area border and Fig. 4 illustrates the values of the magnetic induction measured therein. The highest measured values range from 300 μT to 460 μT.

At the analyzed location, the human factor is present almost 24 hours a day, particularly in the warm months of the year, performing a commercial activity. It is in fact a public access area, with continuous exposure, the human factor not being aware, instructed, nor protected. By comparing the measured values with the standard imposed levels [7, 8, 10,11], several observations can be made:

- high values of magnetic field are determined by the close proximity of high voltage overhead power lines;

- in most points located on the Southern side of the area, near the 110 kV power line, the magnetic flux density exceeds the safety level of 100 μT, indicating a dangerous area for the humans therein;

- the safety level for the magnetic flux density is also exceeded in the N-E corner of the area, next to the 400 kV power line tower, beneath the overhead power line conductors.

Since the measured values were significantly higher than the usual magnetic field within the area of high voltage substations or beneath high voltage power lines [11, 12], there is imposed the analysis of the available data. There are analyzed several models of magnetic fields sources, such as overhead and underground three-phase power lines.

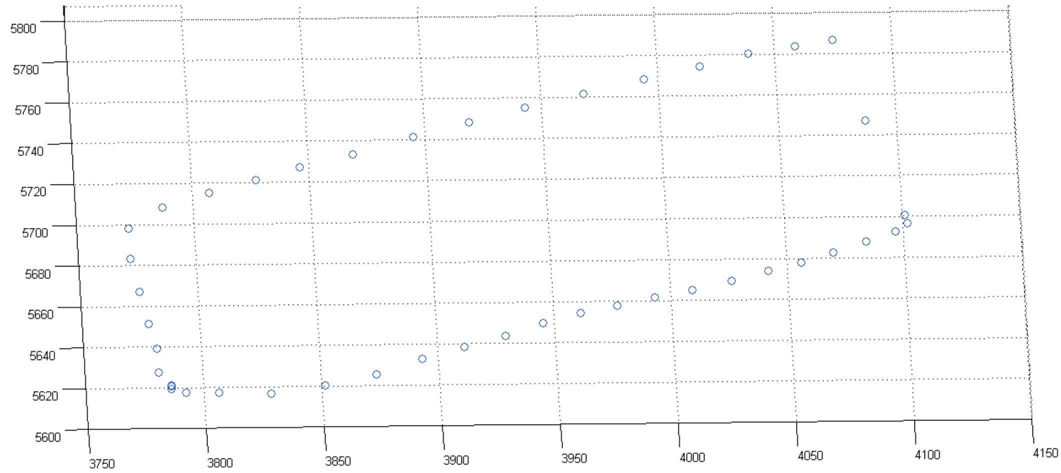

Fig. 3. The measurement points location expressed relative to a reference point

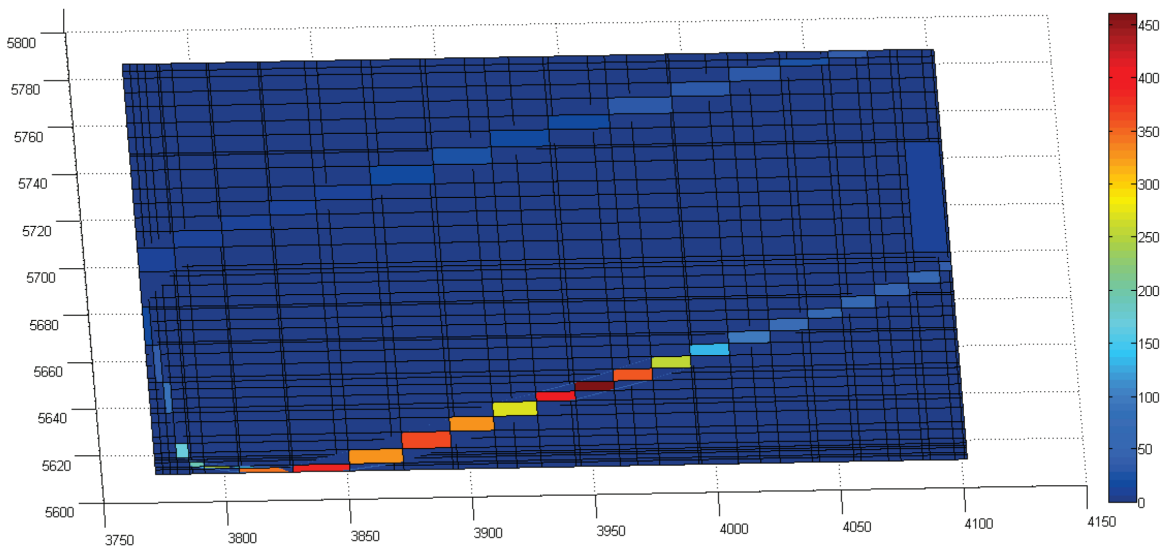

Fig. 4. The magnetic flux density registered in the measurement points

III. THE MAGNETIC FIELD COMPUTATION MODEL

The computational model of the magnetic field generated by a power line is based on the Biot-Savart-Laplace equation; the magnetic field density generated in point M by the current i_k passing through the k-th electric circuit (k = 1, 2 or 3) is determined by the electric current i_k, the magnetic permeability of free space, the distance vector r between the position of the observation point M and that of the cable, and the regular distance element on the electric wire dl.

$$\vec{B}_k\Big|_{M} = \frac{\mu_0 i_k}{4\pi}\int_{\Gamma_k}\frac{\vec{dl}\times\vec{r}}{r^3} \tag{1}$$

The integral is computed along the wire of the k-th circuit (phase) Γ_k; in literature, different shapes of the aerial cable are considered (straight cable or with a proper droop due to its connection between two points at the same elevation or at different elevations, by considering different three-phase line configurations, etc.) [10, 11].

By considering a cross-section through a three-phase power line, there is obtained a simplified 2D computational configuration. Still, the three currents passing through the cables i_k (k = 1, 2, 3) form a symmetrical system. The magnetic field computation is performed in the (x, y) plane, illustrated in Fig. 5. For the three-phase line system, the total magnetic field is obtained through fields' superposition, considering the symmetrical phase shift between the currents.

The magnetic field density generated by the three-phase line, computed in the observation point $M(x_M,y_M)$ has the orthogonal components B_x and B_y:

$$B_x = \frac{\mu_0}{2\pi}\sum_{k=1}^{3} i_k\left[\frac{-(y_M-y_k)}{(y_M-y_k)^2+(x_M-x_k)^2}\right] \tag{2}$$

$$B_y = \frac{\mu_0}{2\pi}\sum_{k=1}^{3} i_k\left[\frac{(x_M-x_k)}{(y_M-y_k)^2+(x_M-x_k)^2}\right] \tag{3}$$

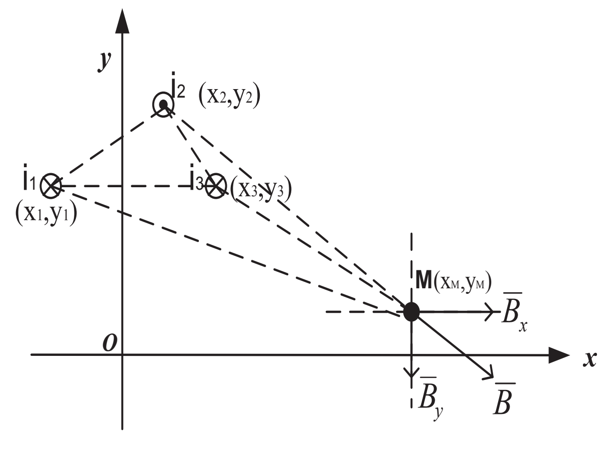

Fig. 5. The components of the magnetic field generated by the three-phase power line

IV. THREE-PHASE OVERHEAD POWER LINE

For the adopted computational model, there is further considered an overhead three phase power line. For a standard a power line tower of 110 kV supporting a three phase power line at approximately 20 meters above the ground, the cable positions expressed in the selected Cartesian system are as follows: (x1, y1) = (-4; 20), (x2, y2) = (2; 24), and (x3, y3) = (4; 20) meters.

The observation point M is 1 meter above the ground (y_M = 1 m), and its horizontal coordinate (x_M) ranges from -10 to 10 meters. The load current is considered to be 400 A (which represents the effective value admissible for a 110 kV power line). The orthogonal components of the magnetic field density are illustrated in Fig. 6 and Fig. 7; as one could observe, the magnetic field components resulting from (2) and (3) render values lower than 1 μT. Such low values are determined by the large distance between the observation point M and the aerial cables - approximately 20 meters.

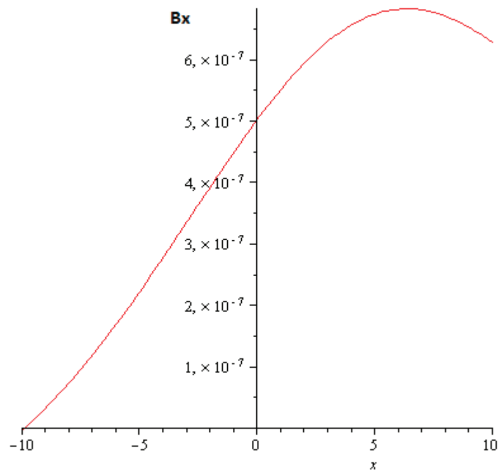

Fig. 6. The horizontal component of the magnetic field Bx generated by the overhead three-phase power line on the *x* axis, perpendicular to the power line

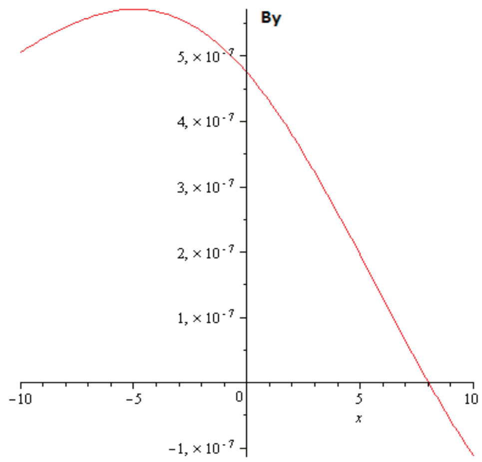

Fig. 7. The vertical component of the magnetic field By generated by the overhead three-phase power line on the *x* axis, perpendicular to the power line

V. THREE-PHASE UNDERGROUND POWER LINE

The computational model needs further improvement and adequacy to the true circuits' configuration; superposition of magnetic field components from many different circuits and possibly the true effective value of the line current could influence the results.

Power distribution specialists state that the magnetic field generated by an underground cable can reach up to 5 times the value of the magnetic field produced by an overhead line, mainly because of the distance between the line and the ground. [13].

For the scope of determining the magnetic field of an underground power line, the computation model was adapted for a 20 kV underground three-phase power line. Two configurations were considered: an axial (horizontal) distribution of the cables and a triangular distribution, respectively. The configurations are illustrated below in Fig. 8.

The reason of choosing the 20 kV voltages lies in the fact that the transformer substation in the analyzed region is distributing the following voltages 400/110/20 kV. Therefore, it was taken into consideration the fact that an underground cable of medium voltage (20 kV) could also be present in the area.

For the 20 kV underground cable, there was considered a copper cable of section S = 240 mm^2 [14]. The maximum load current differs with the cable distribution: it is 445 A for the horizontal distribution and 456 A for the triangular distribution, respectively.

The burial depth is 0.8 meters, and the observation point is located 1 meter above the ground. So, in the case of an underground power line, the distance between the power line and the measurement point is approximately ten times lower. For both cable configurations, there were taken into account two different distances between cables: 7 cm and 25 cm, respectively.

As one can notice in Fig. 9 – Fig. 16, there is registered a field increase with the distance between cables, in both configurations. Still, the obtained values are below 10 µT and lower than the measured values.

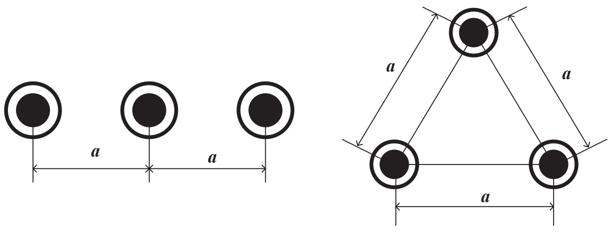

Fig. 8. The selected configurations of the underground three-phase power line - horizontal distribution and triangular distribution, respectively

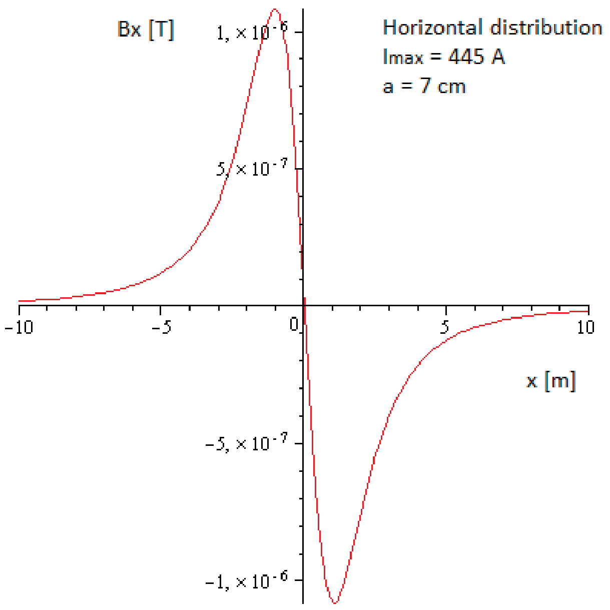

Fig. 9. The horizontal component of the magnetic field Bx generated by the underground three-phase power line, with cables placed in horizontal line configuration, at 7 cm distance

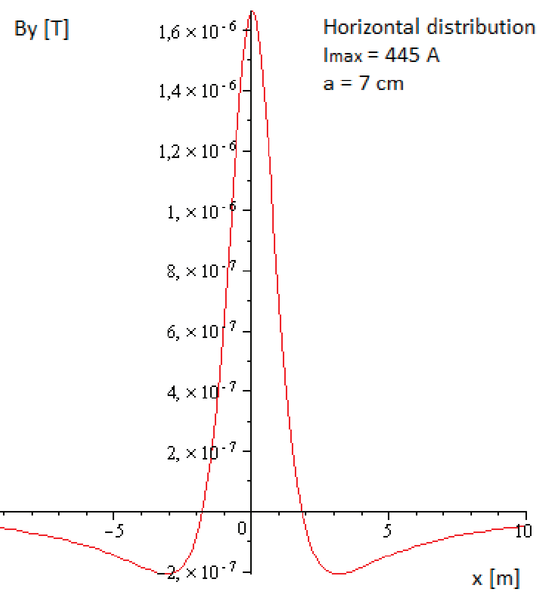

Fig. 10. The vertical component of the magnetic field By generated by the underground three-phase power line, with cables placed in horizontal line configuration, at 7 cm distance

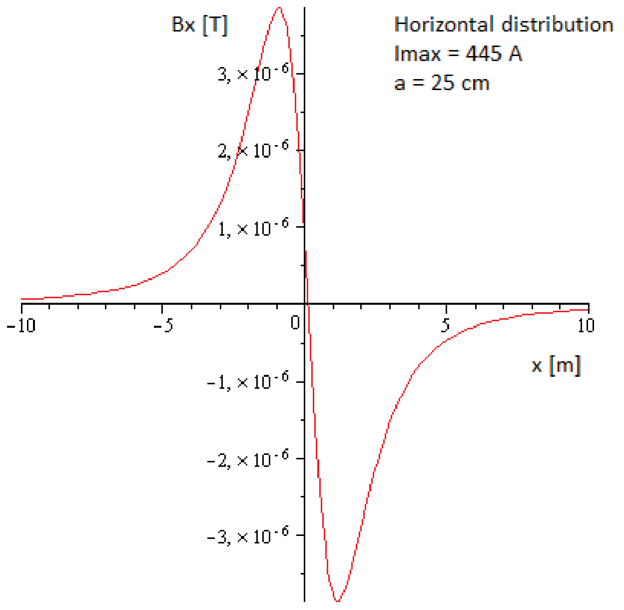

Fig. 11. The horizontal component of the magnetic field Bx generated by the underground three-phase power line, with cables placed in horizontal line configuration, at 25 cm distance

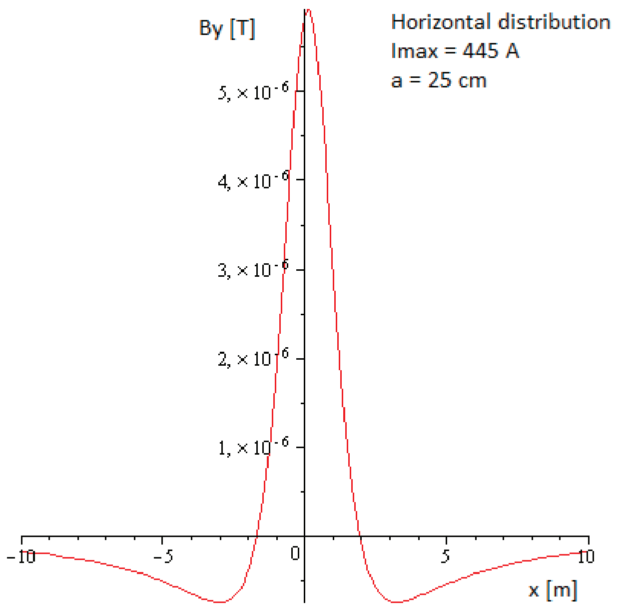

Fig. 12. The vertical component of the magnetic field By generated by the underground three-phase power line, with cables placed in horizontal line configuration, at 25 cm distance

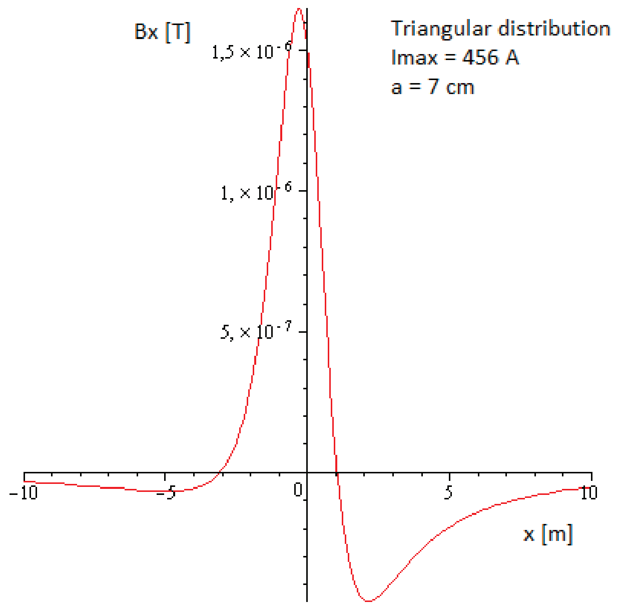

Fig. 13. The horizontal component of the magnetic field Bx generated by the underground three-phase power line, with cables placed in triangle configuration, at 7 cm distance

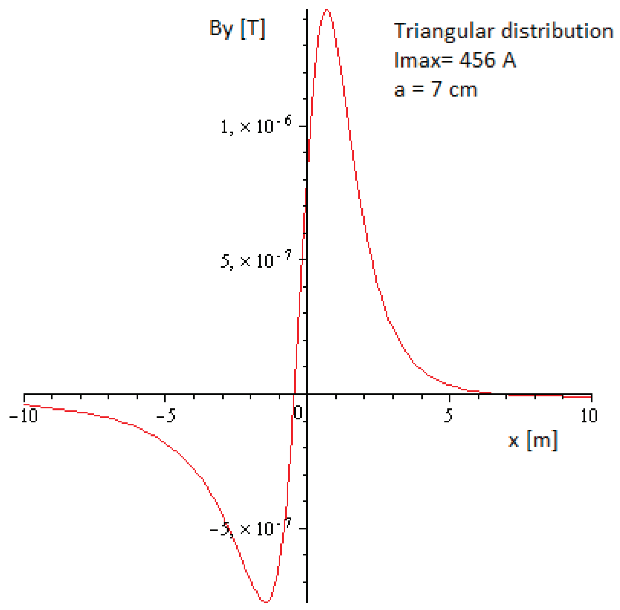

Fig. 14. The vertical component of the magnetic field By generated by the underground three-phase power line, with cables placed in triangle configuration, at 7 cm distance

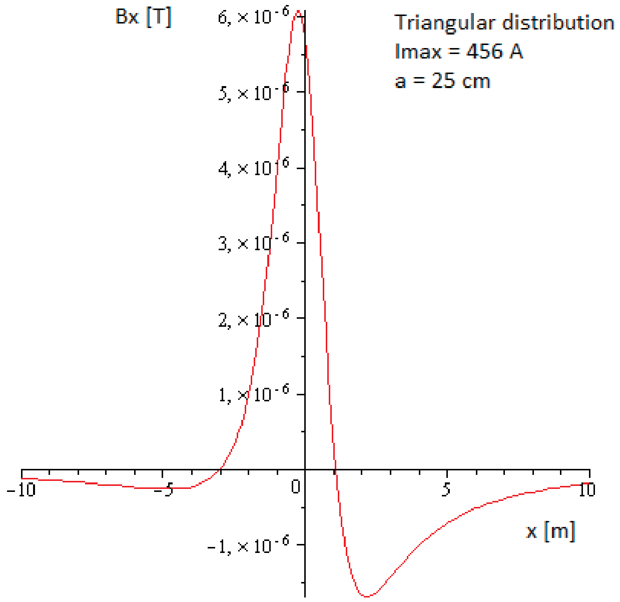

Fig. 15. The horizontal component of the magnetic field Bx generated by the underground three-phase power line, with cables placed in triangle configuration, at 25 cm distance

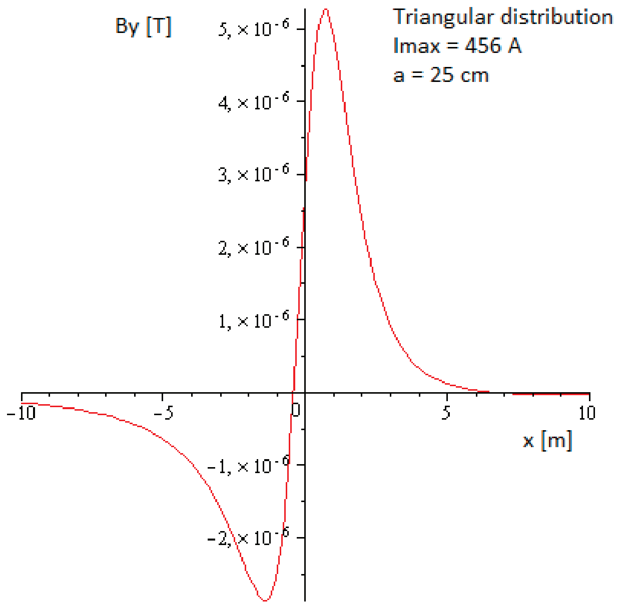

Fig. 16. The vertical component of the magnetic field By generated by the underground three-phase power line, with cables placed in triangle configuration, at 25 cm distance

VI. Conclusions

Starting from a set of measurements performed in a market place area, indicating very high levels of magnetic field, there were analyzed several types of power lines considered to be magnetic field sources. The analyzed area presents a particular type of exposure, being simultaneously populated with workers and ordinary people. The people working there are not aware of electromagnetic field emissions, body exposure, the need for protective measures and limitations, etc.

The analyzed sources render magnetic field values in the range of 1 -10 μT. The maximum measured values reach levels with the order of hundreds of μT. This cannot be explained through the presence of multiple power lines, both overhead and underground, crossing the market area.

Even though it is a market place – therefore a public access area, it is a private property, meaning that the owner is the authority responsible for the assessment of the workplace and for all the needed protective measures. Due to the negative attitude of the market administration, it was not possible to repeat the measurements or to perform supplementary ones. Still, the paper aims to increase awareness to the fact that people perform professional activities in areas unsuitable in terms of electromagnetic field exposure, and to determine measurements resuming.

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