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THE MEASUREMENT OF MAGNETIC FIELD IN TWO POWER DISTRIBUTION SUBSTATIONS

BY

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Abstract. In this paper we present the measurements results of low frequency magnetic fields in two power distribution substations from Iasi city. We made both spot measurements and long term survey in different areas, considering spatial variability and field variability with height. The measurements were performed near various field sources, in control rooms and in technological space by using three different measurement equipments including an instrument for automatic field survey. In view of the spatial variability, we made a few maps of the magnetic field in some areas and graphical representations of the magnetic field variability with height from the floor. Even the highest values were recorded in Station 1 on the section with current transformers (9845 nT) and in Station 2 near the electrical transformer (7408 nT) are much below the ICNIRP reference levels.

Key words: background magnetic field; distribution substation; long term survey; magnetic field measurements; map of magnetic fields.

1. Introduction

The human exposure to low frequency magnetic field is still great concern and also were made various studies on this domain (Morega *et al*., 2014;

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Munteanu *et al*., 2010; Safigianni *et al.,* 2012). Supplementary, the magnetic fields generated by power line can disturb sensible equipment in home and others environments (Breniuc & Haba, 2014; Haba *et al*., 2017). The values of the magnetic field recorded in various areas and near some sources inside the substations and power distribution are compared with the maximum values allowable by some standards (Hotărâre nr. *520*/2016; ICNIRP, 2010). The difficulties encountered at measurements in substations are due to spatial variability in different areas and the magnetic field variability with height. That's why more accurate representation of measurements in the maps or graphs is goods solutions (Nicolaou *et al*., 2012). In this paper we present some results and maps of the magnetic fields obtained in two stations from Iasi city. For the entire study we used two conventional measurements and one automatic instrument made in our laboratory which perform both spot measurement and long-term survey of background magnetic field (David *et al*., 2009; Nica *et al*., 2016). Beside the spot measurements with spatial variability study, for some points, we made an automatic fields survey with time and frequency domain representation. In Section 2 we present the instrumentation and methods which were used for implementation the entire study. Section 3 will mention the collecting results from the stations by using three different measurement equipments, and we present those results in maps form, graphs, and statistical processing.

2. Instrumentation and Methods

For determination of the magnetic field in the two considered transformer stations, we have conducted several measurements in some areas of interest by using three different measurement equipments.

Thus, we used in measurements the gauss meter CA 40 with uniaxial sensor (M1), the gauss meter PCE-G28 with triaxial sensor (M2) and an automated magnetic field measurement system realized in our laboratory. (David *et al*., 2009; David *et al*., 2010).

For magnetic field measurements we selected some areas based on the degree of magnetic pollution, namely near transformers, autotransformers, where the field reaches the highest values and also in personnel/workers areas (control rooms, offices, equipment panels).

In control rooms we made both spot measurements and an automatic survey of magnetic field with a statistical processing.

In 2015 we made some magnetic field measurements inside FAI station (Station 1, Fig.1), located in Valea Lupului in Iasi city. As is indicated in Fig. 1 we performed magnetic field measurements in some areas where the workers have access: all five sections (**1**, **2**, **3**, **4**, and **5**), control room/office (CR_{S1}) and technological space (TS_{S1}). Over the all sections were made measurements at a distance of one meter and one meter height.

The second location, the Station 2, is situated in Industrial Area from Iasi, and the measurements were made on a portion of network CEL110 kV LAMINOR (**1**, in Fig. 2), near the electric transformer (T_{S2}, in Fig. 2), in control room (CR_{S2}, in Fig. 2) and in a point P2 situated on the route of personnel/workers.

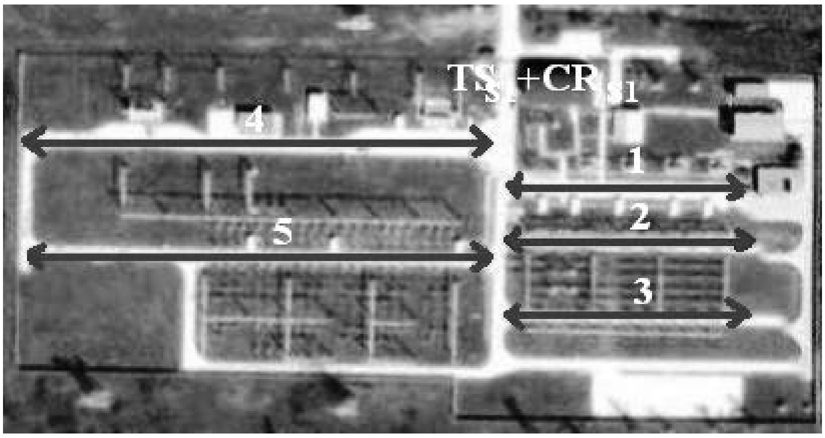

Fig. 1 − Map of Station 1, with the 5 Sections, control room and technological space.

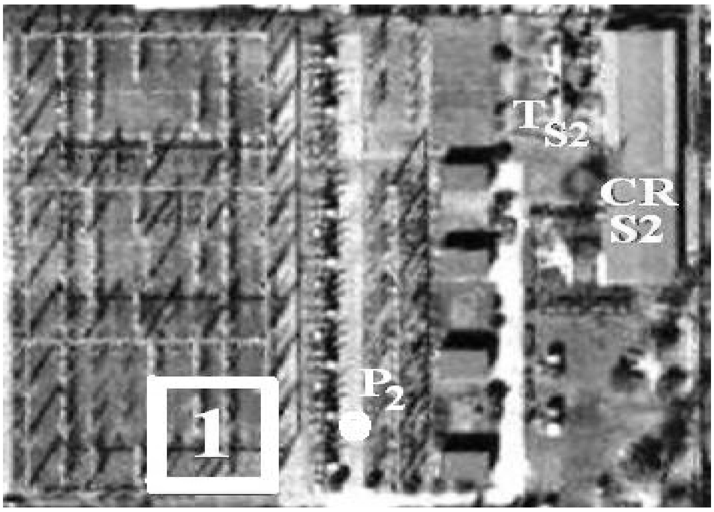

Fig. 2 − Map of Station 2 from industrial area, Iaşi.

For Zones **1** and Ts_2 there were realized only spot measurements of magnetic field by using the first two measurement instruments.

For CRs_2 and P2 more attention was paid, because the staff is working most part of the days. First, we made spot measurements considering spatial variability in this areas and the magnetic field variability with height from the ground. Then, we made an automatic survey of background magnetic fields, with the time domain and frequency domain representations and a statistical processing.

3. Results

3.1. Station 1 (FAI station)

Section **1** contains four transformers (110 kV / 20 kV) and the maximum value obtained on this area is 2920 nT. For Section **2** where are situated the current transformers, the entire longitudinal profile section can be seen in Fig. 3. In this section the highest value of magnetic field is 9845 nT. In Section **3**, where are present voltage transformers and arresters, the maximum value of magnetic field is 4120 nT. In Section **4** of the FAI station, the greatest values of magnetic induction of about 6300 nT in a point situated near the two autotransformers (220/110 kV-200 MVA). In the last section studied, Section **5**, where are situated the current transformers, the greatest value of the field is 7890 nT.

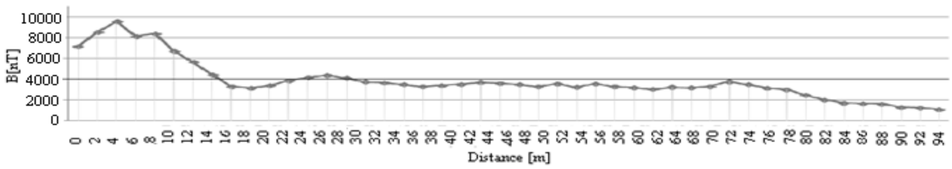

Fig. 3 – The longitudinal profile, Section **2** of FAI Station.

In **CR$_{S1}$** were made measurements of magnetic field in some points (in the central of room, **C,** and in every corner of the control room, **P1, P2, P3** and **P4**) and at different heights (zero meters, one meter and two meters). The highest values of magnetic field were recorded in **P2** (140 nT) and **P3** (190 nT) because these points are located near the corners of the wall of the technological space. As a result of the measurements, we find that the magnetic field values are higher at the floor level, decreasing with the height; due to the fact that the indoor electrical installation is mostly made on the floor. This representation can be seen in Fig. 4.

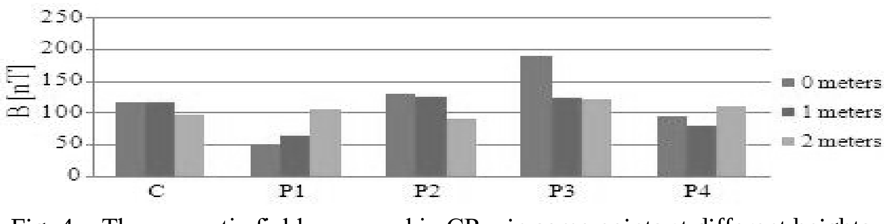

Fig. 4 – The magnetic field measured in CR$_{S1}$ in some points at different heights.

Technological space (TS$_{S1}$) is located besides the control room, here being placed control panels of station, converters and inverters. Also the measurements were made by the same method related to the control room. The highest value of the magnetic field measured in all five points was indicated in the center of the control room (C), there being located the control panels of station as is shown in Fig. 5.

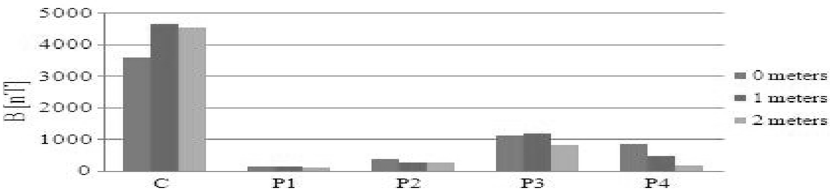

Fig. 5 − The magnetic field measured in TS_{S1} in some points at different heights.

Further, the magnetic field measurements were made near rectifiers and inverters. These sources are found in the technological space where workers have access throughout the entire working day. So, they may be subjects of the long term exposure of magnetic field generated by these sources. We made the measurements at different heights to observe its spatial variability and to find some protection methods. The values of magnetic field collected in these areas are represented in Table 1. It was observed that, with increasing height, the field values are decreasing with the removal from the source.

Table 1
The Magnetic Field Measurements Near Rectifiers and Inverters

Survey zone	$B_{r.m.s.}$, [nT]	
	1 meter height	2 meters height
Rectifier1	800	762
Rectifier 2	1,225	1,129
Inverter 1	5,447	1,471
Inverter 2	6,634	1,713

3.2. Station 2 (Industrial Area)

We performed field measurements in Zone **1** at different points and we draw a map which represents the spatial variability of the magnetic field from this area, as shown in Fig. 6. The size of the area of interest is 7 m × 17 m and contains: phases bar R, S, T, a separator of 110 kV, Iasi South and the earth lead. All these measurements were made at a height of one meter above the ground by using successively the first two measurement instruments (at the same point, but at different times).

The highest values of the field in this perimeter have been identified under each phase of the aerial power line (836 nT, 994 nT, 911 nT).

We made also a comparison between the results obtained with instrument **M1** (Pavel & David, 2016) and the instrument **M2**. We made measurement of the magnetic field with different instruments to accurately determine the spatial variability of the magnetic field. The maximum differences of magnetic fields obtained with the two considered instruments are under 3%, as shown in Fig. 7.

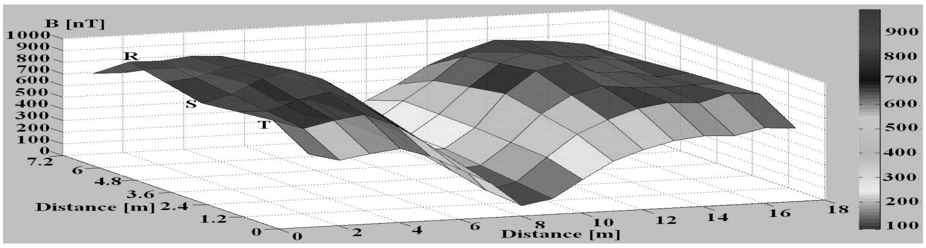

Fig. 6 – The map of magnetic field measurements in Zone **1**, Station 2.

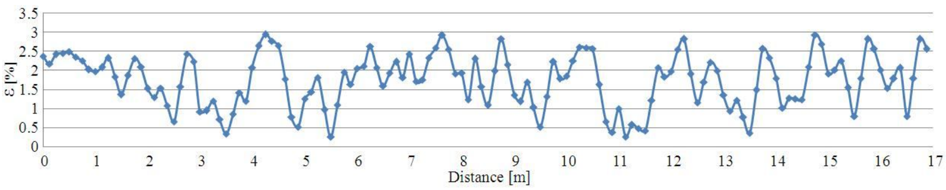

Fig. 7 – The differences between the result obtained with M1 and M2.

The following magnetic field measurements were made in **Ts$_2$** area, where the electrical transformer is located. Due to the fact that the electrical transformer is situated at the exit of the control room, the workers are subjects to long term exposure of the magnetic field. For a most relevant survey and a good representation of the field, it was conducted the longitudinal and perpendicular profile of the magnetic field to the transformer. The measurements were taken at a distance of one meter from the transformer and one meter above the ground. The results are represented in Fig. 8. In this area, we have identified the highest values of the magnetic field of the station, namely 7409 nT. It is collected under the current bar which is situated between the transformer and the control room.

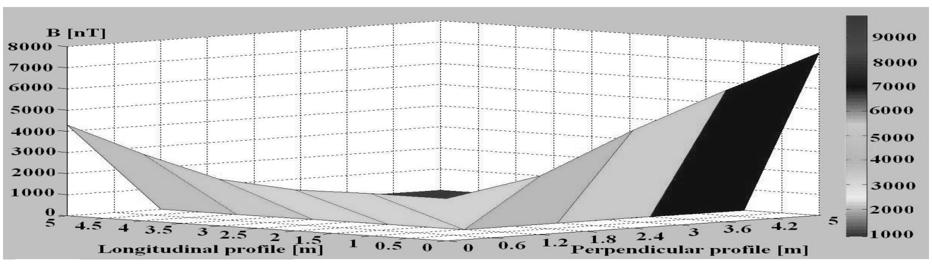

Fig. 8 – The Longitudinal and Perpendicular profile of electrical transformer in Ts$_2$ area, Station 2.

In the control room, spot measurements and an automatic survey have been carried out. More attention was paid to this area because the workers spend most of the time on a working day and this fact represents a risk in terms of long-term exposure to the magnetic field. Referring to spot measurements, we determined the magnetic field values in the CR_{S2} in some points at various heights, as is shown in Fig. 9. The measurements were made with the first two equipments in the following points: the access zone of CR_{S2} (ACC), the left part of the control panel (LP), the right part of the control panel (RP), the command centre (COM) and the middle of the control room (MD). The highest values of the magnetic field in this area have been identified in RP and ACC at 2 meters height, due to the fact that the connection between the external sources and the control room is aerial.

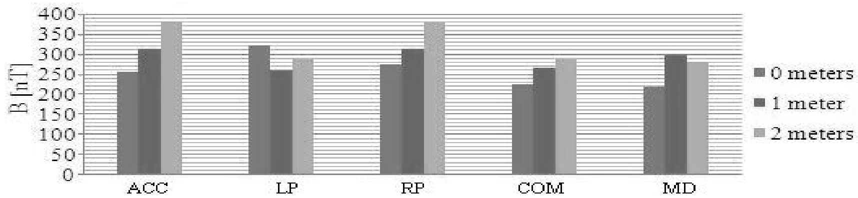

Fig. 9 – The magnetic field measurements in CR_{S2} in some points at different heights.

It is observed that a large variation of field with the height exists, which can reach even up to 30% of the measured value at one meter height.

A survey of background magnetic field was conducted in the control room (**CR_{S2}**) and point **P_2** of Station 2 by using an automatic measurement system. **CR_{S2}** is located in the building near the electrical transformers and **P_2** point near Zone **1**, on the route where the workers are crossing to survey the entire station. These areas received more attention because the staff may be exposed at magnetic field. In Fig. 10 it is shown the time domain and frequency domain representations of the three perpendicular components of the maximum values collected of the magnetic fields in COM point from control room. A recording of the root mean square values of background magnetic fields ($B_{r.m.s.}$) for 15 minutes automatic survey in COM point from control room is shown in Fig.11. This point was selected to be surveyed because the worker is here present during the largest period of a normal working day. The highest value of the magnetic field in this area is 235 nT.

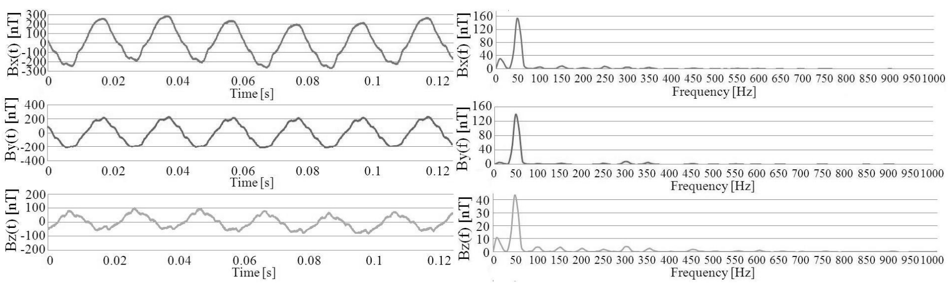

Fig. 10 − Time domain and frequency domain representation of magnetic fields for the control room, Station 2.

Because the P2 point is situated on the route where the workers are crossing to survey the entire station, we made also a 17 minutes automatic survey of background magnetic fields. The time and frequency domain representations of magnetic field from this point is shown in Fig. 12 whereas the recording of $B_{r.m.s.}$ values for 17 minutes field survey is presented in Fig. 13.

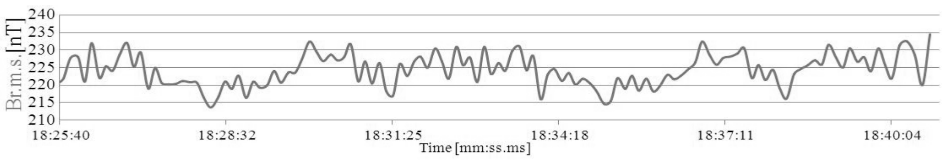

Fig. 11 − Recording of $B_{r.m.s.}$ values for 15 minutes field surveying in the control room, Station 2.

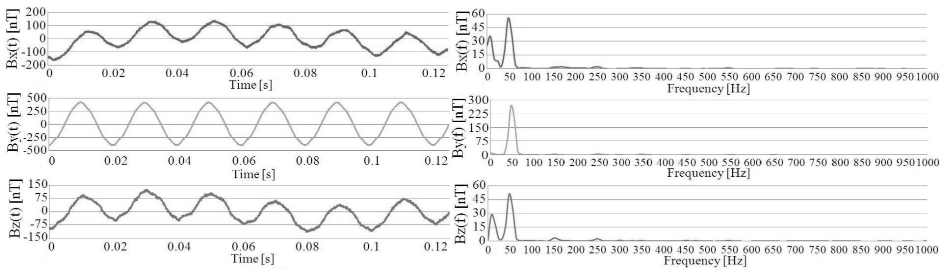

Fig. 12 − Time domain and frequency domain representation of magnetic fields for point P2, Station 2.

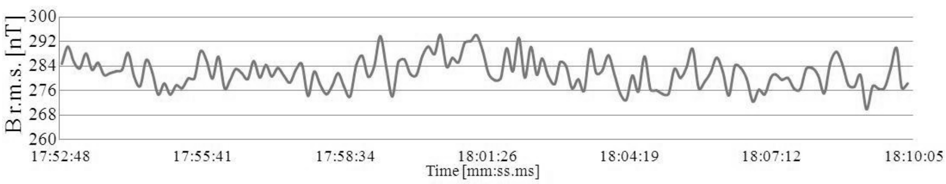

Fig. 13 − Recording of $B_{r.m.s.}$ values for 17 minutes field surveying on point P2, Station 2.

Finally, we made a statistical proceeding of magnetic induction survey ($B_{r.m.s.}$) on these two considered zones. In Table 2 is presented the survey period, number of measurements, the minimum values – Min., average, the maximum values – Max., standard deviation and survey time (in percentage) when the values of $B_{r.m.s}$ are over average.

As a conclusion, we found that both on workers routes where the maximum values are collected and in the control room or in the technological spaces, the levels of magnetic field are much bellow the allowed reference levels established by ICNIRP and Hotărâre nr. 520/2016.

Table 2
A Statistical Processing of Data for Several Minutes of Magnetic Induction Survey in CR_{S2} and P_2 Point

Survey		Number of measurements	$B_{r.m.s.}$, [nT]				$\frac{t_{overaverage}}{t_{survey}} \times 100$ [%]
Zone	Period		Min.	Average	Max.	Standard deviation	
CR_{S2}	15 min	125	213.65	224.21	234.41	4.51	49.13
P_2	17 min	142	272.39	284.79	294.07	8.49	49.97

4. Conclusion

We made magnetic fields measurements in some points of two transformer stations from Iasi city, considering both the spatial and temporal variations of the fields.

To achieve measurements were used several types of equipments including one automatic instrument made by authors, which allows both spot measurements with time and frequency representation and automatic long term survey with a statistical processing. The differences between the results obtained with three different measurement instruments used in our study were below 3%.

The maximum values of magnetic induction recorded in the access areas of staff working were 9845 nT for Station **1** and 7408 nT for Station **2**, being much bellow the reference levels for occupational exposure (ICNIRP, 2010), (Hotărâre nr. 520/2016).

A special attention was paid to the command and control rooms where we found a large spatial variation of the magnetic field and a field variation with height which can reach at 30%.

The average values of the background magnetic field obtained from automatic survey for about 15 minutes were 224.21 nT for control room and 284.79 nT for one specific area on the route of personnel/workers.

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MĂSURAREA CÂMPULUI MAGNETIC ÎN DOUĂ STAŢII DE TRANSFORMARE ŞI DISTRIBUŢIE

(Rezumat)

Sunt prezentate rezultatele măsurătorilor câmpurilor magnetice de joasă frecvenţă în două staţii de transformare şi distribuţie din oraşul Iaşi. Am efectuat măsurători la faţa locului şi o supraveghere pe termen lung, în diferite zone, luând în considerare variabilitatea spaţială şi variabilitatea câmpului cu înălţimea. Măsurătorile s-au efectuat în apropierea diferitelor surse de câmp, în camerele de comandă şi în spaţiul tehnologic utilizând trei echipamente de măsurare diferite, inclusiv un instrument pentru supravegherea automată a câmpului. Având în vedere variabilitatea

spațială, am făcut câteva hărți ale câmpului magnetic în unele zone şi reprezentări grafice ale variabilității câmpului magnetic cu înălțimea, față de pardoseală. Chiar şi cele mai ridicate valori care au fost înregistrate în Stația 1 pe tronsonul cu transformatoarele de curent (9845 nT) şi în Stația 2 langă transformatorul electric (7408 nT), sunt cu mult sub nivelurile de referinta admise de catre standardul ICNIRP.