

CONSIDERATIONS REGARDING ASSESSMENT OF THE EXPOSURE DEGREE IN ELECTRIC AND MAGNETIC FIELD OF HUMAN BODY

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ABSTRACT: The paper present a few aspects regarding to the practical evaluation of electromagnetic environment inside working spaces or public areas where is opening acces for humans. Degree of exposure is assessed based on the determination of values for the electric or magnetic field sizes. These real values are compared with the limit admitted by the regulations. It can thereby determine if the existing electromagnetic environment is or not dangerous to human health. Although there are no certainties and confirmations generalized about negative effects of exposure to electromagnetic fields, negative action thereof on biological systems is quantified by threshold values of electromagnetic field sizes and durations of critical exposure, effects being categorized generally as thermal and non-thermal. The work is based on the results of measurements on electric and magnetic field strength and statistical processing of data obtained.

KEYWORDS: Magnetic induction, electric field strenght, electromagnetic field effects

1. INTRODUCTION

There are many cases in which various researchers have noted and recorded, negative effects related to human exposure to electromagnetic fields[1],[2],[3],[4].

However, more and more reports of recent date mentions concerns about possible negative effect on the health of people working in the areas of electric and magnetic field generated by electric installations or even the general population using, especially, electromagnetic devices for high frequency such as mobile phones or microwave ovens[1],[2].

Among the possible effects of exposure to electromagnetic field[1],[2],[3],[4] states: impairment of vision, producing various forms of cancer, changes in brain activity, changes in enzyme activity, premature births, infertility, decreased immunity, forming triglycerides, depression, fatigue, dizziness, heart arrhythmia, blood pressure oscillations, restless sleep, concentration problems, headaches, Alzheimer disease and others. Many studies published which reveals the negative effects of exposure have sparked both reactions concern and also control or invalidation of the results [3]. The interaction effects between the electromagnetic field and the living matter are influenced by factors such as the frequency of the electromagnetic waves, the amplitude of the characteristic parameters of the field, the amount of energy transmitted to the body and the duration of standing in an environment with intense electromagnetic pollution. [3].

In the case of electromagnetic field exposure,

the employer should ensure regular measuring the level of field sizes and compare them with the limit considered dangerous and foreseen in regulations. If these limits are exceeded must be ensured reductions of real values of the field parameters, even if must change or cancel the sources.

In the case of general population, periodic measurements of values for the field sizes is not mandatory because is not provided for by law. A good information on these effects and how to limit them, leading to the adoption of precautionary measures such as limiting the use of devices generating intense electric and magnetic field or keeping a distance increased to them. Possession of a field meter less sophisticated and cheaper, enable to the general population to assess the level of electromagnetic field quantities in the living space or natural environment.

Exposure degree in the light of this paper is a parameter that quantifies the hierarchical position in a ranking of actual exposure levels determined by measurement of a particular job. The ranking can be obtained by reference percentage or absolute quantities characterizing the electromagnetic environment existing in the reference to the allowable thresholds considered dangerous to national legislation. Thus it is appreciated obvious that category of workers is more affected.

2. PRACTICAL DETERMINATION OF ELECTRIC AND MAGNETIC FIELD

Empirical assessment of electromagnetic field sizes distribution, in space and time is based on measurements. In the case of this paper measuring

devices used for electromagnetic field sizes are: SPECTRAN 5035 și CA 42 fieldmeter. They offer the possibility of measuring both the electric field intensity and magnetic induction for several frequency ranges. The devices contain internal isotropic probes to assess magnetic field distribution and external probes for evaluating electric field. Images of these devices are shown in Figure 1.

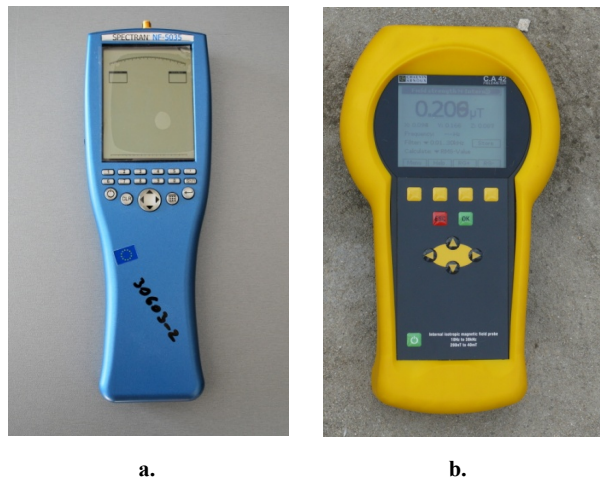


Figure 1. Measuring devices used, without external probes: (a)- SPECTRAN 5035; (b)- CA 42.

To appreciate distance from the source, was used the appliance Bosch PLR 50. Rulers used to determine measuring points were made of metal - for measuring electric field strength, respectively by PVC - for measuring magnetic induction, to not disturb extra the field electromagnetic in space considered.

In accordance with the legislation existing [5], to characterize the exposure of workers to electromagnetic fields, use the following physical quantities:

- *contact current* (I_C) between a person and an object in [A];
- current density* (J) defined as the current flowing through a unit of surface normal to the conductor in a volume of biological tissue [A/m^2];
- electric field intensity* (E) which is express in [V/m];
- magnetic field intensity* (H) which is express in [$A/$];
- magnetic induction or magnetic flux density (B), which is express in [T];
- power density* (S), It is a suitable size for use in the case of very high frequencies, where the depth of penetration in the body is reduced and is expressed in [W / m^2];
- specific absorption of energy* (SA), it is defined as the energy absorbed per unit mass of biological tissue. It is measured in [J/kg];
- specific absorptions rate* (SAR) of medium energy on entire body or just a some part of it. It is defined as the rate at which energy is absorbed per unit mass of body tissue, quantified in [W / kg].

3 ASSESSING OF THE EXPOSURE DEGREE IN ELECTROMAGNETIC FIELD OF THE WORKERS FROM ELECTRICITY DOMAIN

3.1 METHODOLOGY

Through the activities undertaken and functional characteristics of the electricity networks they serve workers are exposed to electromagnetic fields generated by them.

In order to assess the exposure degree into electric and magnetic field, were carried out investigations on two occupational categories from the domain of electricity:

- operational staff in control rooms of power plants (Hydropower plants - HPP and Thermoelectric plan t- TP) belonging to Bihor Power System;

- operational staff in control rooms related to electricity distribution and interconnection stations (PS) belonging to Bihor power System.

Complex electromagnetic environment is being formed due to the operation of all sources of a given chamber, hall or a particular territory. For each location were inventoried all sources of electromagnetic field. To control rooms measurements were performed at the control panel next to the operator who oversees energy processes. Using the CA 42 field meter were made measurements during a working week for a period of 1.5 hours (90 minutes) daily, performed the readings every 5 minutes. Have resulted in total 18 daily readings.

With values obtained were performed average for each time moment considered for each category of location or job. At the end of the calculations, were analyzed which workers category is most exposed and then is performed their hierarchy based on the degree of exposure.

3.2 DETERMINATION OF EXPOSURE LEVEL TO ELECTROMAGNETIC FIELD FOR WORKERS FROM POWER PLANTS AND POWER SUBSTATIONS

To determine the exposure of operators of power stations addressed in a larger study will be presented by way of example where the control room of HPP Fughiu and PS Mecanica Oradea, conceiving two different modes.

For Fughiu case, the number of employees of the HPP is 11 people; of these, 6 powers electrical plants, four are engineers and one central leader (engineer). The categories of age are in the range 26-54 years. Sources of electromagnetic field in space

analyzed from HPP Fughiu, are: 2 personal computers with 3 monitors, controller and process computer, electronic equipment tracking energy processes, destined for monitoring and control of the hydrogenerator(HG) operation, speed governor, panel tracking electrical parameters, panel tracking hydro-mechanical parameters, fan and 3 incandescent lamps.

Figure 1 shows the location of the equipment in the control room of HPP Fughiu and their images. In the power substations are monitored only electrical parameters. The first model of the measurements described in paragraph 3.1 on apply to the PS Mecanica. The values obtained for control room of this substation are indicated in Table 1.

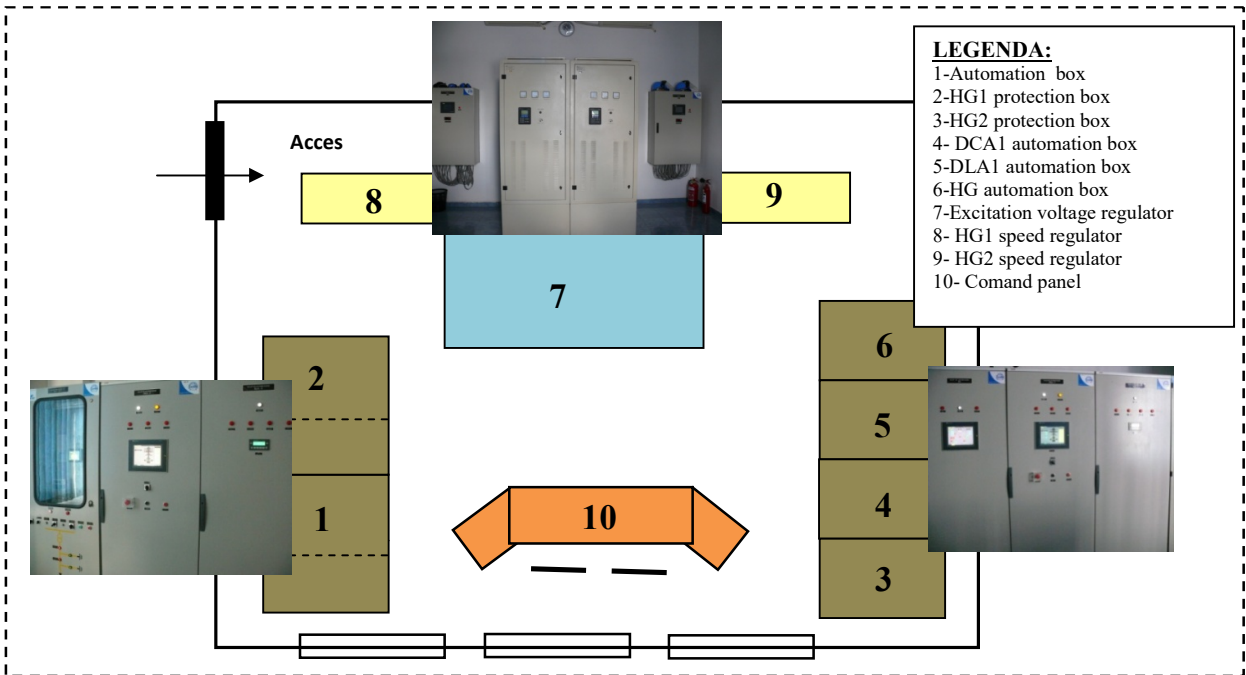


Figure 2. Location of the equipment in the control room of HPP Fughiu

Table 1. The values of magnetic induction for control room of PS Mecanica Oradea

Day	Magnetic induction values[μT] for time moments considered, in time slot 12.00-12.45 p.m.								
	B_{t1}	B_{t2}	B_{t3}	B_{t4}	B_{t5}	B_{t6}	B_{t7}	B_{t8}	B_{t9}
Monday	0,23	0,32	0,22	0,28	0,25	0,28	0,32	0,35	0,31
Tuesday	0,34	0,25	0,44	0,24	0,36	0,34	0,26	0,33	0,32
Wednesday	0,31	0,35	0,34	0,22	0,32	0,24	0,19	0,25	0,22
Thursday	0,24	0,34	0,31	0,27	0,33	0,23	0,31	0,32	0,35
Friday	0,21	0,35	0,34	0,19	0,26	0,29	0,20	0,25	0,22
Saturday	0,27	0,33	0,24	0,32	0,27	0,25	0,19	0,23	0,26
Sunday	0,26	0,31	0,24	0,32	0,26	0,24	0,28	0,35	0,22
Day	Magnetic induction values[μT] for time moments considered, in time slot 12.45-13.30 p.m.								
	B_{t10}	B_{t11}	B_{t12}	B_{t13}	B_{t14}	B_{t15}	B_{t16}	B_{t17}	B_{t18}
Monday	0,21	0,33	0,26	0,32	0,31	0,27	0,22	0,26	0,23
Tuesday	0,22	0,24	0,33	0,32	0,29	0,34	0,25	0,26	0,21
Wednesday	0,31	0,21	0,23	0,35	0,26	0,24	0,35	0,29	0,22
Thursday	0,24	0,21	0,27	0,19	0,22	0,25	0,21	0,29	0,31
Friday	0,31	0,34	0,33	0,25	0,23	0,24	0,27	0,20	0,19
Saturday	0,19	0,22	0,33	0,36	0,24	0,27	0,21	0,25	0,22
Sunday	0,31	0,34	0,28	0,25	0,23	0,24	0,22	0,19	0,24

Figure 3 shows the distribution chart of maximum values of magnetic induction in the control room of PS Mecanica. Permissible limit values for electromagnetic field sizes that characterize exposure of the employees from

electrical installations, are [5]: $E_{lim} = 10000$ [V / m]; $B_{lim} = 500$ [μT]. For each 1,5 hours interval, we calculated average of daily maximum values recorded to magnetic induction, applying the next relation (1).

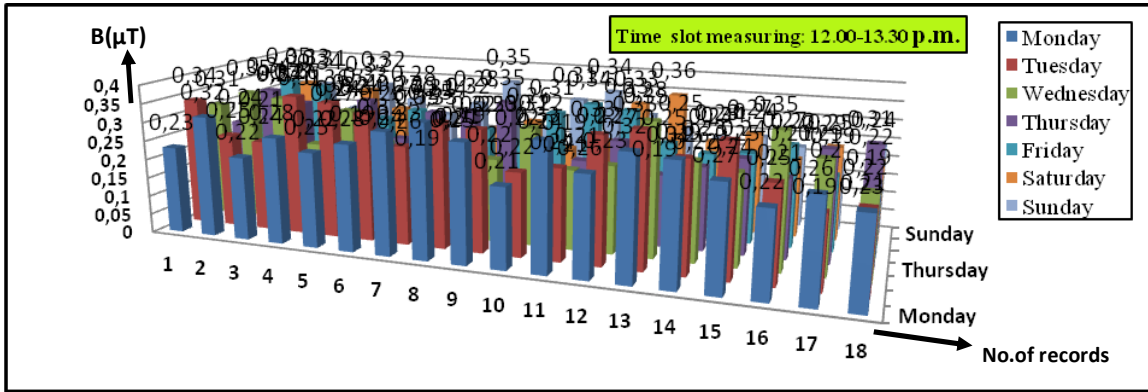


Figure 3. Measured values of magnetic induction for control room of PS Mecanica Oradea[μT]

$$M_{Z_{D_{tk}}} = \frac{B_{t_1} + B_{t_2} + \dots + B_{t_{18}}}{t_k}, \quad (1)$$

where B_{tk} = maximum values recorded in time moment t_k from daily range considered; coincides with order number of registration, $k = 1 \dots 18$ and t_k = the time at which takes a measurement.

Thus, for PS Mecanica daily average values for the magnetic induction in period of time analyzed, successively applying equation (1) will result on working days following values:

Monday $M_1 = 0,29 \mu T$; Tuesday $M_2 = 0,285 \mu T$; Wednesday $M_3 = 0,272 \mu T$; Thursday $M_4 = 0,271 \mu T$; Friday $M_5 = 0,259 \mu T$; Saturday $M_6 = 0,258 \mu T$ and Sunday $M_7 = 0,265 \mu T$.

Figure 4 shows the graphical variation of the daily magnetic induction for control room of PS Mecanica Oradea as arithmetic mean. Considered for the total duration of one week, calculate the arithmetic mean recorded for magnetic flux density maximum values in the measuring point and the considered time.

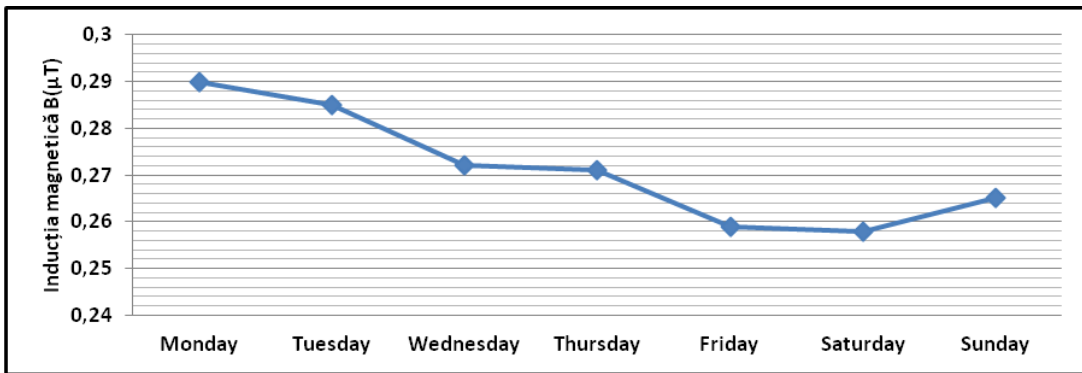


Figure 4. The graph of daily exposure in magnetic field for the operators from the control room of PS Mecanica as arithmetic mean

Applying successively the next relation:

$$M_{S_{B_{zn_{tk}}} = \frac{B_{z_1} + B_{z_2} + \dots + B_{z_n}}{n}, \quad (2)$$

in which,

B_{zn} is daily maximum value of magnetic induction in the measure point p and order of time moment considered $k(t_k)$, with $n = 17$ that is the number of week day; $t_k = 1 \dots 18$, will calculate the average of these values of B .

For exemple, in the first moment of time t_1 , will result:

$$M_{SB1} = \frac{0,23+0,34+0,31+0,24+0,21+0,27+0,26}{7} = \frac{1,96}{7} = 0,266 \mu T \quad (3)$$

For other considered time moments were obtained the following results: time moment t_2 : $M_{SB2} = 0,321 \mu T$; at t_3 : $M_{SB3} = 0,304 \mu T$; at t_4 : $M_{SB4} = 0,291 \mu T$; at t_5 : $M_{SB5} = 0,293 \mu T$; at t_6 : $M_{SB6} = 0,247 \mu T$; at t_7 : $M_{SB7} = 0,248 \mu T$; at t_8 : $M_{SB8} =$

0,297 μT ; at t_9 : $M_{SB9} = 0,271 \mu\text{T}$; at t_{10} : $M_{SB10} = 0,256 \mu\text{T}$; at t_{11} : $M_{SB11} = 0,270 \mu\text{T}$; at t_{12} : $M_{SB12} = 0,242 \mu\text{T}$; at t_{13} : $M_{SB13} = 0,291 \mu\text{T}$; at t_{14} : $M_{SB14} = 0,254 \mu\text{T}$; at t_{15} : $M_{SB15} = 0,264 \mu\text{T}$; at t_{16} : $M_{SB16} = 0,247 \mu\text{T}$; at t_{17} : $M_{SB17} = 0,248 \mu\text{T}$; at t_{18} : $M_{SB18} = 0,231 \mu\text{T}$. The total average value of magnetic flux density for a week, between the hours looked in case of PS Mecanica control room will result by applying the relation 4:

$$M_{ST} = \frac{\sum_{k=1}^{18} M_{SBk}}{18} = \frac{4,841}{18} = 0,269 \mu\text{T} \quad (4)$$

Applying procedure described above will result in average weekly values of magnetic induction that characterizes magnetic field exposure of all operators of power stations considered. These energy objectives listed in Figure 5.

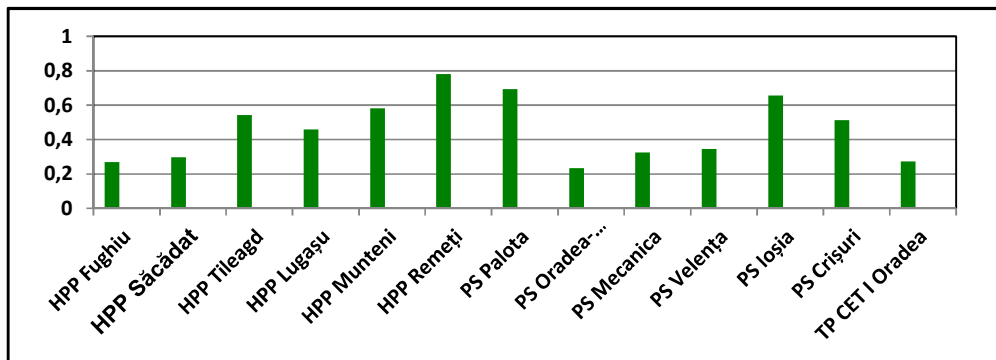


Figure 5. The chart of the exposure degree in magnetic field for all staff categories analyzed

To identify the spatial distribution of the electromagnetic field in the occupational environment, for control rooms of HPP, we designed a cubical scheme by measure. It has the form from Figure 6. In The center of formed structure is falls the operator during the supervision of installations from power plants structure, at the control panel (figure 7). The dimensions of cubic network, are $L \times W \times H = 2 \times 2 \times 2 \text{ m}$.

Each elementary cube has width by 50 cm. To obtain measuring points according to the dimensions of the structures created were used two graduated rulers and a team of three operators. The rulers have markings from 50 to 50 cm and are fitted with device for measuring angles and inclines (level with oil and air bubbles) attached to their ends (laser telemeter - BOSCH PLR 50).

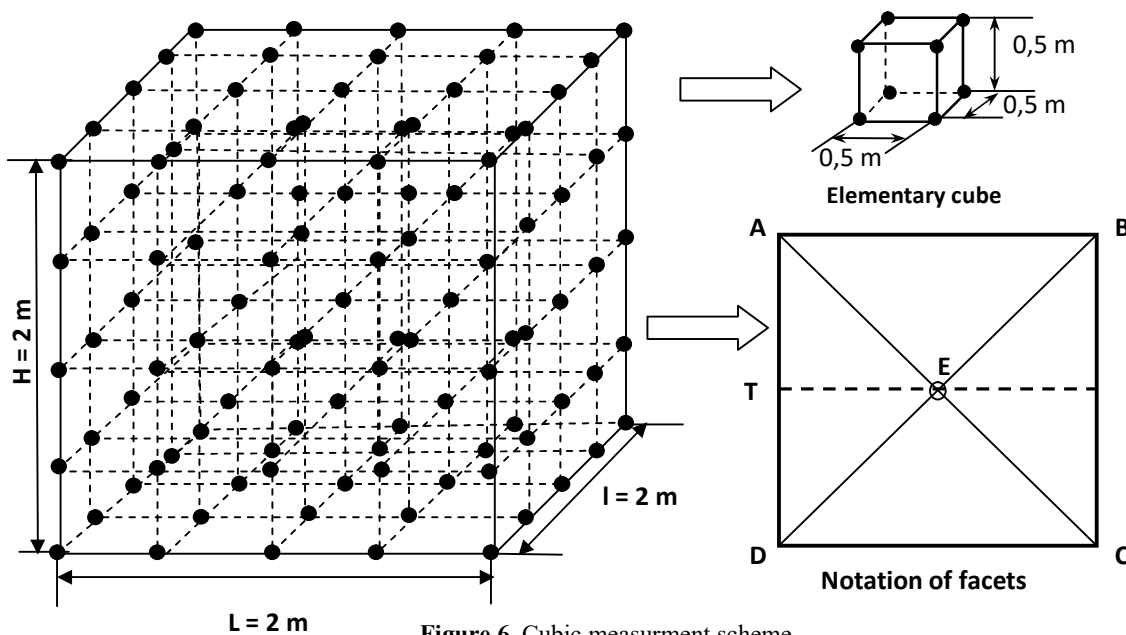


Figure 6. Cubic measurement scheme

By scheme analysis result the following components: the number of elementary cubes on a facet $N_{CEF} = 16$; The total number of elementary cubes $N_{TCE} = 64$, F_n - lateral facets, n - number of

lateral facets; L is the length and direction of the current measurement; Will arise 6 lateral facets and 3 independent horizontal and vertical sections inside the cube having identical measuring points in certain

directions. T denotes the route of measure. The scheme of measure points of the values for magnetic

field in the control room of Fughiu HPP, is shown in Figure 7.

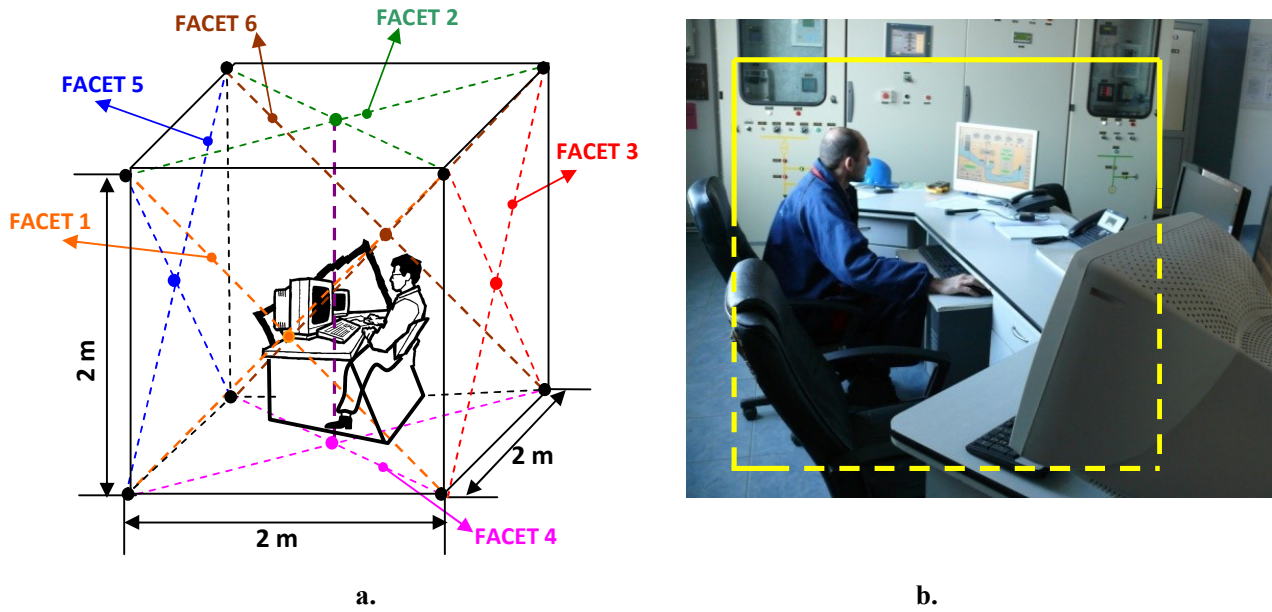


Figure 7. The location of the operator in the measure cubic area: (a)- linear drawing, (b) – photographic scheme

The measure Schemes for two facets of the cubic structure, indicating directions and points of measurement are shown in Figure 8. Following the implementation of the scheme resulted 25 measuring points for each facet, but since some points coincide,

being common to two adjacent facets, the total number of measuring points resulting is equal to 137. The results for the two cases are presented in tables 2 and 3.

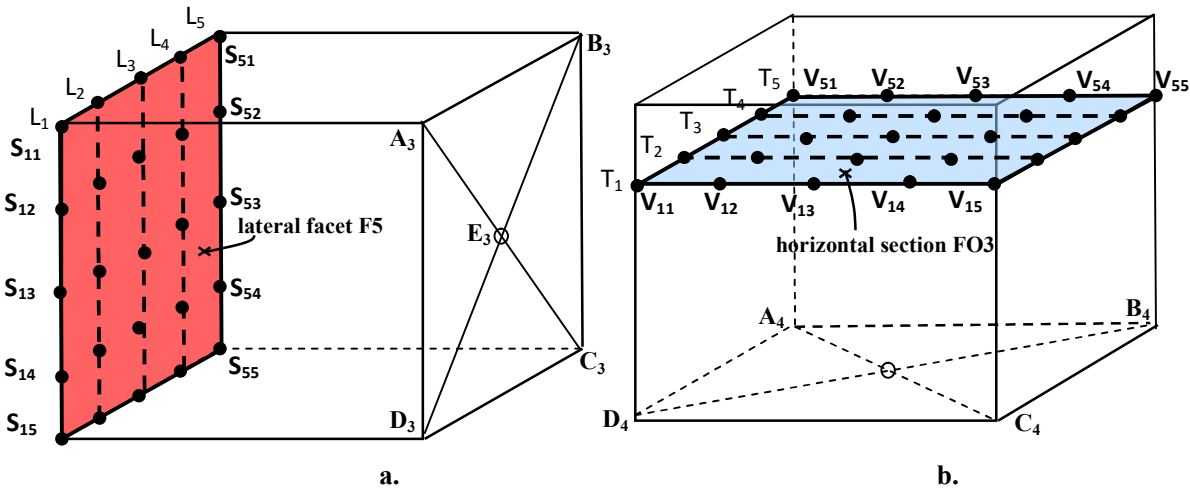


Figure 8. Measurement scheme for lateral facet F5(a) and horizontal section FO3(b)

Table 2. Magnetic induction values for measure points corresponding facet F5

Measurements results for facet 5(F5)										
Nr. crt	L ₁ – F ₅		L ₂ – F ₅		L ₃ – F ₅		L ₄ – F ₅		L ₅ – F ₅	
	S	B[μT]	S	B[μT]	S	B[μT]	S	B[μT]	S	B[μT]
1	S ₁₁	0,18	S ₂₁	0,15	S ₃₁	0,12	S ₄₁	0,17	S ₅₁	0,14
2	S ₁₂	0,18	S ₂₂	0,12	S ₃₂	0,21	S ₄₂	0,21	S ₅₂	0,11
3	S ₁₃	0,09	S ₂₃	0,56	S ₃₃	0,67	S ₄₃	0,24	S ₅₃	0,21
4	S ₁₄	0,09	S ₂₄	0,34	S ₃₄	0,32	S ₄₄	0,09	S ₅₄	0,23
5	S ₁₅	0,08	S ₂₅	0,35	S ₃₅	0,24	S ₄₅	0,12	S ₅₅	0,34

Table 3. Values for magnetic induction of measuring points corresponding horizontal section FO₃

Measurements results for horizontal section 3 (FO ₃)										
Nr. crt	L ₁ – FO ₃		L ₂ – FO ₃		L ₃ – FO ₃		L ₄ – FO ₃		L ₅ – FO ₃	
	V	B[μT]	V	B[μT]	V	B[μT]	V	B[μT]	V	B[μT]
1	V ₁₁	0,11	V ₂₁	0,15	V ₃₁	0,12	V ₄₁	0,17	V ₅₁	0,14
2	V ₁₂	0,12	V ₂₂	0,12	V ₃₂	0,21	V ₄₂	0,21	V ₅₂	0,11
3	V ₁₃	0,09	V ₂₃	0,56	V ₃₃	0,67	V ₄₃	0,24	V ₅₃	0,21
4	V ₁₄	0,07	V ₂₄	0,34	V ₃₄	0,32	V ₄₄	0,09	V ₅₄	0,23
5	V ₁₅	0,06	V ₂₅	0,35	V ₃₅	0,24	V ₄₅	0,12	V ₅₅	0,34

The values shown in the tables are averages of the maximum momentary values measured for same point for 5 days in the same time slot.

4. ASSESSING OF THE EXPOSURE DEGREE TO ELECTRIC AND MAGNETIC FIELD OF THE WORKERS FROM URBAN ELECTRIC TRACTION DOMAIN

The second category of employees consists of drivers of electric traction vehicles belonging to local transportation system of the city of Oradea. Magnetic induction measurements were performed in motorman cabins for each type of existing tram. To establish the electromagnetic environment in which is exposed trams driver were measured and recorded values of magnetic induction when the tram left the depot to enter the daily transportation service up to the terminal station of the bus line. The final point is return station Nufărul. It has traveled a distance of about 1.9 km, speed of each tram of variations in the range 0-25 km / h.

There was not produced a passenger load, in the tram being present only two persons: the motorman

and the operator of the measuring device. Were registered a total of 25 measurements for each type of tram scroll taken throughout the route, at times covering all regimes of speed. Scroll route times fall in the range 5 to 12 minutes including all three types of trams. The values obtained are presented in Figure 9. For each type of tram was conducted average of values for magnetic induction resulting in the exposure of each motorman. These values are shown in the exposure graph from Figure 10.

5. ASSESSING OF THE EXPOSURE DEGREE TO ELECTRIC AND MAGNETIC FIELD FOR THE GENERAL POPULATION

The general population may be exposed more often in the electromagnetic field produced by electrical household appliances, mobile telephones or public electricity grids. In order to assess general population exposure are examined some portions of high voltage overhead power lines(PL), which crosses the city of Oradea. The investigated apertures of PL are located in residential areas or situations with large agglomerations of population.

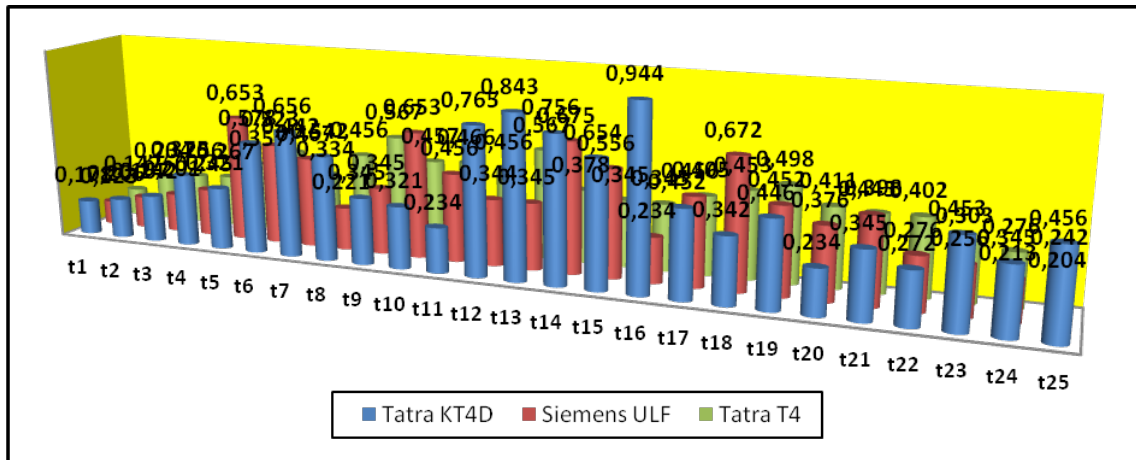


Figure 9. Measured values of magnetic induction in the tram drivers cabin[μT]

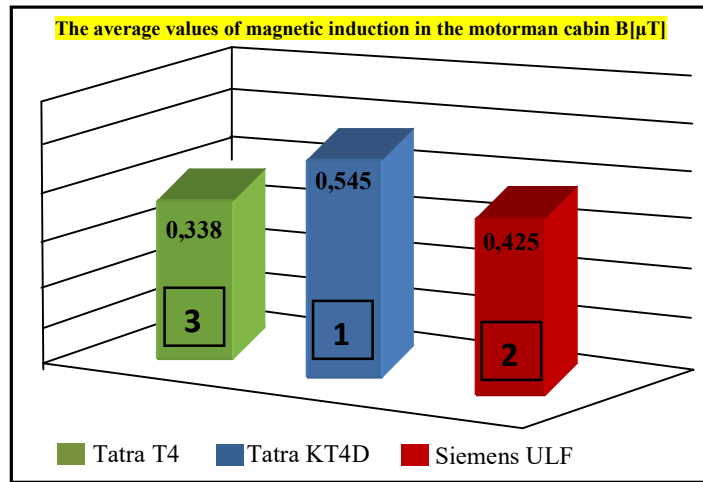


Figure 10. The Chart of magnetic field exposure for tram drivers

The following figures (figure 11 and figure 12) shows the values of the electromagnetic field for apertures cases analyzed. In the territory of city of Oradea are 13 high voltage overhead power lines on the 110 kV level, double and simple circuit type.

The apertures (A_n , n = order of the aperture) considered have the next significance: A_1 of PL 1 – the portion between poles (P_k , k = order of the pole or pillar) P_5 - P_6 on fruit - vegetable market territory - Oradea West; A_2 of PL 1 – the portion between poles P_{11} - P_{12} on the territory of the university campus between the sports hall and the new student hostel; A_3 of PL 1 – the portion between poles P_{12} - P_{13} on auto market territory; A_4 of PL1 – the portion between poles P_{14} - P_{15} Radu Enescu Street, from the neighborhood Calea Aradului; A_1 of PL 2 – the

portion between poles P_1 - P_2 on Oneștilor Street territory, Ioșia Nord neighborhood, in the vicinity of Supermarket Lidl; A_2 din PL 2 – the portion between poles P_3 - P_4 on the territory of Oneștilor Street in the vicinity of Sovata Bridge; A_1 of PL 3 – the portion between poles P_1 - P_2 , on territory of Mecanicilor Street in the vicinity of Company Adeplast, at the exit of PS Mecanica; A_2 of PL 3 – the portion between poles P_{13} - P_{14} on territory of Gurghiului Street in neighborhood Episcopia Bihor. Permissible exposure limit values for electric and magnetic field, for the general population at low frequency (50 Hz) are [6]: $E_{lim} = 5000 \text{ V / m}$; $B_{lim} = 100 \mu\text{T}$. For PL the measuring points are located under the conductors at the height of 1 m and 1.7 m from the ground.

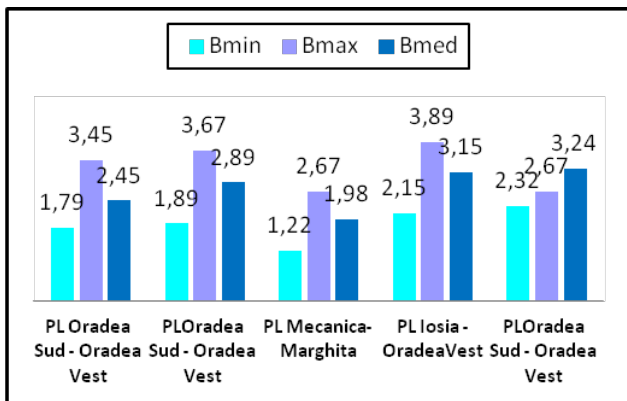


Figure 11. Values of magnetic induction [μT], for apertures considered

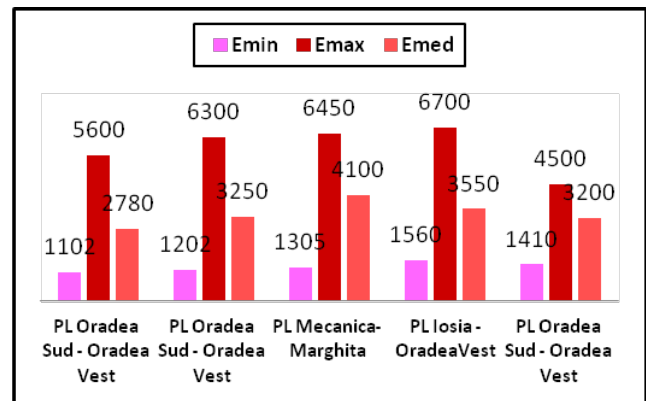


Figure 12. Values of electric field intensity [V / m], for apertures considered

6. DISSCUSSION

Purposes of determining the average daily exposure of operators in each objective analysed is to identify which is the day with the highest load current installations converging in control rooms as well as occupational exposure days hierarchy

specific to each job. For a better rendering of real electromagnetic environment and to highlight as faithful to the values of maximum quantities of electric and magnetic field, it is necessary that between the period chosen for measurements and the dynamic of electromagnetic processes inside spaces investigated, to be a good correlation. For this

purpose must that achievement of the total duration of measurements, covering several stages, within a year of the calendar. The number of measurements must be greatly expanded, to be caught all operating modes of the existing electrical circuits in the control room.

By determining the weekly average of maximum flux density values related to each measuring point for each day and for all workspaces investigated, it could assess which is the level of exposure of workers.

7. CONCLUSIONS

In the context of scientific uncertainty regarding the effects of exposure to electromagnetic fields advisable to adopt the precautionary principle by implementing administrative measures, inform and train the population and employees, especially persons at risk of exposure sources and not least support from policy the decision on the development of an adequate logistics monitoring electromagnetic fields and their effects in the long term. Analyzing the values resulting from measuring the electric field intensity and magnetic induction, sizes that allow assessing the degree of electromagnetic field exposure of workers and the general population can draw the following conclusions:

- by making the spatial distribution of the cubic form, we can say that is the area where magnetic induction values are higher and therefore the source of generating a magnetic field; for control room of Fughiu HPP was observed that these values are above the floor of the level of 2 m above it, in all directions of measurement; in this case power cables pass through that area in cable beds, being positioned immediately below the floor;
- for tram drivers is established that measurements are performed under the most exposed are those who drive trams TK4D type, where the average value of the magnetic induction is 0.545 μT ;
- for overhead power lines (PL) the largest electric field strength values were recorded for the second aperture of line between PS Oradea West and PS Sinteza Ioșia, that reached to 6700 [V / m] in the place where clearance gauge is minimum.

From point of view of average values of field sizes calculated for each case, one can say that they do not exceed the normal limits in terms of adverse health effects at the distances considered to sources. However, there are a few areas into installations where are exceeded the threshold values for both

electric field strength and magnetic flux density. There have been several values over 5000 [V / m], in the case of PL when measuring points are located under conductors. Analyzing the graphs exposure is found fluctuations between the values obtained for the various locations investigated.

REFERENCES

- [1]. Drăgulescu A - *Idolii fără fir. Telefonie mobilă și poluarea electromagnetică*, Editura Christiana, București, 2010;
- [2]. Milham S., 2012, *Dirty Electricity, Electrification and the Diseases of Civilization*, Publisher: Universe Star, New York, U.S.A., ISBN 13: 9781938908187, ISBN 10: 193890818X;
- [3]. Morega Mihaela - *Bioelectromagnetism*, Editura Matrix Rom, București, 1999;
- [4]. Păunescu Gabriela, 2010, *Câmpul electromagnetic. Studii asupra posibilelor efecte ale câmpului electromagnetic asupra sănătății*, www.infoscola.webgarden.ro, ISBN 978 - 973- 0-07974- 6;
- [5]. *** Hotărârea Guvernului României Nr. 1136 din 30.08.2006 privind cerințele minime de securitate și sănătate referitoare la expunerea lucrătorilor la riscuri generate de câmpuri electromagnetice;
- [6]. *** Hotărârea Guvernului României Nr. 1193 din 29.09.2006 privind limitarea expunerii populației generale la câmpuri electromagnetice de la 0 la 300 GHz;