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RISK ASSESSMENT OF THE DAMAGE ON THE HUMAN BODY EXPOSED TO ELECTROMAGNETIC FIELD OF EDUCATIONAL INSTITUTIONS

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Abstract - The paper is structured in five parts. In the first part is presented the specific issues of risk level evaluation. Part two consists of a bibliographical summary regarding the electromagnetic field (EMF), emphasizing EMF with industrial frequency. In the third part is given the methodology proposed and applied by the authors to make an assessment of risk level at which is exposed the human body in EMF. The fourth part includes the results summary, referring on the measured magnitudes and the values of risk level obtained by applying the proposed models. The results refer at two case studies conducted by the authors in public domain.

Key words: electromagnetic field, effect, evaluation, modelling, risk

1. INTRODUCTION

According to [1] the risk means "the possibility of reaching a danger, of having to face a trouble or suffered a loss, potential danger" (derived from the French risque). The notion of risk is used in many fields [2] (9-10), [3] (245-251), [4] (pp.215-216), with different connotations, sometimes improperly. According to the defined notion [1] (pp. 223-224), the risk is related to a random event (uncertainty) and to a specific hazard.

In the electro-energy area the risk theory had been developed, especially in relation to nuclear power plants. Are well known [3] (251-266) the theories and methods of risk assessment in the nuclear area (Farmer, Otway, Rasmunsen). We believe that, with reference to technical systems, risk analysis is ideal for those cases where life, health or human comfort level may be endangered.

Risk analysis involves: identifying risk factors, assessing the level of risk and risk management. Risk factors are practically the causes that lead to the initiation and propagation of an undesirable event. The establishment and the spread of risk has generally two sequences (Fig. 1): inherent risk (initial or initiator) and associated risk (concourse risk).

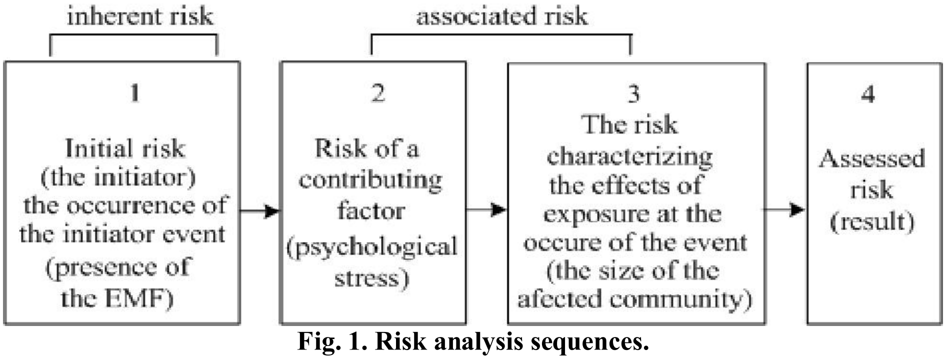

Fig. 1. Risk analysis sequences.

The assessment of the level of risk involves determining the values of following:

- the probability of occurrence (*p*) of the unwanted event, in the analysis period;
- the frequency of occurrence (*f*) of the undesirable event in the analysis period;
- the size (gravity) of the effect (*k*).

The size of the consequences is assessed, in instance, depending on: the impact over life and/or health of people (social consequences), the environmental impact (ecological consequences), the economic impact (losses).

Risk management involves anticipating the possibilities of occurrence, the coordination of actions to minimize the consequences.

A key direction in power systems risk management is the protection against accidents and illness caused by the interference of some disturbance agents in the working environment.

2. LAYOUT OF THE EFFECTS OF THE EMF

The problem of the biological effects of electromagnetic fields is discussed for over four decades, the international scientific community is still seeking a definitive answer. In general, it's analysed, separately, the effects of low frequency fields 50 Hz or 60 Hz and the effects of high frequency electric fields (0.9 - 1.9) GHz [5-7]. The effects of electric and magnetic fields (EMF) on living organisms it's due to the conversion of their energy into other forms of energy (thermal, mechanical, electrical, chemical, etc..) inappropriate for the organism. Serious consequences certainly occur [8, 9] during the long-term exposure to EMF of a certain intensity, but in case of dynamic tension to the organism (changes caused by short circuits or atmospheric discharges, changes caused by a oscillating system in relation to EMF). The risk of serious consequences may be magnified if, in addition to the initial risk factor (EMF), there are additional factors (eg psychological stress, some degradation of general health, etc.). Thermal effect of EMF on biological systems is well known currently, more difficult to quantify are the others effects of EMF (mechanical, chemical, electrical) which can influence the exchange of information with the outside over plasma membranes or may have the opposite effect of heating [6, 8].

The main physical phenomena that characterize the exposure in electric field are [1] (pp. 224-236), [10]: direct perception, the accumulation of electric charge by induction or influence respectively the load variation in transient. Parameters characterizing the biological effects of the exposure of the human body in electric field are: electric field (*E*) and induced current density (*J*). The presence of the human body affects the spatial distribution of an electric field. Analysis of effects is conducted by evaluating the two parameters (*E, J*), and applying the laws of electrical engineering [11] (pp.11-19), given the quantities of material values (conductivity and permittivity). In assessing the effects of electric field on the human body are important, both value, and current distribution. These size ratings are used to assess simulation methods and experimental approaches based model.

Characteristic parameters for the biological effects of magnetic field, are induction (*B*) and induced current density (*J*). The link between the two parameters is based on the law of electromagnetic induction and electric conduction law, having as a influence factor equivalent conductivity of the human body [10].

For the most common case where there is insulation (shoes) between the person and the ground, current intensity through the body area at (a) height from the ground, is expressed as:

$$\mathrm{I(a)} = 5.4 \cdot 10^{-9} \cdot \mathrm{h}^2 \cdot \mathrm{E}_0 \cdot \frac{\mathrm{f}}{50} \cdot \mathrm{g(a/h)} \cdot \left[1 - \frac{\mathrm{U}_{0\mathrm{p}} \cdot \mathrm{g(a/h)}}{\mathrm{E(h/2)}} \right] \qquad (1)$$

Where: h – is the height of the person;

E_0 - undisturbed electric field intensity;

f - frequency;

g (a / h) - the body fraction point of calculating (ranging from 1 in the top of the head to 0 at the top of the feet);

U_{0p} - the tension between person and the ground.

Currently, it operates primarily with the accepted limits of certain sizes (*E_a, B_a*) easily measurable limits based on thermal effect of EMF on the human body. A key parameter used in setting the allowable limits is "specified rate" of power absorption [9, 12, 13]:

$$RSA = \frac{d}{dt}\left(\frac{dW}{\gamma \cdot dV} \right) = \frac{\sigma \cdot E_i^2}{\gamma} \qquad (2)$$

dW - the amount of energy dissipated / absorbed;

dV - volume element;

γ - biological tissue density;

E_i - electric field intensity in tissue.

There are several organizations, internationally recognized [12-14], which sets acceptable limits for size (*E, B*) starting from the fact that the RSA indicator can not be measured directly for professional and public area. International Commission on Non-ionizing Radiation Protection (ICNIRP) is a nongovernmental organization whose acts, based on a broad consensus on the scientific results of the protection against the effects of EMF are recommended by the EC and are the basis of national standards.

This paper refers to the EMF of industrial frequency (50 Hz) of professional and domestic, in which case, the permissible values are shown in [12-15].

3. METHODOLOGY TO ASSESS THE LEVEL OF RISK

To assess the level of risk we assess the probability (*p*) that the values measured, electric field intensity (E_m) and magnetic induction (B_m), to exceed the acceptable values (E_a, B_a) of this sizes. Evaluation will be done in two assumptions:

IP1: permissible values are fixed, specified in the law;

IP2: permissible values are, in fact, the average of some random variable sizes;

Hypothesis 2 is justified on the grounds that, in the presence of EMF response body is differentiated according to the characteristics of intrinsic and extrinsic factors influence. It's natural to assume a dispersion limit of eligibility, due to differential characteristics of human beings (individuals) and favoring factors variation.

The measured values (E_m, B_m) act like a string of variable sizes that fall, naturally, in the normal distribution with the parameters: medium value (*m*) and dispersion (σ) [4] (pp. 27-29). For this reason, for assessing the risk, we work with normal distribution, using appropriate models of the two hypotheses.

For the first hypothesis the representation of Fig.2 is valid, for the second one the representation of Fig 3. For the second hypothesis we consider the accepted sizes (E_a, B_a) random variables with normal distribution. The following equivalences are: $X \equiv \{E, B\}$, $X_a \equiv \{E_a, B_a\}$ şi $X_m \equiv \{E_m, B_m\}$.

Relations for calculating the risk level (p_1, p_2) for the hypothesis IP1, respectively IP2 are:

$$p_1 = \frac{1}{\sqrt{2 \cdot \pi} \cdot \sigma_{Xm}} \int_{X_a}^{\infty} e^{-\frac{(X_m - m_{Xm})^2}{2 \cdot \sigma_{Xm}^2}} \, dX_m \qquad (3)$$

$$p_2=\frac{1}{\sqrt{2\cdot\pi\cdot\sigma_{Xm}}}\int_{X_i}^{\infty} e^{-\frac{(X_m-m_{Xm})^2}{2\sigma_{Xm}^2}}\,dX_m+\frac{1}{\sqrt{2\cdot\pi\cdot\sigma_{Xa}}}\int_{-\infty}^{X_i} e^{-\frac{(Xa-m_{Xa})^2}{2\sigma_{Xa}^2}}\,dX_a \qquad (4)$$

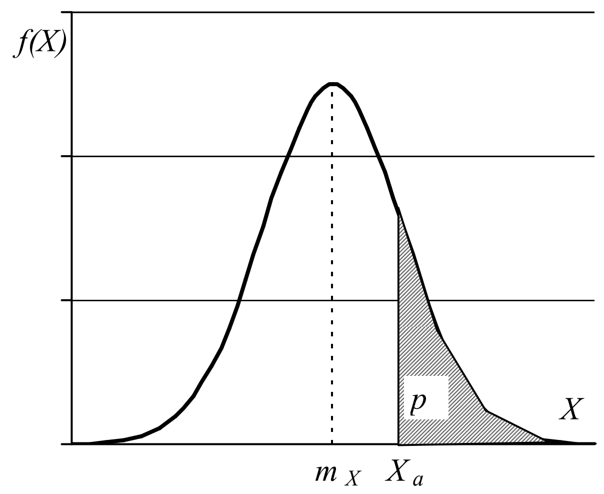

Fig. 2. Risk assessment in IP1.

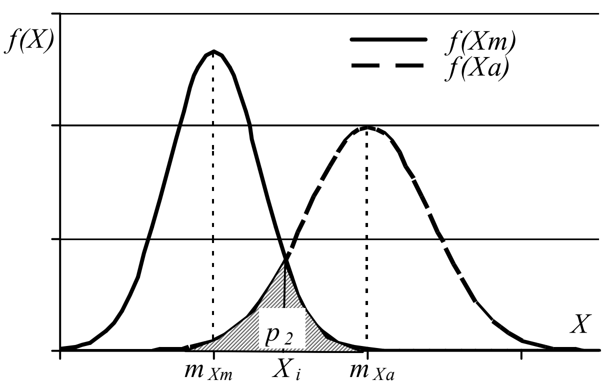

Fig.3. Risk assessment in IP2

(4)

Methodology for assessing the risk level was applied with reference to two investigated areas:

- educational facilities of the University of Oradea (public domain ≡ case study 1);
- educational facilities in Samuil Vulcan High School in Beiuş (public domain ≡ case study 2).

The instrument used for making the measurements was teslameter CA 40 GAUSSMETER. Plants operate at low voltage, which means that the electric field (Em) is negligible and is not under investigation in this work. There have only been measuring the magnetic induction in both indoor (classrooms, laboratories, offices, access roads, gyms) and outdoor (the interior yard and sports fields).

4. THE RESULTS OBTAINED

The work has been summarized in graphical form (for example) and tables, the results obtained in the two case studies. A feature of the two case studies is to allow a dispersion equal to allowable values and measured ($\sigma_{Em}=\sigma_{Ea}$, $\sigma_{Bm}=\sigma_{Ba}$), the hypothesis 2. Permissible limit values, as recommended [13-16], are presented in table 1 and table 2 (m_{Xa}).

For case study 1 were performed 522 indoor measurements at a height of 1 meter (261 measurements) and at a height of 2 meters (261 measurements). The results are shown in Fig. 4, Fig.5 and Table 1

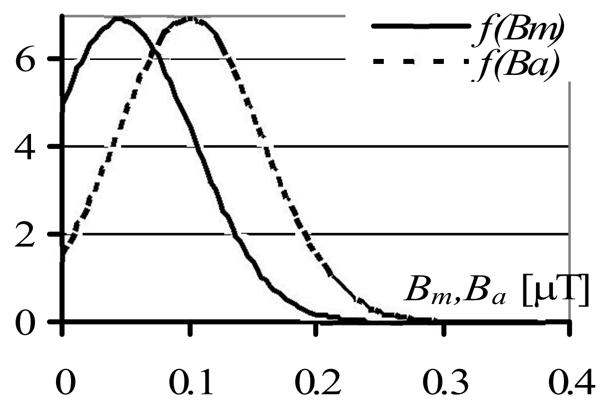

Fig.4. FDP for (*B*), indoor,at a height of 1 m – case study 1

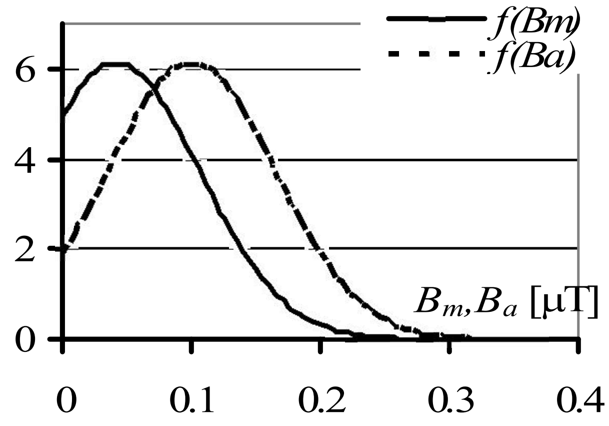

Fig.5. FDP for (*B*), indoor, at a height of 2 m – case study 1

Table 1. The average values (m_{Xm}, m_{Xa}), dispersion (σ_{Xm}, σ_{Xa}) and risk (p_1, p_2) for case study 1

Indoor measurement for magnetic induction (*B*)		at a height of 1m	at a height of 2m
Measured size (B_m)	m_{Bm} [μT]	0.046	0.041
	σ_{Bm} [μT]	0.057	0.065
Accepted size (B_a)	m_{Ba} [μT]	0.100	0.100
	σ_{Ba} [μT]	0.057	0.065
p_1		0.1759	0.1848
p_2		0.6119	0.6091

Table 2.

Indoor measurement for magnetic induction (B)	Measured size (B_m)		Accepted size (B_a)		p_1	p_2
	m_{Bm} [μT]	σ_{Bm} [μT]	m_{Ba} [μT]	σ_{Ba} [μT]		
at a height of 1m	0.046	0.057	0.100	0.057	0.1759	0.6119
at a height of 2m	0.041	0.065	0.100	0.065	0.1848	0.6091

Table 1 and Table 2 presents the average and dispersion of the measured and admissible distributions, as the risks (p1, p2) for magnetic induction (B) in case study 1, case study 2 respectively.

Case Study 2 contains 4562 measurements from which 1055 outdoor and the 3557 indoor at a height of 1 meter (207 measurements outdoors and 1177 indoors), at 2 meters (663 outdoor and 1206 indoor) and at 2.5 meters (135 outdoor and 1174 indoor). FDP functions ($f(B_m)$ and $f(B_a)$), for case study 2 are represented in fig. 6 and fig.7 and the characteristics of distributions in Table 2

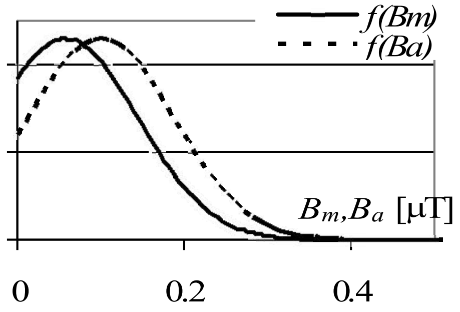

Fig.6. FDP for (B), indoor,at a height of 1 m – case study 2

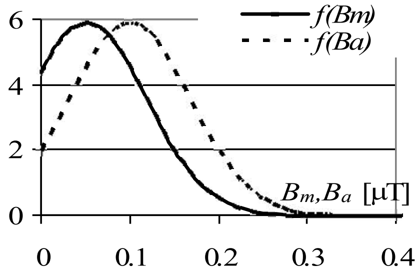

Fig.7. FDP for (B), indoor, at a height of 2 m –case study 2

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Table 2 The average values (m_{Xm}, m_{Xa}), dispersion (σ_{Xm}, σ_{Xa}) and risk (p_1, p_2) for case study 2

Measurements outdoor for (B)		Outdoor at a height of 1 meter	Outdoor at a height of 2 meter	Outdoor at a height of 2.5 meter
Measured size (B_m)	m_{Bm} [μT]	0.030	0.095	0.017
	σ_{Bm} [μT]	1.003	0.159	0.027
Accepted size (B_a)	m_{Ba} [μT]	0.100	0.100	0.100
	σ_{Ba} [μT]	1.003	0.159	0.027
p_1		0.4723	0.5339	0.0011
p_2		0.4889	0.8068	0.1238
Measurements indoor for (B)		Indoor at a height of 1 meter	Indoor at a height of 2 meter	Indoor at a height of 2.5 meter
Measured size (B_m)	m_{Bm} [μT]	0.057	0.051	0.053
	σ_{Bm} [μT]	0.086	0.067	0.069
Accepted size (B_a)	m_{Ba} [μT]	0.100	0.100	0.100
	σ_{Ba} [μT]	0.086	0.677	0.069
p_1		0.3112	0.2363	0.2492
p_2		0.7204	0.6714	0.6839

Table 2

Measurements indoor and outdoor for (B)	Measured size (B_m)		Accepted size (B_a)		p_1	p_2
	m_{Bm} [μT]	σ_{Bm} [μT]	m_{Ba} [μT]	σ_{Ba} [μT]		
Outdoor at a height of 1 meter	0.030	1.003	0.100	1.003	0.4723	0.5339
Outdoor at a height of 2 meter	0.095	0.159	0.100	0.159	0.4889	0.8068
Outdoor at a height of 2.5 meter	0.017	0.027	0.100	0.027	0.0011	0.1238
Indoor at a height of 1 meter	0.057	0.086	0.100	0.086	0.3112	0.7204
Indoor at a height of 2 meter	0.051	0.067	0.100	0.677	0.2363	0.6714
Indoor at a height of 2.5 meter	0.053	0.069	0.100	0.069	0.2492	0.6839

5. CONCLUSIONS

Issues concerning the risk of disease from exposure to EMF of the electricity networks operating staff and the educational institution operating staff are complex, not yet categorical responses can be defined and require deep study with the participation of specialists in the areas concerned: engineers , doctors, biologists, psychologists.

The level of electromagnetic pollution of examined areas was appreciated by comparing the measured values of magnetic field induction (B_m) and electric field intensity (E_m), with the permissible values.

If tests carried out in educational areas shows very high values of measured magnetic field induction (B_m) vs. normal (B_a), that leads to considerable risk whatever the chosen hypothesis is.

We point out that, in addition to the threshold of admissibility involving some customization and could lead to higher levels of risk, another variable that may lead to an evolution in the same direction is the intensity of electric current. Plants investigated, as most electricity networks in Romania, working in subnominală task. Increasing stabilized or momentary load currents cause increased levels of induction of magnetic field which increases the risk of disease by exposure to EMF.

The results also justify the reverse question: is allowable levels for induction (B_a) unreasonably low? These results and questions once again confirms the need to continue and deepen the studies on the impact of EMF on the human body.

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