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Influence of non-ionizing radiation of ELF fields

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***Abstract*—This research paper analysis regulations and standards related to electromagnetic radiation. Also, presents the overview of harmful effects of the electromagnetic fields on people and on the environment in general, with the focus on the extremely low frequency ELF fields of 50Hz, measures for environmental protection of the field effects, as well as the legislation regulating the issue of protection for non-ionized radiation. The aim is to promote activities so as to normatively regulate the protection from electromagnetic radiation in North Macedonia.**

Keywords—electromagnetic radiation; low frequency; standards; measuring

I. Introduction

Power line EMF is classified as extremely low frequency (ELF) radiation. The lower the frequency, the longer the wavelength. In the 1970s many scientists believed that ELF electromagnetic radiation could not possibly have any biological effects, damaging or otherwise, because it was thought that the long wavelength would prevent its interaction with a relatively small body such as a human being. (The wavelength of a 50 Hz power wave is 6000 km.)

II. Regulations And Standards

The most famous international organizations that prescribe standards related to electromagnetic radiation [1] are:

- The International Commission on Nonionizing Radiation Protection ,ICNIRP, (http://www.icnirp.org)
- Comite´ Europe´en de Normalization Electrotechnique European Committee for Electrotechnical Standardization CENELEC, subclause SC111, http://www.cenelec.org)
- The International Electrotechnical Commission IEC, (http://www.iec.ch)
- Directive 2004/40/EC of the European Parliament http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:184:0001:0009:EN:PDF

Recommendations for the permitted levels of exposure to electrical and magnetic fields have also been reported by the International Radiation Protection Association (IPRA) and the World Health Organization (WHO).

The standards and recommendations of these institutions are the only criteria for harmfulness. But there are differences in permitted levels and time of exposure [2], [3].The status and background of each standard are related to several clear categories: there are real differences, which are dependent on the legal arrangements of individual states and factors influencing the establishment of standards. Political and social factors can play an important role as well as scientific factors. Other constraints are based on the position and structure of buildings in different countries.

International protection standards and recommendations prescribe permissible exposure limits characteristic magnitudes of the electromagnetic field. The prescribed limit levels are:

- Basic restrictions - the size of the interaction electromagnetic energy with biological tissue, expressed as SAR (specific rate absorption; W/kg) and current density J (A/m^2) induced in biological tissue.

- Reference levels - quantities that describe the incident electromagnetic field - electric field strength E (V/m), magnetic field strength H (A/m^2) and electromagnetic wave power density S (W/m^2)

Table 1 shows reference limit values according different standards and regulations.

TABLE I.

	Occupational		***Public***		***Current density***
	E (V/m)	B (µT)	E (V/m)	B (µT)	J (A/m^2)
ICNIRP (2010)	5	200	10	1000	2
IEEE	5	904	-	-	-
CENELEC (1995)	10	640	30	1600	-
EU	5	100	10	500	2

The basic requirement in protecting people from electromagnetic radiation is to satisfy the fundamental ones limitations. If limitations cannot be calculated or measured, the harmfulness assessment can be take a comparison with reference limit levels. In order to reduce the risk of possible harmful effects of electromagnetic radiation there are protective norms regulated by state and international recommendations. There are regulations that define limit values fields and forces to which humans may be exposed, and the values themselves vary with respect to the country, and about whether it is a general or working population. The most widely accepted international security standards were issued by an international association, the Institute of Electrical and Electronics Engineers (IEEE) and the International Commission on Non-Ionizing Radiation Protection (ICNIRP). IEEE C95.1-1999 regulations set the limits of the maximum allowable exposure (Max permissible exposure- MPE) for amounts of time-varying electric and magnetic fields in free space, and for appropriate power densities. The ICNIRP standard has equal approach, but defines the reference limit values of the electric and magnetic fields in free space. Both ordinances prescribe limit values above which people do not may be exposed to radiation. The limits prescribed by the IEEE regulations have been adopted in the US as well as in a few more countries, while most Western European countries have accepted the norms prescribed ICNIRP standards [4].

III. Legislative Regulation In Repuclic Of North Macedonia

According to the Rulebook on the minimum requirements for safety and health at work of employees from risks associated with exposure to physical agents (electromagnetic fields), published in the Official Gazette of RM number 40 dated 25.02.2014, the Ministry of Labor and Social Policy prescribed the minimum occupational safety and health requirements of employees from risks associated with exposure to physical agents (electromagnetic fields) during their operation from 0 Hz to 300 GHz.

Measurements and/or calculations of exposure to electromagnetic fields are plan and perform at regular intervals, from accredited laboratories in North Macedonia in this area, in accordance with MKS EN ISO/IEC 17025, and on the basis of which measurements and/or calculations a risk assessment is performed.

When preparing a risk assessment, care should be taken to:

- the level, frequency spectrum, duration and type of exposure;
- exposure limit values and exposure values at which they are take measures;
- impacts on the health and safety of employees at risk;
- indirect effects, such as: interference with the functioning of the medical electronic equipment and devices (including pacemakers);
- projected risk of ejection of ferromagnetic bodies in environment under the action of magnetostatic fields with magnetic flux density greater than 3 mT;
- initiation / activation of electro-explosive devices (detonators);
- fires and explosions as a result of ignition of flammable materials with sparks caused by induced fields, contact currents or electrical sparks emptiness;
- presence of additional equipment, designed to reduce the levels of exposure to electromagnetic fields;
- appropriate information obtained from the monitoring of the health status of employees;
- exposure to multiple sources;
- Simultaneous exposure of fields with different frequencies.

IV. Teoretical Calculation Of EM Fields

Nowadays, humans are exposed to all kinds of external electromagnetic fields. It is an indisputable fact that we are increasingly dependent on mobile phones, computers, external wiring and transformers, as well as electronic devices. No matter how much we are unaware or unwilling to be aware of their harmful effects, we should not ignore it. In the body of every living organism there is an internal electric field which is denoted by E_i, and it is directly proportional to the electric field in the air itself which exists next to the very surface of the human body which is denoted by E_o. These two fields are connected through the following relation:

$$E_i \cong \frac{2\pi f \varepsilon_o}{\sigma} * E_o \cong 10^{-7} * E_o \qquad (1)$$

where:

f - Frequency [Hz]

ε_o - Dielectric constant in vacuum

σ - Electrical conductivity of the body

Man himself is a good conductor, while electric force lines are always normal to the surface of the body. If we stand at a distance between two transmission lines, we will notice that the electric field is larger at the head because the head has a small radius, and is smaller at the feet. In addition to electricity, the human body also has a magnetic field caused by the action of induced electric fields, which can be more easily measured in humans. The difference between these two fields is explained by Ohm's law, which states that the density of current in the human body itself is always directly proportional to the electrical conductivity $\vec{J}$ and the electric field in the body $\vec{E}$.

$$\vec{J} = \sigma * \vec{E} \quad (2)$$

The equation that represents the relationship between the variable magnetic field, on the one hand, and the induced electric field, on the other hand, is called Faraday law (described in [5]) and is explained by the following equation:

$$rot\,\vec{E} = -\frac{\partial \vec{B}}{\partial t} \quad (3)$$

where;

$\vec{B}$ - Magnetic induction [T];

t – Time [s]

If we want to measure electromagnetic radiation in space through the spatial coordinates x, y and z, we will do it using the following equation (4) and (5):

$$\vec{E} = \sqrt{E_x^2 + E_y^2 + E_z^2} \quad (4)$$

$$\vec{B} = \sqrt{\vec{B}_x^2 + \vec{B}_y^2 + \vec{B}_z^2}$$

(5)

V. PRACTICAL MEASURMENT OF SING THE TEMPLATE

A. *Instrument*

For this purpose, I used the measuring instrument to check the value of the magnetic induction B and the value of the strength of the magnetic field H. The measuring device is 3D EMF TESTER, Model: EMF-828 shown in Fig. 1.

Lutron EMF-828 is a 3D electromagnetic field tester for low frequencies. Can be used to measure EMF nearby high voltage pylons, transformers, industrial high power machines etc. It has heavy duty separate probe, data hold, DC 9V battery, LCD display, three axis (X, Y, Z direction) electromagnetic field measurement, range: 20/200/2,000 micro Tesla, 200/2,000/20,000 milli-Gause and band width: (30-300)Hz.

This measuring device measures the electromagnetic field along three axes (x, y, z), and is designed to provide the user with a fast, reliable and easy way to measure the level of radiation of the electromagnetic field around power lines, electrical devices and industrial devices.

Fig. 1. The measuring instrument *3D EMF Tester EMF-828*

B. *Results of measuring*

TABLE II. TABLE STYLES

	0.6 m.	***1.5 m.***	***2.3 m.***
E_x (μT)	0.25	0.06	0.38
E_y (μT)	0.07	0.31	0.75
E_z (μT)	0.45	0.52	0.08
E (μT)	0.519	0.60	0.84

The upper table 2 shows the values of electromagnetic radiation caused by very low frequencies at a distance between two 20kV transmission lines. The measurements were performed in three positions, at a height of 60 cm from the ground, at 1.5 m and at a height of 2.3 m from the ground.

VI. ANALYSIS AND CONCLUSION

From the measurement results it can be concluded that the values obtained are much lower than allowed by regulations.

But for transmission lines with a higher voltage level, those values will increase. Also, beside the magnitude of the radiation values, the factor of radiation exposure time, which would be considered in further work and measurements, is also very important.

The distribution of the electric field in the vicinity of the transmission line in the presence of man shows that the presence of man deforms the lines of the field and that the human head is exposed to high values of electric field. This indicates the need to apply protective measures for workers working in substations, but also for the population living near the transmission lines.

In many countries around the world, various projects are implemented in order to solve the extremely complex problem, to assess human exposure to electromagnetic fields. The main goal of the current programs that are active in the EU countries is to inform and educate the population about the consequences of exposure to electromagnetic fields. The number of information brochures and measurement reports, which are also available online, is constantly increasing. One of the goals of the national programs in each country is to support the development of legislation from planning to the placement of new sources of electromagnetic fields in the environment. To determine the degree of human exposure, it is necessary to estimate the level of electromagnetic fields in the working and environmental environment, taking into account the sudden increase in the number of new artificial sources of radiation in the human environment.

Aaccording to EU recommendations, humans should not be exposed to magnetic induction greater than 100 µT. But on the other hand, this number does not take into account long-term exposure, so in Sweden, after many years of research, the maximum limit is 0.2 µT. Such recommendations and measurements should provide insight for further possible changes in the legislation in the Republic of North Macedonia, by stricter specification of exposures to electromagnetic fields, instead of recommendations intended only for employees exposed to this type of fields, they would also contain appropriate legal form for all citizens.

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