AN OVERVIEW OF THE HAZARDOUS EFFECTS OF INDUSTRIAL FREQUENCY ELECTROMAGNETIC FIELDS AND THE LATEST PERSONAL PROTECTIVE EQUIPMENT TO LIMIT THEM

Tretiakova L. D., doc. of tech. sc., Prof. (Dep. LPICS of Igor Sikorsky Kyiv Polytechnic Institute); Zarubin N. S., student (gr. EP-02, Faculty of Electric Power Engineering and Automatics of Igor Sikorsky Kyiv Polytechnic Institute)

Анотація. Під час проведення робіт на електроенергетичних об'єктах високої напруги (110-750 кВ) електротехнічні працівники потрапляють під вплив електромагнітного поля промислової частоти. Метою статті є оцінка рівнів небезпечного впливу та розробка підходів до створення засобів індивідуального захисту та захисного одягу. Запропоновано дизайн нового електропровідного одягу з композитного текстильного матеріалу, який використовується в поєднанні із засобами захисту голови, рук і ніг.

Ключові слова: високовольтні електроустановки, умови праці, матеріал і конструкція.

Abstract: When working at high-voltage electrical facilities (110-750 kV), electrical workers fall under the influence of the electromagnetic field of the industrial frequency. The purpose of the article is to evaluate the levels of hazardous effects and develop approaches to the creation of personal protective equipment and protective clothing. The design of the new conductive clothing made of composite textile material is proposed, which is used in combination with head, hand, and foot protection.

Keywords: high-voltage electrical installations, working conditions, material and construction.

Introduction. At the present time, the problem of electromagnetic safety and limiting the influence of the electromagnetic fields (EMFs) of the industrial frequency on human and on the environment have acquired urgent and social significance at the international and national levels. Taking into consideration the importance of this problem, the World Health Organization in 1995 introduced the term «global electromagnetic pollution of the environment». The questions of the EMF influence on the environment and ecosystem elements were included in the WHO program «WHO International EMF Project» in 1998, the task of which is to develop the scientifically based assessments, recommendations and regulatory restrictions that deal with the biological effects of the EMF.

Analysis of the state of the issue. EMFs are an important part of our modern industrial society, used in a wide range of applications from power generation to communication. Industrial frequency EMFs, which are those with a frequency of 50 or 60 Hz, are particularly ubiquitous and can have significant impacts on human health if not properly managed. With the increasing reliance on electronic devices and the expanding infrastructure of wireless communication, EMF exposure is becoming more widespread. Therefore, understanding the risks associated with industrial frequency EMFs and the latest technical and personal protective equipment is crucial.

The sources of high-power EMF of the industrial frequency are air lines (AL) and powerful electric equipment with voltage of 110-750 kV, located in the open area. The total length of the high voltage AL in Ukraine equals to 85 thousand km, more than 200 open transformer substations are built.

The purpose of the work is to provide an overview of the current understanding of industrial frequency EMFs and the latest technical and personal protective equipment (PPE) available for limited exposure. The article will explore the main advantages and disadvantages of the proposed models and highlight the key considerations for choosing appropriate protective equipment.

Methods, materials and research results. Industrial frequency EMFs are generated by any device that operates on an alternating current (AC) power supply. This includes power lines, electrical appliances, and motors. The strength of the EMF is determined by the amount of current flowing through the device and the distance from the source. The World Health Organization has classified EMFs as a possible carcinogen, and there is growing concern about the long-term effects of exposure, particularly in high-risk professions such as electrical workers and radiologists.

Researches, conducted in the recent years, have shown that the mechanism of the external EMF influence on the humans is determined due to the formation of the internal induced currents. The level of the influence depends on the electrical and magnetic properties of the human clothing, on the orientation of the body relative to the vectors of electric (EF) and magnetic (MF) fields, as well as on the distance to the electrical installations, on the duration of the influence and on the availability of the protective equipment. The intensity of the EF is proportional to the intensity of the electrically-powered equipment and inversely proportional to the distance to the object of the influence. External EF affects the charges in the human body and this leads to the flow of the currents in the internal tissues and to the appearance of the additional internal MF [1]. Measured values of currents flowing through the body of the worker, who is in open 500 kV switchgear and has contact with the ground (through his shoes) or with earthed parts of the equipment, are (130 ... 250) mcA. During the time of finding the employee on the 500 kV transmission line support at the wire level, the currents reach (500 ... 600) mcA [2].

The intensity of the external MF is proportional to the current, flowing through the current-carrying parts of the electrical installations, and inversely proportional to the distance to them. The current magnitude in the existing electrical installations tends to be constantly changing during the day and the seasons, so the impact of the MF is not constant. In case when a person fall under the influence of the external variable MF, matched elementary currents appear in the body, which form their own MF. For example, the MF with strength of 100 A/m causes the flow of the current through the vital organs of a person of 70 mcA. The EF of the industrial frequency is characterized by a weak penetration into the human body, while for the MF human tissues are almost transparent.

Most of the international standards, aimed at the establishment of the permissible levels of EMF parameters, assume that the density of the electric current of 10 mA/m^2 is safe for humans. The recommended or normative values for the individual categories are determined taking into account the stock factors. When determining the working conditions at production facilities, the stock ratio is set at the level of 2.5 ... 3.5, for the population – at the level of 10 ... 12.

In view of these provisions, the task is to create conductive protective clothing and other types of personal protective equipment. The proposed concept is based on the provisions, which provide for the implementation of certain stages of the research:

– analysis of the working conditions in open electrical installations and determination of the basic parameters of the EMF intensity, microclimate, static, dynamic and vibration loads at workplaces;

– assessment of the risk of performance of work without switching off the voltage in the existing electrical installations;

– evaluation of the effectiveness of existing means of protection;

– definition of the set of requirements to the properties of materials, which can be used in protective clothing of a given purpose;

– optimization of the design, aimed at the provision of modular-differentiated protection of individual areas of the human body.

The analysis of the working conditions has shown that electrotechnical workers during their work are been affected by the complex of dangerous factors: increased mechanical stresses, unfavorable climatic factors, local vibration. The most dangerous factors are the effect of the external EMF and the possibility of direct or remote impact of the electric current. Electrotechnical workers who work near the existing electrical installations should be protected from the influence of the EMF and induced current as the most dangerous production factors.

The risk of occupational diseases depends on the likelihood of the undesirable events and their consequences [3]. Theoretically possible risk at work, which is understood as the basic risk, can be evaluated as follows:

$$R_i = P_i \cdot D_i, \tag{1}$$

where R_i – certain kind of risk; P_i – probability of the occurrence of i-risk; D_i – consequence of the occurrence of i-risk.

After the implementation of the measures, aimed at the improving of the safety of work, it is possible to estimate their effectiveness in residual risk.

The level of the residual risk is determined by the formula:

$$R_{oc} = \sum_{i=1}^{n} (P_i \cdot \nu_i) \cdot D_i \cdot W_i, \tag{2}$$

where $К_i$ – protective measures.

To manage the risks associated with industrial frequency EMFs, a range of technical and personal protective equipment is available. Technical protective equipment includes shielding, grounding, and other measures to reduce exposure to EMFs. Shielding can be applied to power lines, transformers, and electrical appliances to reduce the strength of the EMF. Grounding is used to reduce the potential difference between conductive materials and the ground, which can reduce the risk of electric shock and other hazards.

It is offered to estimate the risk at use of the personal protective equipment, using the following formula:

$$R_{on} = P_{on} \cdot w = \left(P_p \cdot P_в\right) \cdot w, \quad (3)$$

where $P_{оп}$ – probability of the negative EMF impact, $P_р$ – probability of working under the conditions that do not correspond to the permissible ones; $P_в$ – probabilities of loss of the protective properties by means of individual protection; w – the value of the energy flow that dissipates in the worker`s body. The permissible value of w, when the body of the worker is been fully exposed, is set at the value of 4 W/kg, during the local irradiation of the limbs – 10 W/kg (head) and 20 W/kg (hands and legs).

The reduction of the probability of $P_{оп}$ and irradiation energy is achieved by increasing the quality and reliability of protective clothing, which in turn requires its improvement and value appreciation.

PPE is particularly important for workers who are exposed to high levels of EMFs, such as electrical workers and radiologists. PPE can also be used to protect the general public from exposure to EMFs in public places, such as airports and train stations.

It is proposed to make protective conductive clothes from composite textile two-layer materials. In order to limit the influence of the EMF, the material must have a high electrical conductivity and a minimum possible magnetic permeability. For clothes, a two-layer material is used, which consists of a non-woven polypropylene fabric (inner layer) and a layer of carbon fabric (outer layer). Polypropylene fabric has an electrical resistance of 10^8 ... 10^{10} Ohm and is used as an insulating layer. Carbon fibers have a small electrical resistance (12 ... 25) 10^{-3} Ohm and are a conductive material. The protection of the worker in the conductive set takes place as follows: when the wave passes through the first conductive layer, a partial absorption and reflection of the wave occurs. Further, the wave passing through the nonwoven layer, is partially absorbed and further weakening occurs.

When creating the protective clothing, it is important to assess the levels of the intensity directly on the human body. The person, who is near the AL, strongly distorts the picture of the distribution of intensity around him. The real environment contains elements that have electromagnetic properties and significantly affect the propagation of the radiation. Because of the difference in the magnitude of the resistances for individual parts of the human body and, correspondingly, in the magnitude of the induced currents, the EMF inside the person is inhomogeneous and its parameters differ from the external EMF. The method for mathematical modeling of the EMF near and within a person's body has been developed, which is surrounded by air on the surface of the earth or by the conductive element (tower). As the simulation results showed, the intensity of the EF on the surface of the worker`s body can exceed the strength of the external field E_0 by (7 ... 12) times. The zone of the increased intensity is located near the head (up to 12 E_0), near the in chest – up to 7 E_0 and decreases near the hip to 1 E_0.

The main advantage of personal protective equipment is that it provides a physical barrier between the worker and the EMF. This can be particularly important for workers who are exposed to high levels of EMFs, such as electrical workers and radiologists. PPE can also be used to protect the general public from exposure to EMFs in public places, such as airports and train stations.

The main disadvantage of personal protective equipment is that it may not be suitable for all work environments or situations. For example, PPE may be uncomfortable or impractical for workers who need to move around quickly or work in confined spaces. PPE may also be ineffective if it is not worn properly or is damaged.

Conclusion. Industrial frequency EMFs are an important part of our modern industrial society, but they can have significant impacts on human health if not properly managed. Technical protective equipment and personal protective equipment are available to manage the risks associated with exposure to EMFs, but each has its own advantages and disadvantages. Technical protective equipment can reduce exposure without requiring changes in work practices, while personal protective equipment provides a physical barrier between the worker and the EMF.

It is important to carefully consider the risks associated with exposure to industrial frequency EMFs and choose appropriate protective equipment. Analysis of the working conditions of workers in open electrical installations showed that the most dangerous factors are: the impact of the external electromagnetic field and electric current; increased mechanical loads; adverse climatic factors. The basic level of risk for occupational diseases significantly exceeds the recommended levels.

New type of conductive protective clothing, made of a two-layer conductive composite material with improved protective properties and ergonomic characteristics, is proposed. Individual conductive set of clothing are designed to protect workers who work in open electrical installations with a voltage of 110-500 kV.

References

1. Третякова Л.Д., Мітюк Л.О. Оценка нормативного и технического обеспечения для ограничения влияния электромагнитного поля промышленной частоты на здоровья электротехнических работников. Scientific Wiorks Azerbaujun technical university. 2017. V 1. P 37-43.

2. Третякова Л.Д., Мітюк Л.О. Способи удосконалення системи захисту працівників від впливу електромагнітного поля промислової частоти. Вісник Національного технічного університету України КПІ, Серія Гірництво. Київ:НТУУ КПІ. 2017. Вип. 32. С. 93-102.

3. Tretiakova L, Opryshko V., Rebuel E. Assessment of the working environment risks for the workers of electrical engineering industry. 2020 IEEE 7th International Conference on Energy Smart Systems (ESS). 12-14. 05. 2020, Kyiv. C. 409-412. DOI:10.1109/ESS50319.2020.9160182.