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Oil and gas complex of Ukraine: analysis and prevention of electrical traumatism

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The work is devoted to the analysis of injury cases from the electric current influence on the oil and gas complex objects. The principles, the main provisions of the system analysis and the classification of electric traumatism cases at power enterprises are presented. Main causes and patterns of the electric trauma occurrence on dependence of the various production features, as well as for various categories of workers are determined in the article. The structural scheme of the relationship between the elements of the system "man – electrical engineering – production environment" is given. A set of preventive measures and practical recommendations that can be successfully applied to assess occupational risk and reduce the level of injury from electric current in the energy sector of Ukraine is proposed.

Keywords: electrical safety, traumatism, electrical traumatism, industry, oil and gas complex, safety management.

Нафтогазовий комплекс України: аналіз і профілактика електротравматизму

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Проведено аналіз випадків травматизму від дії електричного струму на об'єктах нафтогазового комплексу України. У статті представлені принципи, основні положення системного аналізу і класифікація випадків електротравматизму на енергетичних підприємствах та визначені основні причини і закономірності виникнення електротравм у залежності від різноманітних особливостей виробництва, а також для різних категорій робітників. Виявлені основні організаційно-технічні, технічні, організаційні, санітарно-гігієнічні та психофізичні причини виникнення нещасних випадків і професійних захворювань у робітників нафтогазового комплексу. Системний аналіз випадків електротравматизму дозволив сформулювати основні принципи системного підходу до проблеми наукового обґрунтування системи управління електробезпекою на промислових підприємствах. Розглянуті основні етапи розробки, погодження, затвердження і функціонування системи управління електробезпеко. Приведена структурна схема взаємозв'язку між елементами системи «людина – електротехніка – виробниче середовище» і запропоновано комплекс профілактичних заходів і практичних рекомендацій які можуть бути успішно застосовані для оцінювання професійного ризику та зменшення рівня травматизму від дії електричного струму в енергетичному секторі України. Запропонована методологія аналізу та оцінки ризиків аварій на об'єктах нафтової та газової промисловості, що дозволяє порівнювати дію небезпечних чинників різної природи, визначати, з урахуванням вкладу кожного окремого фактора, інтегральну ступінь небезпеки будь-якого промислового об'єкта. Застосування даної методології оцінки ризику дає можливість розробляти механізми і стратегії різних заходів щодо підвищення безпеки об'єктів нафтової і газової промисловості; встановлювати межі величин ризику і невизначеностей, пов'язаних з обмеженістю вихідних даних або з невирішеністю наукових проблем.

Ключові слова: електробезпека, травматизм, електротравматизм, промисловість нафтогазовий комплекс, управління безпекою.

Introduction

Every year, the electricity production and consumption increase, thus, the number of people, who use (operate) electric devices and installations during the life-cycle of their lives, increases too. According to [1], the approximate forecast for electricity production by 2035 year can be 195 billion kWh that is 31.3 billion kWh more than in 2015 year (163.7 billion kWh), so the issues of electrical safety are on particular importance.

Exploitation of electrical equipment by the personnel is associated with the electric shock risk, as well as with the probability of electric injuries among technicians who do not connected directly with the operation of electrical installations. The risk of electric shock is significant increase during the direct conduct of repair, prophylactic, start-up and commissioning works with the voltage removal near the current-operated parts or without the voltage removal from electrical installation by electrical personnel. Therefore, the main task is to reduce the electric trauma in all spheres of production activity.

The analysis of industrial traumatism shows that the number of injuries caused by the action of electric current is about 1% of the total number of the injured persons. However, accidents with a lethal consequence of the electric current are equal up to 7% and occupy one of the first places in the industry. The largest number of injuries, including 80-85%, with fatal consequences, occurs when using electrical installations up to 1000 V, due to their distribution and relative availability for practically anyone working at the production site. Accidents during operation of electrical installations with a voltage over 1000 V are rare, which is due to the insignificant proliferation of such electrical installations and their servicing by highly skilled personnel.

Consequently, the questions devoted to establishing the main causes and patterns of the electric traumas occurrence, depending on the characteristics of industrial production, as well as the development of preventive measures, are definitely relevant.

Review of research sources and publications

Many publications are devoted to the issues of industrial objects electrical equipment safe usage [2, 3]. These publications provide methods for the safe usage of machinery and equipment. The increase of technological processes with the usage of electric current causes the need for continuous monitoring of the electric current influence on the workers body and the possible negative effects of this effect [4 -- 7]. However, a general analysis of the causes of electrical injuries on industrial objects and the oil and gas complex objects is not given.

The conducted analysis of recent researches and publications showed that today there is no single methodology that determines the principles of electrical safety management and the procedure for assessing the risk of electric trauma during the performance of technological operations in the extraction and transportation of hydrocarbons. Famous methods for assessing the electrical safety level are based on a comparison of the measured design values of the contact voltage, current strength passing through the human body, and the time of their action with the normalized parameters or on the methods of analysis of the electrical traumas statistical data without taking into account the electric trauma probable nature and the permissible level value of the electric energy absorbed by the worker body.

Definition of unsolved aspects of the problem

The limited information does not enable to implement effective measures on electrical safety in industry. Therefore, systematization and elimination of serious shortcomings in the existing analysis determines the relevance of research in this direction.

Problem statement

Considered the above mentioned, the purposes of this article are to systematize and classify cases of electrical injuries at the objects of the oil and gas complex, to identify the main causes of workers injury, to develop the main directions of preventive measures, and to improve the control and management of the electrical safety system for construction organizations workers, taking into account the combined approach of professional assessment risk. The choice of a certain alternative between ensuring the continuity of the production process and achieving the necessary level of electrical equipment operation is followed by the development and implementation of innovative technologies in the field of electrical safety production management.

Basic material and results

Modern construction site can not be imagined without mechanisms and mechanized tools, which are driven by electric current. Widespread of the electrical current was obtained by heating the concrete, stone masonry, finishing works, defrosting of the ground, as well as lighting the construction worksite.

Violation of electrical safety rules when using machines and mechanisms, that is, direct contact with the conductive parts of the electrical equipment, which is under voltage, creates the danger of human damage by electric current. The energy sector is ranked second by the injuries among all types of economic activity.

An analysis of the industrial safety state in Ukraine shows that in 2016, the number of industrial accidents increased by 4% compared to last year, or by 168 accidents (at the enterprises of Ukraine in 2016, 4428 people were injured, in 2015 - 4260 people). The number of fatal accidents involving the production increased by 7%, or by 25 accidents, compared to the same period last year (400 people were fatal in enterprises in Ukraine in 2016, 375 people in 2015). Electric traumas accounted for approximately 15.6% of the total number of accidents at enterprises of the oil and gas complex. This is the second rank in the number of electric traumas after the agro-industrial complex (27.7%) [8 – 10].

Electrical injury accidents among workers of different professions show that workers of non-electrical occupations are injured 6.2 times less frequently than electric ones. But the frequency of electrical traumas among the workers of some non-electric professions is very high.

For example, the frequency of electrical injuries is higher for locksmiths and mechanics. For electric locksmiths, this frequency is lower, although according to the nature of their activities, the former are much less likely to deal with electrical installations than the latter. A similar inconsistency is observed when comparing the data from electrical injuries to electric welders and drivers of motor vehicles and mechanics of various aggregates.

The main causes of electric shock in industrial enterprises are:

– accidental contact with conductive parts that are under voltage;

– false actions during work or malfunction of protective devices, through which the victim has been touched by the conductive parts;

– the appearance of voltage on the metal structural parts of the electrical equipment due to damage of the conductive parts insulation;

– the short-circuit of the network phase to the ground, the voltage wire drop on the structural elements of the equipment;

– the appearance of voltage on the switched-off conductive parts due to the incorrect activation of the device or the short-circuit.

Data analysis shows that the maximum frequency of electric traumatic accidents comes on workers aged 26 ... 40 and young workers aged 18-25 years (Fig. 1).

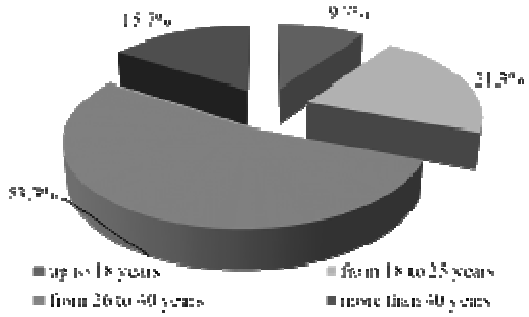

Figure 1 – Electrical traumatism at workers of all ages in % of the number of electric traumas for all types of economic activity

It is suggested that workers in these age groups are either lacking in certain experience or caution and accountability, which is typical for older people, confirming injury data, depending on the production experience (Fig. 2).

Workers with a work experience of up to 5 years have a frequency of electrical traumatism 2 times more than workers with a work experience of 5 ... 10 years, and 5 times more than workers with a work experience of more than 10 years. Accordingly, young and inexperienced workers should be constantly at the attention center of persons who are responsible for the safety work.

The analysis of electric traumatism cases enabled to reveal the main organizationally-technical, organizational, sanitary-hygienic and psychophysical causes of accidents at the workers of the oil and gas complex.

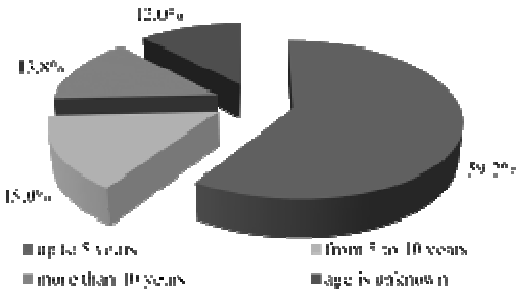

Figure 2 – Electrical traumatism at workers of different production experience in % of the number of electric traumas for all types of economic activity

For sanitary-hygienic causes include: increased content of harmful substances; insufficient or irrational lighting; increased levels of noise, vibration, infra- and ultrasound; unsatisfactory microclimatic conditions; the presence of various radiation above the permissible levels, etc.

Psychophysical causes include the following factors: false actions of workers due to fatigue, illness, carelessness; discrepancy between the psychophysical and anthropological data of the employee to the performed work.

Distribution of organizationally-technical and technical reasons is shown on Figure 3.

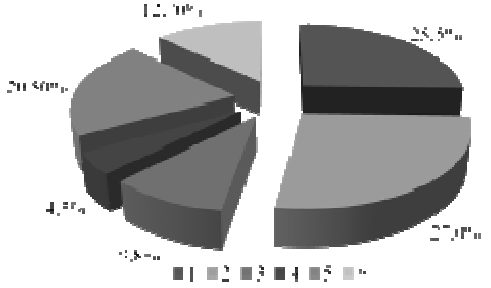

Figure 3 – Electrical traumatism from organizationally-technical and technical causes in % of total electric trauma:

1 – forbidden work or non-use of precautionary technical measures when working under voltage;
2 – violation of the air lines protection zone, transportation of oversize cargoes, non-use of fences and locks, mechanical damage to the insulation;
3 – use of inappropriate voltage, incorrect inclusion, switching, inclusion of zero conductors per phase;
4 – convergence of conductors of the included and off network, phase and zero conductors of one line, breakage or sagging of wires;
5 – defects of the structure and installation of electrical equipment; 6 short circuit to the frame, the short circuit between the electrical windings of transformers, the inverse transformation.

The organizational causes of electric trauma can be attributed: work without admission or job-order, or improperly executed job-order; absence or irregularity of the safety briefing; absence or non-use of protective equipment; mismatch of accident preventions qualification to the performed work; illegal combining of professions; work in extra-ordinary time; unsatisfactory work organization of personnel on a business trip; wrong or prohibitive actions of work performers; violation of discipline.

As it can be seen from the above data, the usage of protective equipment only by the enterprises provided by the Rules for the installation of electrical installations (RIEI) can not create conditions for complete safety during the installation, operation and repair of equipment. It is possible only when these measures are supplemented by other organizational measures (instructions, studying, verification of knowledge, etc.) and take into account: voltage of electrical installations, neutral regime, environment conditions, etc.

It is also necessary to consider insufficient level of safe organization of labor during the operation of equipment, machinery, mechanisms, vehicles, violation of the technological process, poor condition (deterioration) of production facilities, structures, and production goods.

Based on the analysis of the causes and cases of electrical traumatism, it should be noted that the problem of electrical safety and prevention of electrical traumatism refers to mixed problems, which consist of both qualitative elements and less well-known, which are of a random nature. It is suggested that solving the problem of providing electrical safety at the enterprises of the oil and gas industry should be carried out on the basis of system analysis and development of the electrical safety management system.

Since the main parameters of electrical safety are regulated by rules and standards, within the framework of the management system, proposed complex and technical measures aimed at ensuring the electrical safety, is preventive, should be additional to the normative work regulations and should not conflict with the current normatively-legal acts on supervision and control of work safety. The operation of the control system must be coordinated with the energy services that carry out direct operation, technical maintenance, repair of electrical installations and authorized by the relevant energy monitoring services.

The direct management of measures and decisions on the use in operational practice of the electrical safety management system is carried out by the Chief Mechanical Engineer Service (Power Engineer) of the enterprise. Feasibility report on the need for implementation of control technical means, effective means of protective shutdown, information and analytical system for managing the database on electrical safety, training of qualified specialists and technical staff studying for protection systems maintenance is carried out at the same time. The prepared normative and technical documentation is approved by the management of the enterprise.

The management of the measures and decisions implementation on the management system accomplishment is carried out in accordance with the approved stage-by-stage program under the direct supervision of the responsible person (Chief Power Engineer).

The problem solution efficiency of providing electrical safety at the enterprises of the oil and gas complex is determined in the process of the equipment direct operation according to the criteria, which laid down in the basis of the management system functioning in accordance with the applicable normative and legal documents.

The system analysis of electric traumatism cases enable to formulate the basic principles of a systematic approach to the electrical safety management system scientific substantiation problem [11 – 12].

1. Electrical safety is a system of organic measures and technical facilities that protect workers of all professions from harmful and dangerous effects of electric current, electric arc, electromagnetic field and static electricity.

2. The control management system of electrical safety by structure, internal content and external communication has all the signs of a multi-level system.

3. The control system includes a set of the system elements, which are defined both within the framework of internal interconnections, and in the implementation of external links with subsystems of operation, technical maintenance and repair, technical control, etc.

4. Within the framework of a specific organizational management structure, not only analysis of the system elements is carried out, but also the establishment of interrelationships between them. In this process, the functioning of the control system is equally due to the properties of its individual elements, as well as the properties of the structure itself.

5. The description of the system separate elements and their interrelation within the framework of the current electrical safety control system is carried out by many models: physical, mathematical, cybernetic, statistical and economic.

The system approach to the problem of electrical safety involves the studying and practical usage of the following aspects:

1. System-element or system-complex aspect involves the identification of elements that make up the system of electrical safety, taking into account the specifics, technological processes organization and management in the conditions of construction and building materials and structures manufacturing.

2. The system-structural aspect is the establishment of internal connections and interconnections between elements of the control system, which allow identifying the internal organization of the system under investigation.

3. System-functional aspect involves the establishment of functions implemented by each element of the control system.

4. The system-target aspect involves the definition of target management settings and their interconnection.

5. The system-resource aspect is to determine the resources necessary for the functioning of the management system.

6. The system-integration aspect involves the integration of the electrical safety management system into the general system of occupational safety.

In accordance with the aforementioned principles of a systematic approach, the structure of the electrical safety control system in general is presented in Fig. 4.

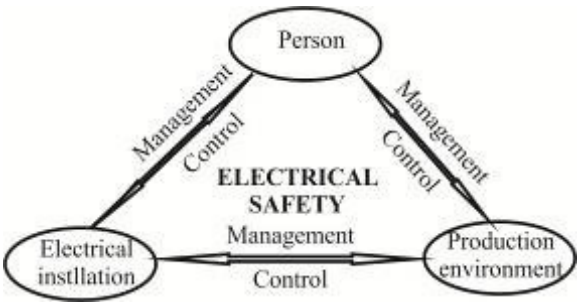

Figure 4 – The general structure of the electrical safety provision at the enterprise

The electrical safety management system has a complex internal structure, which elements are interconnected both in a hierarchical plan and at each of its levels.

The operation of the electrical safety management system should be considered directly in connection with its component subsystem "man-electrical installation-environment". This is due to the fact that the dangers of industrial electrical traumatism impairment arise precisely in this subsystem, when there is a direct contact between a person and an electrical installation. At the same time, the environment affects both the person and the electrical installation.

The reduction of the electric trauma probability in the specific conditions of the electrical equipment operation at the enterprises of the oil and gas complex through the usage of organizational and technical measures is a direct task that is solved in the electrical safety control system.

There is an interconnection between the system ensuring elements of the electrical safety at the enterprise. The definitive functioning of this subsystem, the person as a subject, affects the electrical installation by providing it with safe properties both at the stage of its design (development, creation), and directly in the process of operation. Such properties are: constructive execution, level of explosive protection, spark protection, level and class of insulation, etc. All these characteristics and electrical installations characteristics are directly connected with the operating condition that is directly connected with the environment, which specificity is related to the technology of drilling and other works.

A person performs certain operations that affect both the electrical installation and the environment. The influence on the electrical installation is determined by the instructions for operation, repair, technical maintenance and other normatively-technical and legal documents. The impact on the environment is carried out by creating and maintaining a comfortable microclimate, which are regulated by sectoral norms and rules at the enterprises of the oil and gas complex.

Electrical installation, as an object of part man influence, also has its influence. In the process of operation, aging and wear of electrical equipment (reduction of insulation resistance, mechanical wear of hanging parts, their damage, etc.) leads to decrease in reliability and safety. Electrical installation also affects the environment, as the deterioration of the protective characteristics of the electrical equipment can lead to emergency situations and electrical traumatism.

The environmental impact of the electricity management system is also interrelated with the specifics of production, governed by applicable norms and rules, has its own parameters and characteristics. The negative impact of the environment is strongly manifested in the specific field conditions of extraction, preparation and transportation of oil and gas.

Thus, the system "man-electrical installation-environment" is a complex structured subsystem of interconnected elements, which interaction in the production environment is regulated b electrical safety control system.

Since the complete damage elimination from the technological -industrial and environmental hazards associated with electrical installations in industrial enterprises engaged in exploration, extraction, processing and marketing of oil and gas is impossible, therefore, in order to minimize the risk of electric trauma for the personnel. This personnel serves electrical installations. It is necessary to choose the way of minimizing the total socio-economic costs. There is a set of measures and means of electrical safety should be chosen from the possible variety, which introduction reduces the risk of electrical traumatism in electrical safety to an acceptable level.

The implementation of a risk-based approach to management can be seen as a functioning of a system or “control system”. That is, specially developed on the basis of the system accounting, analysis, valuation, planning, control and management traditional methods integration. That provides obtaining, processing and aggregation of information about enterprise activity, continuous monitoring with the use of technical diagnostics means of electrical equipment operation regime parameters. Also it provides application of special protection means against harmful and dangerous effects of electric current, electric arc, electromagnetic field and static electricity.

For an effective controlling electrical safety system for oil and gas workers, it is proposed to use a closed information contour on the electrical energy. This contour contains a sequence of logically related

control functions: the risk parameters estimation of personnel damage by electric energy; planning and implementation of planned measures on electrical safety in order to eliminate the chain of preconditions for the appearance of electrical trauma aimed to the risk minimization of electrical traumatism and professionally determined disease; control over the implementation of planned activities; assessment and analysis of electric traumas risk parameters after the taken measures; making decisions to improve the electrical safety system, which allows to constantly compare the actual state of the controlled process, in order to minimize the risk of electric traumatism.

Conclusions

The methodology of analyzing and assessing the risks of accidents at the objects of the oil and gas industry is actively developing, therefore, the development of new and improved existing approaches, models and methods for assessing the risks of accidents, their computer realization remains a topical task for our state. The determination of the accidents risk assessment should be based on the results of monitoring the technical condition of potentially hazardous objects, statistics on accidents and man-caused emergencies, integrated monitoring of dangerous geological and hydrometeorological processes, the natural systems state, as well as the results of the relevant hazardous situations simulation and their influence on public health. The application of the risk indicator enables to compare the different nature dangerous factors effect, determine, considering the contribution of each individual factor, the integral degree of any industrial object danger. The application of the risk assessment methodology enables to develop mechanisms and strategies for various regulatory measures to improve the safety of oil and gas industry objects; to set the limits of the risk and uncertainties associated with the limited source data or the unresolved scientific problems.

Summing up, it can be determined that the main preventive measures for workers of non-electric specialties are: improving their professional level, explaining the work danger with electrical equipment, systematic and qualitative safety training and control strengthening by officials in compliance with safety measures at the enterprise, obsolete equipment replacement or its modernization in accordance with modern labor safety requirements.

Vocational education is of great importance for providing electrical safety on the oil and gas enterprises. The analysis of injuries shows that individuals who have graduated from special educational institutions, including vocational and technical, are much less likely to be injured than those ones without special education.

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