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OCCUPATIONAL RISK MANAGEMENT FOR ACTIVITIES IN ELECTRICAL INSTALLATIONS AT HEIGHT

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Abstract: *The activity of workers in electrical installations at height is, simultaneously, a complex and dangerous activity, given the major risks to which the performers are exposed: the risk of electrocution and the risk of falling from a height. Statistics indicate an increase in work accidents caused by falls from a height, including in the activities performed on electrical installations. Thus, any work performed at height in electrical installations or near them must be very well structured and procedural, and the duties and responsibilities of each performer must be very clearly established.*
The paper presents some of the results of studies and research on managing occupational risks for entities that perform activities in electrical installations at height.
Keywords: *work, height, electrical installation, management, safety.*

1. INTRODUCTION

Electrical installations at height have a fairly wide area, from overhead power lines to electrical lighting installations to installations that supply monitoring and control systems, advertising panels, etc.

Works in these electrical installations, whether in the construction, assembly, operation or maintenance phase, require a careful analysis of the workload, the work area and the dangerous area(s), defined as the circular or semicircular area in which the danger generated by falling objects is significant.

These works must be correlated with the working and environmental conditions to establish the most effective technologies and methods of work in electrical installations at height and safety and health measures.

Analyzing the consequences of work accidents in electrical installations as a result of falls from height and the statistical data from the last 10 years, reported by the Labor Inspectorate, corroborated with the statistical data recorded by the National Statistics Institute (NSI) regarding work accidents produced at the national level, the high percentage of fatal accidents is noted. However, in the last five years, there has been a decrease in the number of collective work accidents [1, 2].

Figure 1 presents the share of work accidents depending on severity.

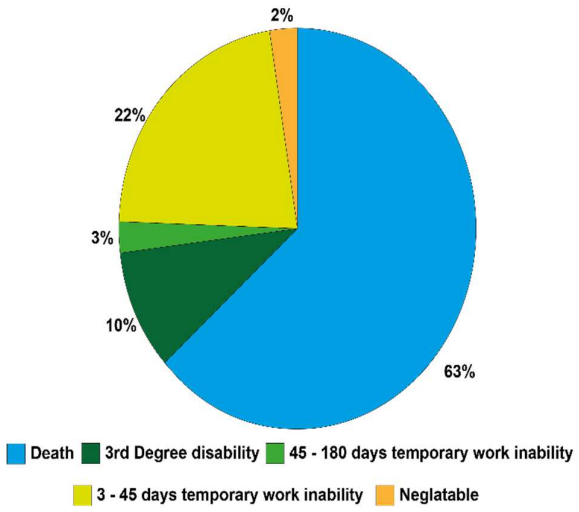

Fig. 1. Share of work accidents by severity

The paper presents part of the research carried out within the project "Research for the development of occupational risk management procedures for people performing activities in electrical installations and the development of

work equipment intended for their protection in electrical installations necessary for the prevention of professional risks" and the occupational risk management procedures developed after the project's completion.

The use of collective protection measures is the first option dictated by the Law on Safety and Health at Work no. 319/2006, respectively, of Council Directive no. 89/391/EEC on introducing measures to promote improving workers' safety and health at work, supplemented by individual protection measures.

In many cases, access and work at height for electricians can sometimes be solved relatively simply, using different types of ladders, somewhat more complicated, on scaffolding, nacelles, winches or platforms and in extreme cases, using the rope work technique, called in Romania "utilitarian mountaineering" or in international specialized literature "acrobatic work".

Common to all these workplaces is the permanent combination of the risks specific to working at height with the risks generated by electrical installations and work equipment used during the work task, to which are added the risks related to the environment and those generated by the performer. If interventions are made in electrical installations in operation (under voltage) that cannot be de-energized for safety/security reasons, the risks can reach the maximum limit.

The current OSH legislation contains provisions regarding work equipment for working in electrical installations and at height. The minimum requirements applicable to electrical installations and work equipment are provided in Chapter 3.3. of Annex No. 1 of GD No. 1146/2006 on the minimum health and safety requirements for workers using work equipment. Chapter 4 provides the requirements and methods of using work equipment available for temporary work at height.

Current OSH legislation establishes the obligation for employers to draw up their own occupational health and safety instructions (OHS-IP) specific to the workplace and the activity carried out. At the employer level, the OHS-IP of the workplace is, where appropriate, supplemented with Work Instructions.

For complex electrical installations with a high risk of significant accidents and occupational diseases, GD no. 1146/2006 provides that the organizational measure of protection against electric shock is the development and application of Internal Technical Instructions for Labor Protection (ITI - PM). In addition, some employers who have implemented management of hazardous activities have imposed "permits for working at height" so that work at height cannot be performed without developing and approving compliance with the respective content.

2. DESIGN AND DEVELOPMENT OF THE PROCEDURE FOR EVALUATING ACTIVITIES PERFORMED AT HEIGHT IN ELECTRICAL INSTALLATIONS

Occupational risk management in electrical installations is a critical process that involves the systematic identification, assessment, and mitigation of hazards inherent in working at elevated heights [3 - 5].

In the first part of the research, in order to design and develop the evaluation procedure, the activities performed in electrical installations at height were analyzed and evaluated, dividing them into several categories depending on the type of installation in which the work is to be performed, its nominal voltage, the type of work, respectively: (assembly, operation and maintenance work; work performed on the ground, at low height, at height (work performed at a height greater than 2 meters from the ground/floor), work performed in enclosed spaces, etc.

The evaluation of activities performed at height in electrical installations had as a starting point the analysis of the following:

- technical and occupational health and safety documents (IP SSM, work instructions/ procedures, ITI PM, operational procedures, internal standards, etc.);
- work methods;
- organizing access to and from the workplace at height;
- effective organization of the execution of works at height in electrical installations (de-

energized, in live electrical installations, in the vicinity of other live installations, etc.);
- the ability to execute the work taking into account time limits (e.g. interruption of power supply to critical installations/equipment/consumers);
- the capacity of organizing assessments in the work area and bringing them to the ground in the event of a work accident;
- analysis of recorded and reported work events and accidents.

The diagnosis and evaluation of work equipment used for access to heights and work equipment used to perform work in the electrical installation were carried out in terms of the technical conditions and the minimum health and safety requirements established regarding the manufacture, selection, use, and maintenance, respectively those provided for by legislative and technical regulations [3, 5, 6]. The conditions and mode of operation of the electrical work equipment were also considered. Proper functioning of electrical equipment requires a supply voltage as close to nominal. Even relatively small deviations from the nominal value can produce sub-optimal operation of equipment that is functioning with a reduced efficiency or increased power consumption with additional losses and reducing lifespan, or defects [7].

The protective equipment that is part of the PPE category was diagnosed and assessed based on the essential health and safety requirements set out in Regulation (EU) 2016/425 of the European Parliament and of the Council of 9 March 2016 on personal protective equipment and repealing Council Directive 89/686/EEC and technical regulations, as well as the minimum requirements for manufacture, selection, use and maintenance [3, 5, 6].

The plans and periodic checks of work equipment, electrical insulating protective equipment, and PPE in use were analysed. It was found that some entities, especially small ones (under 10 employees), did not implement and/or comply with the periodic check programmes for work equipment at height, electrical insulating work equipment, and PPE.

In the case of work carried out at height in live electrical installations, emphasis was placed on the analysis and assessment of:
- live working technologies, including their documentation. According to national regulations issued by the National Energy Regulatory Authority (ANRE), they must be tested and certified for the specifics of the installations where they are applied and comply with national legislation regarding the quality of the works [5, 6];
- the safety quality of work equipment, electrical insulating protective equipment and individual protective equipment used, respectively their planning and periodic verification;
- the capacity to organize the execution of live works [6].

The interplay between human factors and safety practices is a critical element in the management of occupational risks associated with electrical installations at height. Variables such as fatigue, psychological stress, and insufficient training can severely compromise a worker's compliance with established safety protocols, thereby escalating the likelihood of accidents in high-risk environments [3, 5, 8].

From the analysis of the causes of work events and accidents resulting from falls from height, it was found that the wrong actions and omissions of the performers have the greatest weight, according to Fig. 2.

Thus, one stage of the research was dedicated to establishing the criteria and technical and occupational health and safety requirements that workers performing at height in electrical installations must meet. To this end, a series of work events and accidents caused by them were analysed. This paper established:
- technical criteria for personnel selection;
- the criteria and requirements regarding professional training and continuing education in the field; the medical criteria for personnel selection, starting with a medical check-up specific to both requirements, electrician, and work at height, and continuing with a permanent check-up of physical and mental health;

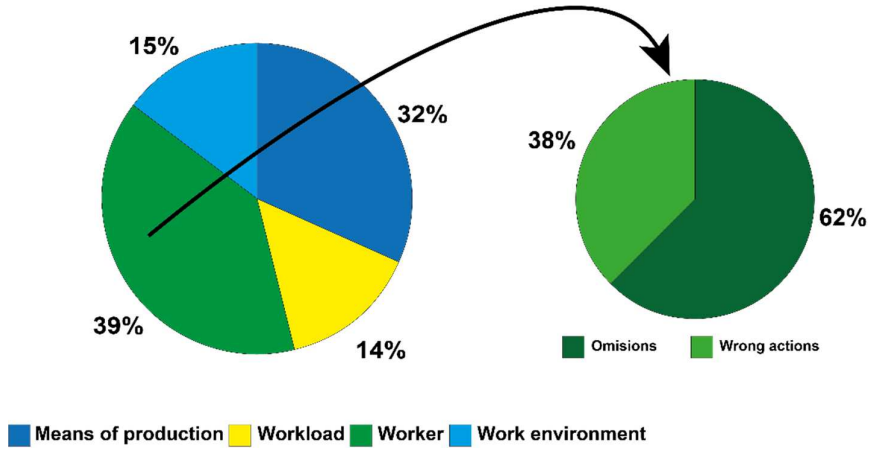

Fig. 2. The share of work events and accidents, structured on the four components of the work system

- criteria and requirements regarding the periodic training and improvement of workers regarding access and work at height techniques in conjunction with working methods in electrical installations;
- the duties and responsibilities of electricians established at the work level;
- the duties and responsibilities of electricians established at the work level;
- the criteria for promoting, rewarding and penalizing workers.

In national energy companies on the analysis of work tasks about the capacity of the performers have shown their concern for reducing stress factors to maintain a favourable working atmosphere. However, the impact of stress on human health is underestimated in small organizations - SMEs. In the short term, stress can lead to various disorders: lack of concentration, irritability, anxiety, insomnia, migraines, depression, blood pressure problems, etc. In the long term, stress is responsible for chronic fatigue, worsening of cardiovascular diseases, digestive diseases, allergies, asthma, chronic depression, etc.

The identification of ergonomic and psychological risk factors, the analysis of physical and neuropsychic effort to ensure the health and safety of workers at work, the optimal use of human resources and the maintenance of work capacity throughout professional and personal life led to the establishment of:

- medical criteria for personnel selection, starting with a medical check-up specific to both requirements, electrician and work at height, and continuing with a permanent check-up of physical health.
  Regarding the physical health of the personnel, criteria and duties have been established regarding the observation of workers before starting the activity and keeping them under observation throughout the entire period of work at height in electrical installations.
- personnel selection criteria by assessing psycho-professional skills upon employment, periodically and upon resumption of activity, specific to both requirements and permanent control of mental health;

Thus, about psychological behaviour, criteria and attributions have been established regarding the observation of workers before starting the activity and keeping them under observation throughout the entire work period at height in electrical installations.

In the case of live works, electricians must be authorized to work under voltage by the provisions of Government Decision No. 1146/2006 and the provisions of the Technical Norm on establishing the requirements for performing live works in electrical installations, code NTE 010/20/01.

The assessment of the risks of accidents and occupational diseases and the establishment of the technical conditions and health and safety requirements that electrical installations, work equipment, equipment for access to heights, work technologies, and operators must meet had as its goal the fulfilment of the objective of the study, which was to establish and develop a risk

- causes - consequences - prevention measures structure [3, 4].

The technical conditions and health and safety requirements applicable to activities performed at height in electrical installations were essential elements and the starting point for the design and conception of the decision support system for the prevention of risks associated with disasters and of the means of protecting people in order to prevent risks in electrical installations [3, 4, 10].

Based on this structure, procedures were designed and developed for evaluating activities performed at height in electrical installations. These procedures formed the basis of the logic schemes developed to represent the specific knowledge of the field, thereby preventing occupational risks and ensuring the protection of people who carry out activities at height in electrical installations [3, 8, 10].

The logic schemes formed the basis for the functional model of the expert decision support system, which was developed in the last part of the research work.

Figure 3 shows some input data specific to electrical installation work – the input page of the general decision support system (DSS).
The input data can be modified or supplemented depending on the type of work performed or other criteria or requirements imposed by contracting or subcontracting.

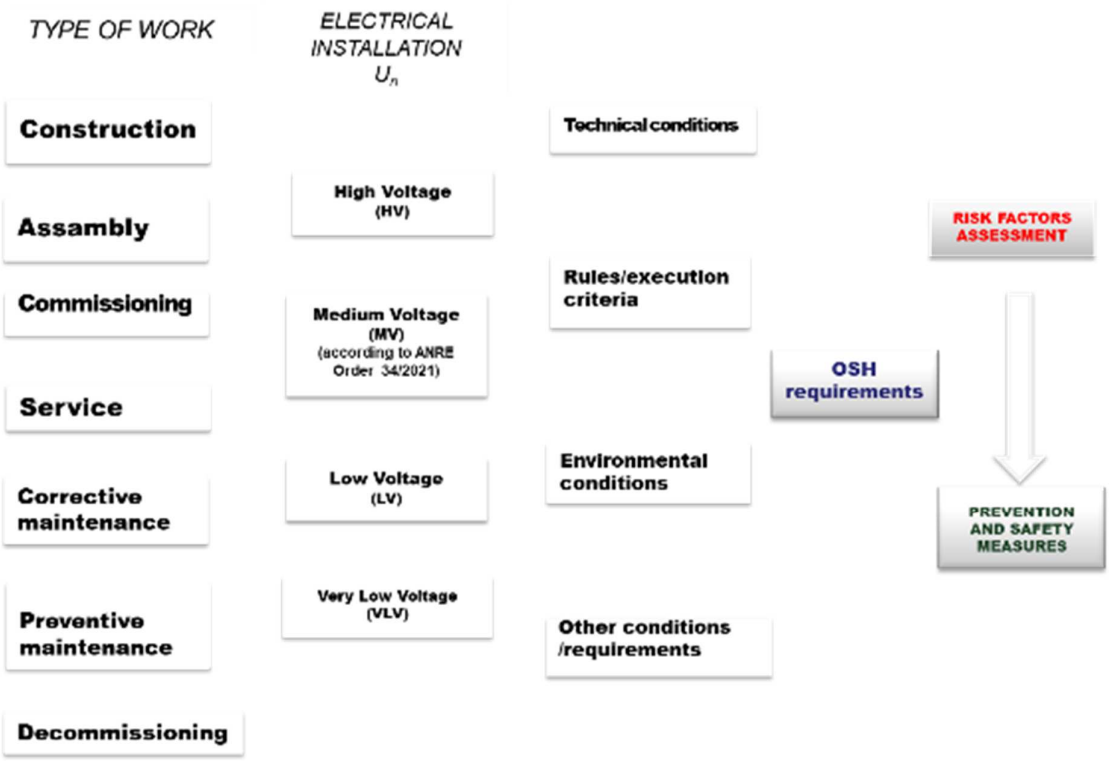

Fig. 3. Integration of work types - input data - DSS

Before starting any work on the electrical installation, the site manager must establish and implement the work area in which all technical and organizational measures have been taken to reduce the risks of accidents and occupational diseases. In the case of work at height, he must solve as safely and accurately as possible, implement and ensure the protection of the "dangerous area". The dimensioning of the dangerous area must take into account a series of elements such as the height of the place where the work is performed, the type of work, the construction details, if applicable, the number of performers working simultaneously and their arrangement, the work equipment and installations contained in this space, the speed and direction of the wind and other details [8].

The protection of the dangerous area must be very well analysed from the stage before establishing the work area because the risks, efforts and, ultimately, the costs of this operation can far exceed the initial forecasts. In many cases, the technical and organizational measures adopted are as superficial as possible. Applying these measures in the specific workplace conditions represents a great responsibility for the admitting party, as the case may be, the head of the work team and for each electrician. The dangerous area must be fenced and guarded in such a way as to exclude any accident within the work team and with persons who may enter, with or without intention, this space. Dropping an equipment/tool or dislocating an object from a height represents a real and frequent risk, which must be taken into account by all electricians and requires taking both technical and organizational measures [8]. Thus, all the elements necessary for establishing the work area and the technical and organizational measures in this work area were identified and integrated into the General Decision Support System (DSS). Figure 4 presents a page with the input data necessary for establishing/sizing the hazardous area and, implicitly, the work area through DSS.

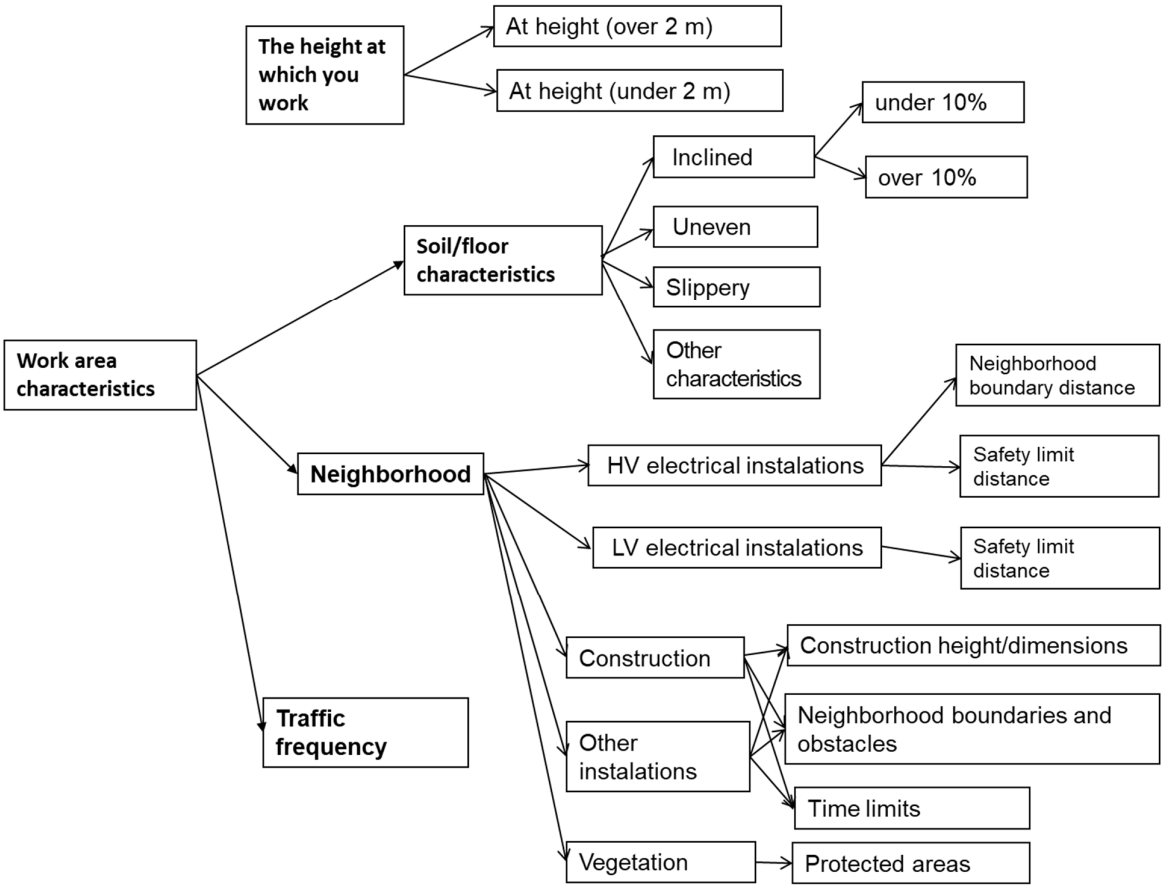

Fig. 4. Establishing/sizing the hazardous area and the work area respectively - input data - DSS

After identifying the data needed to establish the work area, the risks generated by accidents and occupational diseases identified for work at height in electrical installations were integrated into the general decision support system (DSS).

Accidental releases of toxic/flammable/ explosive substances can have serious consequences for workers or the neighbouring population, but the need to identify and evaluate chemical risks must also be considered in terms of the impact on establishing the work area [11 - 14]. These analyses not only emphasize the importance of environmental awareness, but also highlight the need for systematic approaches in risk assessment frameworks specific to electrical installation practices [3, 9].

Figure 5 shows a screenshot of the risks of accidents and occupational diseases identified for work at height in electrical installations in the work area.

The expert DSS is developed in Romanian language to be accessible to workers and eliminate any interpretation regarding the risks of occupational injury and occupational diseases, as well as the safety and health measures necessary to be adopted by the user.

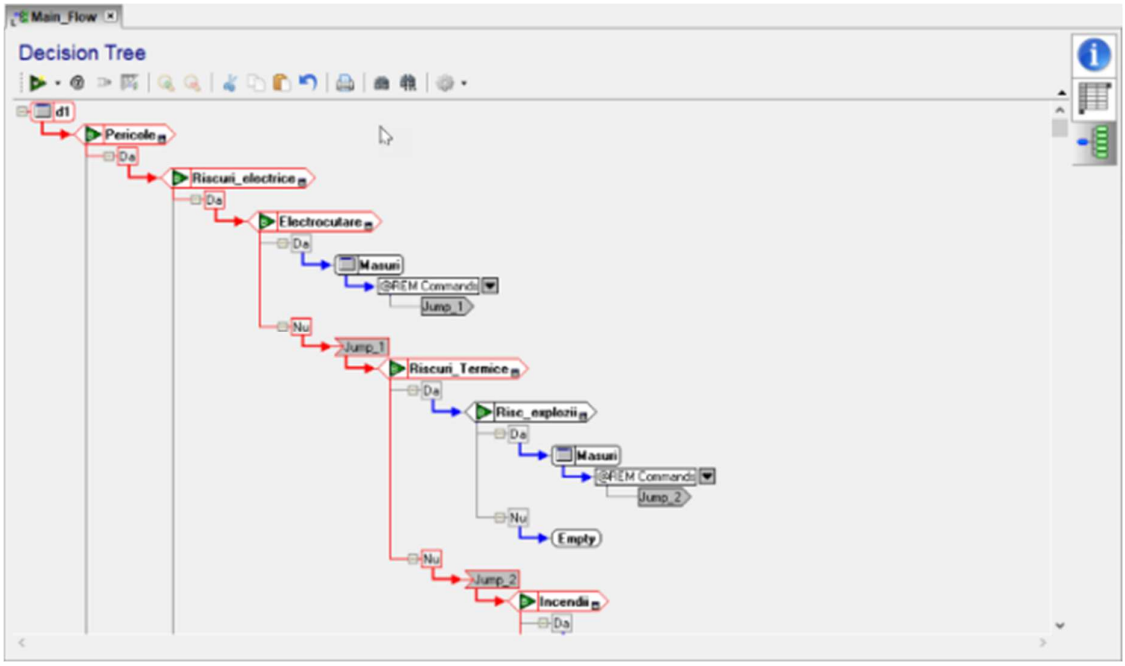

Fig.5. Integrating the risks generated by accidents and occupational diseases identified for work at height in electrical installations into the DSS (screenshot)

In the research, measures were suggested for each recognized risk factor to either minimize or eliminate them, with a strong emphasis on collective technical solutions. The implementation of safety and health protocols established by the DDS leads to a significant decrease in occupational accidents and occupational diseases in the workplace. Risks introduced by contractors, such as neglect (for instance, not verifying the technical condition or the expiration dates of periodic inspections for work equipment, protective gear, and PPE prior to commencing work; disregarding work guidelines and technologies; failing to utilize individual protective equipment, venturing into hazardous areas, using mobile devices, etc.), are greatly mitigated.

Accurate input of data concerning the work environment necessitates a comprehensive understanding of the electrical systems involved, the methodologies for the tasks at hand, the techniques for accessing and working at heights, and the features of the area and its surroundings. Effectively applying the gathered information related to the work setting considerably diminishes the risks faced by workers.

The research carried out has highlighted the need to assess the conformity of electrical installations in use, which have a high level of occupational accidents, taking into account the new digital technologies used at European level, namely safety devices, access tools and control equipment, which make work safer [15]. Thus, one of the measures proposed to reduce the risks identified in the stage of creating the work area is the use of unmanned aerial vehicles - drones.

Unmanned aerial vehicles can scan electrical installations automatically or remotely, on pre-established routes or at predefined angles [16], provided that the data entered with these routes and angles are correlated with the security requirements regarding proximity and security distances.

Drones can scan the area and collect information about the technical condition of the electrical installations, the characteristics of the area and the respective surroundings.

With the help of the data collected and transmitted to the ground system, a geo-referenced map can be made, interactively indicating to the work team the nature of the event/failure, for a very well-organised intervention [17]. In addition to high-resolution photo and video cameras, drones can be equipped with infrared analysis sensors and thermographic analysis to detect imperfect contacts/hot spots, oxidation, assembly defects, etc.

With the help of drones, information can also be collected regarding environmental conditions, ambient temperature, humidity, wind speed, wind direction, etc.

The drone allows its operator to work from a great distance, not being exposed to the risks of accidents in the work area, as he is in a safe place [17].

Although it requires investments in both equipment and operator training, these prove to be efficient, especially in the case of work to be performed in electrical installations located in difficult-to-access areas.

The methodology developed to ensure effective technical and organisational measures also focuses on the assessment of occupational risk factors determined by work equipment with effects on the work environment and the activity carried out by the operator [9]. Their implementation's opportunity, aim and necessity resulted from the present occupational safety and health (OSH) law requirements [18].

3. IMPLEMENTATION OF NEW DIGITAL TECHNOLOGIES

One of the future directions of the research work will focus on innovative technologies to develop methodologies for working at height in electrical installations and methodologies for assessing occupational risks and integrating them into risk management.

Industry 4.0 has a significant impact on the management of occupational accident and occupational diseases risks due to the technology developed in order to reduce occupational accidents and occupational diseases, and the execution times of works implicitly improving the quality of electricity for consumers through reduced to a minimum times of electricity interruption.

Studies have shown that technologies such as remote data transmissions via SCADA, information modelling, drones, wearable sensing devices, virtual reality and exoskeletons have the potential to improve electrical workers' safety [19].

Wearable devices are one of the technologies that flourished with the fourth industrial revolution or Industry 4.0, allowing employers to monitor and maintain safety at workplaces [20].

In the context of occupational risk management for electrical installations at height, wearable sensors emerge as a pivotal technology for enhancing worker safety through real-time monitoring of vital signs and environmental conditions. These devices facilitate immediate alerts for potential hazards, such as falls or electrocution, thereby significantly improving situational awareness among personnel engaged in high-risk activities. Furthermore, the integration of data harvested from these sensors into a centralized monitoring system enables the application of predictive analytics, which can identify risk patterns and inform proactive safety interventions. This dual approach not only augments individual safety measures but also contributes to a holistic understanding of risk dynamics in electrical installation environments [3, 9].

4. CONCLUSION

Working at height in electrical installations is essential for maintaining and developing the energy infrastructure, but it is also dangerous.

The work aimed to analyse the technologies and working methods, the use of equipment and protective means for working at height, the criteria for selecting and admitting workers to work, and the establishment and development of procedures for evaluating activities performed at height in electrical installations in order to adopt the most effective technical and organizational measures to minimize the risks in this activity.

Working at height in electrical installations is extremely dangerous, but the risks can be significantly reduced by implementing occupational risk management and complying with health and safety measures.

The paper highlighted the need to develop procedures for assessing the conformity of electrically insulating work equipment and PPE for access and work at height, given the high level of work accidents recorded in the energy sector, and to develop a methodology for periodic checks and their periodicity, which determines the continuation of research in this regard.

Considering the research carried out within the project, a methodology for professional training and continuous education of personnel in the field, periodic training and evaluation, is to be developed in order to guarantee a high level of safety at workers' workplaces and prevent the occurrence of events during work carried out in electrical installations.

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Managementul riscurilor ocupaționale pentru activitatile la înălțime în instalațiile electrice

Activitatea lucrătorilor in instalațiile electrice aflate la înălțime este în același timp, o activitate complexă şi periculoasă, având in vedere riscurile majore la care sunt expusi executanții: riscul de electrocutare si riscul de cădere de la înălțime. Statisticile indică o crestere a numarului de accidente de muncă cauzate de căderile de la înălțime, inclusiv în cadrul activitaților executate instalațiile electrice. Astfel, orice lucrare executată la înălțime în instalațiile electrice, sau în apropierea acestora, trebuie foarte bine structurată si procedurată, iar atribuțiile si responsabilitățile fiecărui executat trebuie stabilite foarte clar. Lucrarea prezintă o parte din rezultatele studiilor si cercetărilor cu privire la managementul riscurilor ocupaționale pentru entitățile care efectuează activități în instalații electrice la inaltime**.**

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