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MANAGING THE RISKS OF INJURY AND OCCUPATIONAL DISEASE IN THE MAINTENANCE ACTIVITY OF WIND FARMS

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Abstract: In the context of climate change and through the lens of the objectives set at the EU level regarding climate neutrality, through the Integrated National Plan in the field of Energy and Climate Change 2021-2030, Romania proposed to increase the share of sources to 55.8% in 2030 of renewable energy in the electricity sector. For this purpose, one of the targets established at the national level is related to the construction and commissioning of new electricity production capacities from wind and solar sources. The paper aims to present a synthesis of the research carried out regarding the assessment of accident risks and professional improvement in the exploitation and maintenance of wind farms. Considering the new regulations regarding the safety of machines, in the category of which wind turbines fall, taking into account the European and national strategies regarding digitalization, the implementation of software systems for monitoring, control and data acquisition in the integrated management systems of electricity producers led to the reduction over time of the risks of occupational injury and desease.

The paper considers new research regarding the risks that may appear as a result of the aging of the workforce and its fluctuation/migration in the activity of exploitation and maintenance of wind farms in order to establish some measures to prevent the risks of accidents and occupational diseases determined by the introduction of new digital production technologies.

Key words: risk, evaluation, safety, wind turbine.

1. INTRODUCTION

Romania attaches great importance to developing internal sources of electricity production, pursuing two aspects: their diversification and reducing greenhouse gas emissions.

The national policies regarding the fulfilment of the European Union's energy targets for 2030-2050 emphasize the integration of localized renewables by increasing

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wind and solar potential. Through the Integrated National Plan in the field of Energy and Climate Change 2021-2030 from April 2020, updated in 2023, Romania proposed as a target for 2050 the achievement of an installed capacity of 30.4 GW, of which 76% would come from renewable sources of energy [1], [22], [24], [27].

After 2010, wind farms registered rapid growth in Romania, with wind energy becoming an integral part of the national energy system. According to the data reported by the Ministry of Energy, the share of electricity produced from renewable sources (wind, solar, biomass, biogas and geothermal) in 2023 was a significant 18% of the total electricity produced [2]. This achievement is a testament to Romania's commitment to renewable energy.

The data reported on the Transelectrica website show that in June 2024, 116 wind energy farms with a net power of 2966.439 MW provided electricity in the NES [3 - 5]. This specific data provides a clear picture of the current state of wind energy production in Romania.

Figure 1 shows the electricity production from 07.05.2024, by types of energy, graphically presented.

On 07/05/2024, the net production of electrical energy was 5923 MW, of which the average wind energy production was 566 MW [3 - 5].

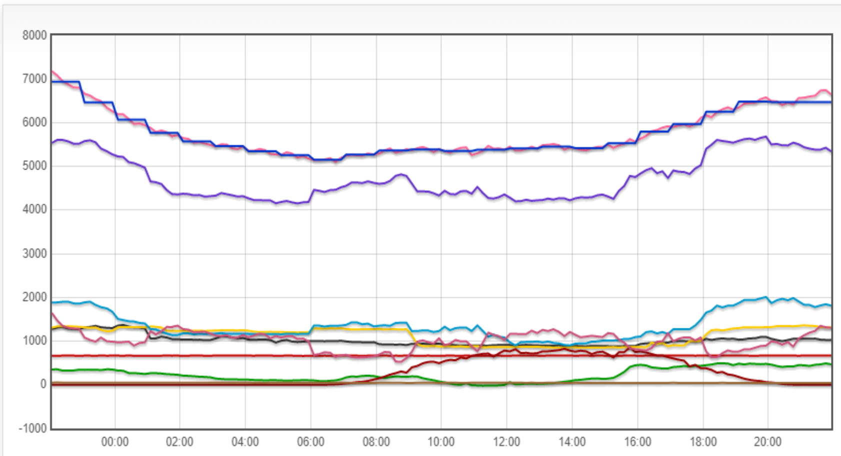

Fig.1. Electricity production from 07/05/2024 by types of energy [5]

In order to reach the targets proposed by Romania, it must build and implement new electricity production capacities from renewable wind, solar, biomass, biogas and geothermal sources.

Although wind energy is considered environmentally friendly, at the European and national levels, dangerous working conditions both during construction and during exploitation have generated events. The paper presents the results of the research carried out regarding the assessment of the risks of accidents and professional improvement in the exploitation and maintenance of wind farms.

The research was carried out within the framework of three contracts signed with economic agents, producers, and distributors of electricity from 2010 to 2022, with the aim of identifying and evaluating the risks of accidents and occupational diseases, analyzing them, and proposing security measures to comply with technical conditions and security and health requirements and ensure safe and healthy workplaces.

One hundred thirty-nine wind turbines, with an installed capacity of 2.5 MW each, 4 110/33 kV electrical substations, a 400/110/20 kV electrical transformer station and the 33 kV and 110 kV cable networks were evaluated and diagnosed. kV, the 33 kV and 110 kV cable networks, but also in the ensemble as a workplace for maintenance and repair operators [6, 7].

The evaluated and diagnosed wind turbines are installed onshore and mainly consist of a foundation that also contains the grounding installation, the metal tower, three vertical blades, the turbine nacelle/housing, the shaft, the rotor, the kinematic chain, the electrical part/electrical system (generator, converter system, MV transformer, medium voltage distribution installation, control systems) batteries for energy storage, azimuth system and wind measurement devices, control, monitoring, measurement and data acquisition systems [6 - 8].

2. ASPECTS REGARDING THE OCCUPATIONAL HEALTH AND SAFETY REQUIREMENTS APPLICABLE TO WIND TURBINES

The main components of wind farms, wind turbines, must guarantee the essential safety and health requirements applicable provided by Directive 2006/42/EC, respectively HG no. 1029/2008 regarding the conditions for placing machines on the market, Directive 2009/104/EC, respectively HG no. 1146/2006 regarding the minimum safety and health requirements for the use of work equipment by workers, as well as Directive 2014/35 /EU, respectively HG no. 409/2016 regarding the establishment of the conditions for making low-voltage electrical equipment available on the market, the applicable European and national standards, national technical regulations and codes of good practice [6, 9 - 14].

Since maintenance activities usually occur at high heights, wind turbines must guarantee the safety and health requirements regarding access/work at high heights. Thus, the work equipment for access and work at height must guarantee the applicable safety and health requirements provided by Directive 2009/104/EC regarding the minimum safety and health requirements for the use of work equipment by workers at work and the harmonized European standards. The stairs for access to each level of the turbine and the platforms/walkways at each level must comply with the clauses of the SR EN ISO 14122 Machine Safety series of standards — permanent means of access to machines. The climbing stairs must have a protective basket and fall protection equipment/s - anchor points, safety lines or "lifeline" as the utility climbers call them and, if necessary, a fall arrester [23], [25].

Anchorage points and protective equipment against falling from a height (e.g. a sliding fall arrester on a flexible support equipped with an energy absorber or a retractable fall arrester) must guarantee the essential safety and health requirements applicable under the Regulation (EU) 2016/425 of the European Parliament and the Council regarding personal protective equipment and applicable standards.

Also, the wind turbines must be equipped with an emergency descent system with a friction braking system, which must meet the essential safety and health requirements mentioned above [26], [28].

Wind turbines must meet the safety and health requirements for workplaces from Directive 89/654/EEC regarding access, working spaces, ventilation, lighting, ergonomic principles, vibrations, Wind turbines must meet the safety and health requirements for workplaces work from Directive 89/654/EEC regarding access, platforms, workspaces, ventilation, lighting, noise and vibrations and principles, respectively the provisions of HG no. 1091/2006 regarding minimum safety and health requirements for the workplace.

Wind turbines must also meet the minimum safety and health requirements regarding the exposure of workers to the risks generated by physical agents - noise provided by Directive 2003/10/EC, respectively HG no. 493/12.04.2006 regarding the minimum safety and health requirements in work related to the exposure of workers to the risks generated by noise [6, 9].

3. EVALUATION OF WORK ACCIDENTS AND OCCUPATIONAL DISEASES

The wind energy industry registers many professional risks identified in each phase of the technological process. From the testing and production of components necessary for wind turbines to the transportation, installation, and maintenance of the turbines, the safety and health risks at the workplace can be quantified in each phase.

Improving the reliability of wind turbine manufacturing technology, transportation, installation, and maintenance directly impacts their safety in use.

Also, improving diagnostic methods through the intelligent use of data can further reduce breakdowns, so as to limit the severity of defects when they occur, which actually leads to a reduction in the duration of maintenance/service interventions and fewer accidents of work, under the conditions of compliance with operational procedures.

The final goal resulting from improvements in the reliability of wind turbine manufacturing technology, as well as transportation, installation and maintenance, leads to operations that become much more efficient and thus reduce the need for workers to be in a dangerous work environment.

The purpose of the research study was to identify and analyze the professional risks generated by the components of the wind farm, taking into account the applicable safety and health requirements, the technical documents that are the basis of their design, operation and maintenance, respectively the OSH management documents and the history of the events generated by them in use.

The research methodology carried out in order to identify and analyze the risks of occupational injury and illness at the wind farm had in mind compliance with:

- the safety and health requirements stipulated by the regulations regarding the safety of cars, in the category of which wind turbines fall;

- the safety and health requirements provided by the regulations regarding low-voltage electrical equipment, in the category of which the electrical part of the wind turbines and the low-voltage electrical equipment in the power station and substations fall.

- the provisions of the technical regulations for the design and execution of electrical installations (electrical stations, electrical cable networks, etc.);

- the safety and health requirements stipulated by the regulations regarding the work equipment.

As regards the operation and maintenance activity, it must be carried out in safety and health conditions, which ensure compliance with the safety and health requirements provided by the regulations regarding workplaces, considering the permanent safe access (stairs, platforms, anchor points, lighting, etc.) to reach the locations for inspection and maintenance activities and to carry out these activities safely.

Risk assessment involves identifying all risk factors in the analyzed system and quantifying their size based on the combination of two parameters: the severity and frequency of the maximum possible consequence on the human body [15, 16].

The identification of the professional risks generated by the components of the wind farm was carried out taking into account the applicable safety and health requirements, the technical documents that are the basis of their design, operation and maintenance, respectively the OSH management documents and the history of the events generated by them in use, for which applicable security requirements sheets were drawn up in the first phase of the studies.

The operation and maintenance activity must be carried out in safety and health conditions by the safety and health requirements provided by the workplace regulations, with the specifications from the internal documents of integrated management, and those from the organizational forms of work, in the case of electricians.

In establishing the security and health requirements, the aging and fluctuating workforce and, more recently, the integration of workers of other nationalities, especially those who emigrated from Asian countries, into the maintenance teams of Elolian parks were taken into account.

Based on the security and health requirements established for wind turbines, non-conformities were identified with regard to [6, 7].

- The lighting system. Following the visual examination and the technical documents, it was found that the lighting circuit was provided with a single switch located on level 1 of the wind turbine. No other switches were identified on the other levels. Also, the reserve power source with the lighting system ensures 30 minutes of operation.

- Elevator. It was found that the door could open during boarding/descent. Also, no stops were identified at any level of the wind turbine.

- The door of the fence of the "elevator gap." The fence door of the "elevator void." From level x, it was found that it is not equipped with a mechanical lock.

- The anchoring points: It was found that the anchoring points on the upper part of the turbine/nacelle were mounted at a distance of more than 1 m between them, a fact that implies difficulties, especially for the small operating personnel (e.g. for workers originating from Asian countries. Given that at the national level, there is an increase in the number of workers from Asian countries in the field of construction but also the field of electricity and utility climbing);

- Detection and signalling in case of fire. It was found that the wind tower did not have a fire detection and signalling system.

- The communication system. There was a lack of a communication system with the operating staff in the control room or between the maintenance staff;

- Access. At level x of the turbine, it was found that the space between the turbine wall and the elevator is narrow, forcing the staff to pass (crouch) under the electrical cables.

It was also found that:

- the markings and order labels were in English and other international languages and not in the user's language;

- the warnings regarding the residual risks of the work equipment were in English and other languages of international circulation and not in the language of the user;

- missing emergency number 112 on the information posters regarding providing first aid.

Nonconformities identified in the station and electrical substations [6, 7]:

- the 33 kV electrical cell access doors in all substations were provided with mechanical locking devices, but when they are opened, the installation remains under tension. According to art. 3.3.8 from annexe no. 1 of HG no. 1146/2006, the doors of the high voltage electrical cells must be provided with an optoacoustic voltage warning system in the respective cell [10, 13 - 14].

- several protection conductors connected to the single protection terminal in the low-voltage electrical cabinets (identified H1, F1 and D3);

- protective conductors that were not provided at the ends of the shoes (the area of the cable trunks in substation three and at the internal services in the power station).

The maintenance and upkeep of wind turbines offer challenges regarding safe work, especially in winter conditions and/or with strong winds.

The maintenance operators ensure the proper functioning of the work equipment in the station, substations, and wind turbines and perform specific activities.

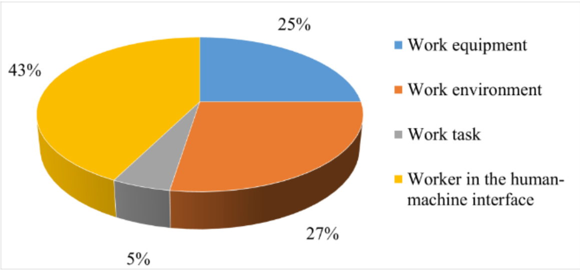

Fig.2. The weight of the identified risk factors on the four elements of the work system for maintenance

Figure 2 shows the weight of the risk factors identified on the four work system elements for the maintenance activity. It was found that the risk factors generated by the operator in the interface with the work equipment and risk factors generated by the work equipment have the highest weight, 68%.

Figure 3 shows the weight of the risk factors in the interface between the contractor and the work equipment for the activity to be maintained. The contractor has the largest weight in the interface with the work equipment through the wrong actions and omissions due in large part to the residual risks of the equipment for work.

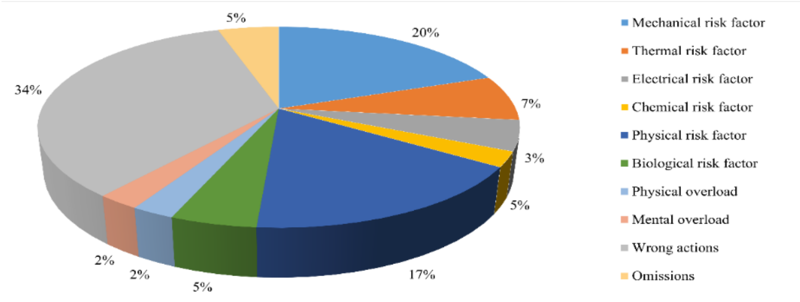

Fig.3. The weight of the risk factors for maintenance

The risk factors generated by work equipment are of a mechanical and thermal nature, such as burns caused by flames or explosions, of an electrical nature, such as contact with live parts, and of a chemical and physical nature, such as noise, and lighting.

The mechanical risk factors are mainly generated by falling from a height due to the specifics of maintenance work at height and the non-conformities identified at the anchoring points and the lift. These factors have been reduced by the security measures proposed and generated by the fall of pieces of ice during the winter from the metal structure of the wind turbine. In the maintenance activity, the chemical risk is generated by working with solvents, degreasing and greasing substances for the rotor, generator, and generator motors, and oil samples from transformers. The chemical risk assessment was carried out using two criteria: the classification of substances from the point of view of danger and, respectively, the quantitative threshold at which the presence of the substance can lead to accidents, the weakening/deterioration of the protective quality of work equipment and protection [17, 18].

The introduction of new digital monitoring production technologies through the implementation of monitoring, control and data acquisition software systems has led to a reduction in risk exposure time, to a decrease in the number of wrong actions and omissions generated by executors. Some of the electrical risks and thermal risks identified during the execution of the manoeuvres in the electrical installations and/or the operations of stopping and de-energizing the work equipment on which maintenance operations are carried out have been eliminated. The implementation of monitoring, control and data acquisition software systems regarding the operating parameters of work equipment has reduced the time to identify defects and exposure to unfavourable work conditions due to the work environment: strong winds and dust, varying temperatures from low to very high and less, lately, of snowfall, due to climate changes.

The new digital technologies are designed to provide a useful tool for assessing the technical condition of wind turbines, to overcome the specific problems of monitoring, control and data acquisition, and to find a solution that best meets the technical requirements and customers [19].

The data produced from the application of risk analysis can be used to ensure safe equipment and methods of protection and strike a balance between technical and safety needs, dependability, and economic requirements [20].

The research conducted on operational wind turbines has led to the development of a robust methodology. This methodology is designed to effectively identify, assess, and monitor occupational risk factors, particularly those associated with work equipment. It serves as a practical tool for predicting and preventing technical events and work accidents, with a specific focus on the human-equipment interface.

The INCDPM method, a scientifically rigorous approach to assessing the risks of occupational injury and illness at work, played a pivotal role in our research. It allowed us to evaluate the ratio of factors determined by work equipment and other components of the work system. This evaluation focused on the effects on workload, work environment, and the executor, who is the primary interface with the work equipment.

The developed methodology focuses on evaluating the professional risk factors determined by the work equipment, their effects on the work environment, and the activity carried out by the operator.

Their implementation's opportunity, aim and necessity resulted from the present occupational safety and health (OSH) law requirements. [21].

The research carried out highlighted the need to evaluate the conformity in the use of this category of work equipment, considering the high level of work accidents recorded in the energy sector, taking into account the new digital technologies used at the European level, respectively safety devices, safety tools access and control equipment, which make the work safer, such as the drones used when inspecting a wind turbine. This solution eliminates the need to climb the wind turbine.

The studies highlighted the need to evaluate the level of noise generated by the wind turbines to determine the risks for the workers exposed in the activities carried out, respectively, the population in the areas where these wind farms are located.

Another aspect resulting from the research studies carried out refers to the need to develop standards of professional training, improvement, and training of workers in this sector, mainly from the operation and maintenance services, where a large number of accidents are recorded.

Professional training is an important element in reducing costs and professional risks in the wind sector to ensure a safe and healthy work environment. It must be adapted to consider the risks specific to the wind sector and new risks that may appear determined by the introduction of digital technologies.

5. CONCLUSIONS

Risk assessment, based on the principles established by Directive 2006/42/EC, Directive 2009/104/EC, and the applicable security standards, is essential to prevent dangers and guarantee the safety of work equipment in use, considering the new technological challenges regarding digitization.

The research resulted in the identification of new approaches regarding the assessment of occupational risks at the workplace, determined by the introduction of new digital technologies. It also highlighted the need to comply with and certify the fulfilment of the safety and health requirements applicable to this category of work equipment, both from the point of view of the use as well as of the preparation and training of the serving personnel.

Following the results of the analysis of the causative factors of the production of electric arcs, the diagnosis of the existing protection measures in use corroborated with the established technical and security requirements; it was found the need to develop a specific methodology for the evaluation and control of the risks and dangers generated by the electric arc in the installations electrical.

The research studies carried out aimed at evaluating and eliminating the risks that can lead to the occurrence of technological or human events and identified the need to develop new technical diagnostic tools for work equipment, as well as through new professional training methods in the wind energy sector that taking into account all technological operations from manufacturing, construction per wind farm location, use and maintenance of this category of machines, in the digitization decade.

The tools to be developed will be made available to companies to increase their market competitiveness and ensure a high level of safety for the people who carry out these activities in the wind energy sector.

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