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Work accidents prevention by risks assessments to 400 kV Tantareni power substation from Romania

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Abstract. Based on the principles of prevention, the employer must seek to eliminate risk at source and, in order of priority, to replace hazards through non-dangers, to separate or isolate areas where there are hazards, ensuring adequate collective and individual protection. However, workers from high and very high voltage power substations continue to be exposed to occupational hazards, suffering accidents at work and occupational diseases with significant repercussions on their health, on colleagues or National Power System. Accidents at work and occupational diseases are the unseen face of wage labor, industrialization and economic development. Unfortunately, they are most often the general concern of society when tragedies occur, as was the case with explosions, of collective accidents with many victims or of particularly dangerous incidents that could have had dramatic consequences. According to the Law on Occupational Health and Safety no. 319/2006, the event means the accident that caused the death or injuries of the body, produced during the work process or in the performance of duties, the situation of missing person or the accident of route or traffic, under the conditions in which employed persons were involved, the dangerous incident, as well as the case susceptible to occupational or occupational disease.

Key words. Work accidents, risk assessment, substation

1. Introduction

The assessment is carried out using the National Research and Development Institute of Occupational Safety – NRDIOS Bucharest method, in order to establish the risk/safety levels in a quantitative manner, based on a systemic analysis and on the assessment of risks of accidents and professional diseases. The role of OHS for power substation high voltage (critical power infrastructures) is to generate the national economy electricity, well-being, and safety work and health environment, workers and workplaces secured, and security of industrial and power process, in order to optimally operate the national economy and ensure energy security. [1]

In accordance with the provisions of art. 5, letter e of the Law on Occupational Health and Safety, no. 319/2006, prevention is "the set of provisions or measures taken or provided for at all stages of the work process, in order to avoid or reduce occupational risks". Consequently, carrying out prevention and protection activities, as well as the conditions to be met by persons who ensure the optimal performance of these activities are essential elements in order to ensure a work environment without danger of injury or illness to workers. The performance of prevention and protection activities is influenced by a number of aspects such as: [1] [2].

- the dynamics of the enterprise and / or units and the changes occurred in their structure;
- changes in working hours and working relationships;
- changes in work organization;
- use of information and communication technology;
- changes in the structure of the active population, the increase in the number of older workers and working women;
- legislative changes.

These aspects can be impacted on occupational safety and health, having impact both on the type and nature of occupational risks, as well as on their management. Prevention and protection activities will be organized according to:

- size of the enterprise / unit;
- occupational risks from workplaces;
- the way of territorial organization of the activity of an enterprise and / or of the unit.

In the current language, the term accident designates an unexpected event, which occurs suddenly, is unpredictable and interrupts the normal course of action. The notion of work accident must be limited to a work process and necessarily implies the presence of man as executor. Thus, the work accident is defined as ”violent injury to the body, as well as acute occupational intoxication, which take place during the work process or in the performance of duties, regardless of the legal nature of the contract under which the activity is carried out and which causes temporary incapacity for work of at least three days, disability or death.” Labor and those produced in the following circumstances shall also be considered as accidents: [3]

- the accident suffered by persons visiting the enterprise and / or unit with the permission of the employer;
- the accident suffered by persons performing state or public interest tasks, including in cultural, sports activities, in the country or abroad, during and due to the performance of these tasks;
- the accident occurred within the organized cultural-sports activities, during and due to the fulfillment of these activities;
- the accident suffered by any person as a result of an action taken on their own initiative to save lives;
- the accident suffered by any person, as a result of an action taken on their own initiative to prevent or eliminate a danger that threatens public and private property;
- the accident caused by activities unrelated to the labor process, if it occurs at the legal entity's premises or at the address of the natural person, as an employer, or in another job organized by them, during the work schedule and is not due to the exclusive fault of the injured party;
- the route accident, if the trip was made during and on the normal route from the worker's home to the workplace organized by the employer and vice versa;
- the accident suffered during the trip from the legal entity's premises or from the natural person to the workplace or from one workplace to another, for the performance of a work task;
- the accident suffered during the trip from the legal entity's premises or from the natural person to whom the victim is employed, or from any other workplace organized by them, to another legal or natural person, for the performance of work tasks, during the normal period of travel;
- the accident suffered before or after the cessation of work, if the victim takes over or teaches the work tools, work, machinery or materials, if he changes his personal clothing, personal protective equipment or any other equipment provided by the employer, if he was in the bathroom or in the laundry or if he was moving from work to leaving the company or unit and vice versa;
- the accident suffered during the regulatory breaks, if it took place in places organized by the employer, as well as during and on the normal route to and from these places;
- the accident suffered by workers of romanian employers or by romanian individuals, delegated for the performance of service duties outside the country, during and during the route provided in the travel document;
- the accident suffered by romanian personnel performing works and services on the territory of other countries, based on contracts, conventions or other conditions provided by law, concluded by romanian legal entities with foreign partners, during and due to the performance of service duties;
- the accident suffered by those taking qualification, retraining or improvement of professional training courses, during and due to the performance of activities related to the internship;
- accident caused by natural phenomena or calamities, such as storm, blizzard, earthquake, flood, landslides, lightning, if the victim was in the process of working or in the performance of duties;
- disappearance of a person, in the conditions of an accident at work and in circumstances that justify the assumption of his death;
- the accident suffered by a person in the performance of his duties, as a result of an aggression.

2. Work accidents assessment at 400 kV Tantareni power substation within National Power System

The 400 kV kV Tantareni power substation is located in Tantareni commune, Gorj county, belonging to the Center for the Exploitation of Electricity Transmission Networks Târgu-Jiu – Craiova Electricity Transport Unit, represents an important power node of the Romanian Power System, through which the electricity produced in the Turceni Thermal Power Plant is discharged and the transfer of electricity to the Oltenia, Transylvania and Bulgaria. (figure 1) [4]

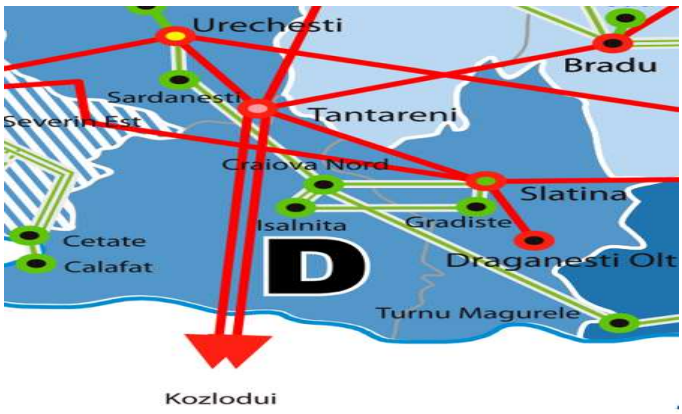

Fig. 1. Situation of 400 kV Tantareni power substation

The overall risk levels determined for each workplace at the 400 kV power substation are generally as follows (table 1):

Table 1. Workplaces at the 400 kV power substation

No.	WORKPLACE	Level of Risk (Nrp)
1	400 kV Operational Service	X
2	20 kV Operational Service	X
3	400 kV Primary Circuit Maintenance	X
4	20 kV Primary Circuit Maintenance	X
5	20 kV Secondary Circuit Maintenance	X

Means of production: [5]

400 kV Power Substation:
The 400 kV power substation is of the external type and is equipped with two bussbar systems and transfer bussbar, to which the following power cells (switchgears) are connected:

- *400 kV Urechesti OHL (overhead power line);*
- *400 kV Bradu OHL (overhead power line);*
- *400 kV Turceni Power Plant 1 OHL (overhead power line);*
- *400 kV Turceni Power Plant 2 OHL (overhead power line);*
- *400 kV Turceni Power Plant 3 OHL (overhead power line);*
- *400 kV Turceni Power Plant 4 OHL (overhead power line);*
- *400 kV Koslodui 1 OHL (overhead power line);*
- *400 kV Koslodui 2 OHL (overhead power line);*
- *400 kV Sibiu Sud OHL (overhead power line);*
- *400 kV Slatina OHL (overhead power line);*
- *400 kV – 100 MVAR 1 Coil Compensation;*
- *400 kV – 100 MVAR 2 Coil Compensation.*

20 kV Power Substation:
The 20 kV power substation is of the internal type and is equipped with double bussbar systems conected with longitudinal couple, to which the following power cells (switchgears) are connected:

- *TSI 1 – 20/0,4 kV – 400 kVA;*
- *TSI 2 – 20/0,4 kV – 400 kVA;*
- *TSI 3 – 20/0,4 kV – 400 kVA;*
- *TSI 4 – 20/0,4 kV – 400 kVA;*
- *20 kV Petrol OHL (overhead power line);*
- *20 kV Filiasi OHL (overhead power line);*
- *20 kV Turceni OHL (overhead power line);*
- *20 kV Measures 1; 20 kV Measures 2.*

A. Risk level assessment for the activity: 400 kV Operational Service
The object of the activity is the operational service of the power installations:

- *supervision;*

- *control;*
- *maneuver.*

Risk factors specific to the means of production:

- *mechanical risk* (falling from the same level, slipping or tripping, explosions of equipment with a lifetime exceeded, falling from a height);
- *electrical risk* (direct contact with electrical installations);
- *thermal risk* (burns due to electric arc).

Risk factors specific to the work load:

- psychic stress in the 400 kV power substations, when installing shortcircuits by hand.

Risk factors specific to the performer:

- *wrong action:*
  - incorrect identification of the installation and non-verification of the lack of voltage, when mounting the short circuits;
  - failure to respect the neighbouring distances with risk of electric shock by direct contact;
  - not checking the lack of voltage before mounting the mobile short circuits.
- *omissions:*
  - omissions of operations during manoeuvres, with risk of burns caused by electric arc, when closing grounding knives or mounting the mobile short circuits without checking the lack of voltage;
  - non-use and/or non-verification of the personal protective equipment provided and/or of the electrical insulating means and devices.

Risk factors specific to the work environment:

- *physical risk factors:*
  - exposure to adverse weather conditions (low/high temperatures, rain, snow, air currents) during installations' control.

$$N_{400kV\text{-}220kV} = \frac{\sum_{i=1}^{7} R_i \cdot r_i}{\sum_{i=1}^{7} r_i} = \frac{2\cdot(1\cdot1)+3\cdot(2\cdot2)+2\cdot(3\cdot3)}{2\cdot1+3\cdot2+2\cdot3} = \frac{32}{14} = 2,28 \quad (1)$$

B. Risk level assessment for activity: 20 kV Operational Service

The object of the activity is the operational service of the power installations:

- *supervision;*
- *control;*
- *maneuver.*

Risk factors specific to the means of production:

- *mechanical risk* (falling from the same level, slipping or tripping, explosions of equipment with exceeded lifetime, falling from a height);
- *electrical risk* (direct contact with electrical installations);
- *thermal risk* (burns due to electric arc).

Risk factors specific to the work load:

- psychic stress in the 20 kV power substations, when installing short circuits by hand.

Risk factors specific to the performer:

- *wrong action:*
  - incorrect identification of the installation and non-verification of the lack of voltage, when mounting the short circuits;
  - failure to respect the neighbouring distances with risk of electric shock by direct contact;

- not checking the lack of voltage before mounting the mobile short circuits.

- *omissions:*
  - omissions of operations during maneuvers, with risk of burns caused by electric arc, when closing grounding knives or mounting the mobile short circuits without checking the lack of voltage;
  - non-use and/or non-verification of the personal protective equipment provided and/or of the electrical insulating means and devices.

Risk factors specific to the work environment:

- *physical risk factors:*
  - exposure to adverse weather conditions (low/high temperatures, rain, snow, air currents) during installations' control.

$$N_{20\,kV} = \frac{\sum_{i=1}^{11} R_i \cdot r_i}{\sum_{i=1}^{11} r_i} =$$

$$= \frac{11 \cdot (3 \cdot 3)}{11 \cdot 3} = \frac{99}{33} = 3,00 \qquad (2)$$

C. Risk level assessment for activity: 400 kV Primary Circuit Maintenance

The purpose of maintenance and repair of primary equipment is the following types of work:

- *servicing primary equipment;*
- *mechanical activities;*
- *welding and painting activity;*
- *masonry repair;*
- *dismantling of appliances.*

Risk factors specific to the means of production:

- *mechanical risk factors:*
  - hazardous movements;
  - cutting edges and sharp corners when replacing broken insulators;
  - explosion of molten metal particles or electric shock to electric welding;
  - explosions at transformers.

Risk factors specific to the work load:

- failure to properly prepare and/or failure to comply with the required steps in the performance of maintenance activities;
- failure to comply with measures to ensure the working area;
- oversized physical effort when removing the cutting-off switches from the switchgears.

Risk factors specific to the performer:

- *wrong action:*
  - misidentification of the installations in which work is being carried out;
  - wrong maneuvers when performing operational tests;
  - exceeding proximity distances when transporting materials to the work area and during work;
  - displacement, stationing in hazardous areas outside the working area;
  - falling from the same level by unbalancing, during the transport of materials within the area of the power substation,
- *omissions:*
  - non-use of personal protective equipment as provided or use of non-certified personal protective equipment.

Risk factors specific to the work environment:

- *physical risk factors:*
  - inhalation of noxious in paint work;
  - bad weather conditions (high/low temperature, wind).

$$N_{400-220kV} = \frac{\sum_{i=1}^{14} R_I \cdot r_i}{\sum_{i=1}^{14} r_i} =$$

$$= \frac{1 \cdot (1 \cdot 1) + 3 \cdot (2 \cdot 2) + 10 \cdot (3 \cdot 3)}{1 \cdot 1 + 3 \cdot 2 + 10 \cdot 3} = \frac{103}{37} = \mathbf{2,78} \quad (3)$$

D. Risk level assessment for activity: 20 kV Primary Circuit Maintenance

The purpose of maintenance and repair of primary equipment is the following types of work:

- *servicing primary equipment;*
- *mechanical activities;*
- *welding and painting activity;*
- *masonry repair;*
- *dismantling of appliances.*

Risk factors specific to the means of production:

- *mechanical risk factors:*
  - hazardous movements;
  - cutting edges and sharp corners when replacing broken insulators;
  - explosion of molten metal particles or electric shock to electric welding;
  - explosions at transformers.

When assessing the severity and probability of manifestation of these risk factors, the age of 20 kV power substations is also taken into account, an age that amplifies the accidental potential of electrical equipment.

Risk factors specific to the work load:

- failure to properly prepare and/or fail to comply with the required steps in the performance of maintenance activities;
- failure to comply with measures to ensure the working area;
- oversized physical effort when removing the cutting-off switches from the switchgears.

Risk factors specific to the performer:

- *wrong action:*
  - misidentification of the installations in which work is being carried out;
  - wrong maneuvers when performing operational tests;
  - exceeding proximity distances when transporting materials towards the work area and during work;
  - displacements, stationing in hazardous areas outside the working area;
  - falling from the same level by unbalancing, during the transport of materials within the area of the power substation.
- *omissions:*
  - non-use of personal protective equipment as provided or use of non-certified personal protective equipment.

Risk factors specific to the work environment:

- *physical risk factors:*
  - inhalation of noxious during in paint work;
  - bad weather conditions (high/low temperature, wind).

$$N_{20kV} = \frac{\sum_{i=1}^{16} R_I \cdot r_i}{\sum_{i=1}^{16} r_i} =$$

$$\frac{5 \cdot (2 \cdot 2) + 11 \cdot (3 \cdot 3)}{5 \cdot 2 + 11 \cdot 3} = \frac{119}{43} = \mathbf{2,76} \quad (4)$$

E. Risk level assessment for activity: 20 kV Secondary Circuit Maintenance

The team of revisions-repairs of equipments and secondary circuits and prophylaxis have as object of activity:

- *revision;*
- *maintenance;*
- *repair of secondary protection and circuits;*
- *prophylaxis of power installations.*

Risk factors specific to the means of production:

- *electrical risk:*
  - direct contact (unprotected terminals, unprotected heating elements);
  - indirect contact (housing, metal parts).
- *mechanical risk:*
  - functional movements of technical equipments;
  - displacements under the effect of propulsion.
- *thermal risk:*
  - flames, explosion of molten metal particles.

Risk factors specific to the work load:

- psychic stress on decisions in circuit and scheme modification operations in relation to the consequences of mistakes in performing these operations;
- physical strain, forced working positions during check at the clamp strings.

Risk factors specific to the performer:

- *wrong actions:*
  - touching the current paths during the high voltage tests;
  - touching a point of the current paths;
  - touching the terminals of devices, strings of clamps, relays;
  - parking, hazardous movements.
- *omissions:*
  - non short circuiting of the secondary windings at the current transformers for carrying out works related to low voltage circuits;
  - non short circuiting of the secondary terminals of the current transformers when opening the current circuits for mounting or dismounting the measuring devices;
  - omission of the connection to the null busbar of the internal services of a conductor from the protection circuit to the own busbar;
  - non use and/or non verification of personal protective equipments.

Risk factors specific to the work environment:

- *physical risk factors:*
  - lighting.

$$N_{EP} = \frac{\sum_{i=1}^{17} R_I \cdot r_i}{\sum_{i=1}^{17} r_i} =$$

$$\frac{13 \cdot (3 \cdot 3) + 3 \cdot (2 \cdot 2)}{13 \cdot 3 + 3 \cdot 2} = \frac{129}{45} = \mathbf{2,87} \quad (5)$$

F. Global risk level assessment of the 400 kV power substation

The risk levels, determined for each workplace in the 400 kV power substation are generally the followings:

Table 7. Workplace from 400 kV power substation

No.	WORKPLACE	LEVEL RISK (N_{rp})
1	400 kV Operational Service	2,28
2	20 kV Operational Service	3
3	400 kV Primary Circuit Maintenance	2,78
4	20 kV Primary Circuit Maintenance	2,76
5	20 kV Secondary Circuit Maintenance	2,87

The global risk level of the 400 kV power substation is:

$$N_{rg} = \frac{\sum_{p-1}^{n} r_p \cdot N_{rp}}{\sum_{p=1}^{n} r_p} =$$

$$\frac{(2,28 \cdot 2,28) + (3 \cdot 3) + (2,78 \cdot 2,78) + (2,76 \cdot 2,76) + (2,87 \cdot 2,87)}{2,28 + 3 + 2,78 + 2,76 + 2,87} =$$

$$\frac{37,75}{13,69} = 2,75 \quad (6)$$

$$\mathbf{N_{rg\text{-}power\ substation} = 2,75}$$

3. Conclusions

After the OHS risk analysis, the following conclusions are generated:
Global risk level of the 400 kV Tantareni power substation was calculated 2,75 – low – very low risk;
The operative staff of the 400 kV Tantareni power substation complies with the occupational safety and health norms;
The maintenance staff of the 400 kV Tantareni power substation complies with the occupational safety and health norms;
The danger of injury and professional illness is very low;
The entire 400 kV Tantareni power substation works correctly and does not show OSH non-conformities and does not pose a danger to the National Power System.

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