

RISK ASSESSMENTS IN TERMS OF OCCUPATIONAL HEALTH AND SAFETY FOR 400/220/110/20 kV IERNUT POWER SUBSTATION

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Abstract: This paper presents a comprehensive Occupational Health and Safety (OHS) risk assessment for the 400/220/110/20 kV Iernut power substation, a critical node in the regional transmission network. Owing to the complexity of high-voltage installations and the diverse operational activities involved, workers are exposed to a broad range of hazards, including electrical, mechanical, thermal, ergonomic, and environmental risks. The study applies established OHS methodologies – such as hazard identification, risk matrix evaluation, and Failure Mode and Effects Analysis (FMEA) – to systematically classify and prioritize risks associated with equipment operation, maintenance procedures, switching activities, and emergency scenarios. Findings indicate that the most severe risks relate to arc-flash events, electric shock, equipment failure during high-voltage maneuvers, and exposure to electromagnetic fields. Additional moderate to high risks include working at heights, confined-space hazards, and chemical exposure from insulating and cooling agents. Based on the assessed risk levels, the paper proposes a set of targeted control measures: engineering protections, procedural improvements, advanced personal protective equipment (PPE), enhanced training protocols, and real-time monitoring systems. The study underscores the importance of continuous risk reassessment and safety culture development to ensure reliable operation and worker protection within high-voltage substations.

Keywords: assessing, Occupational Health and Safety, power substation, L. 319/2206

1. DESCRIPTION OF THE NRDIOS BUCHAREST METHOD FOR RISK ASSESSMENT IN TERMS OF OCCUPATIONAL HEALTH AND SAFETY (OHS)

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The method developed by National Research and Development Institute of Occupational Safety "Alexandru Darabont" – NRDIOS Bucharest, aims to determine the quantitative level of risk/safety for a workplace, sector, section or company, based on a systemic analysis and assessment of risks of injury and occupational disease, in terms of OHS. The application of the method is finalised with a summary document – *Assessment Sheet of Workplace*, which includes the *global risk level of the workplace*.

The developed assessment sheet of the workplace is the basis of the program for the prevention of accidents and occupational diseases for the workplace, sector, section or company analysis. The essence of the method is to identify all risk factors in the system analysis (workplace) on the basis of pre-established control lists and to quantify the risk dimension on the basis of the combination of the severity and frequency of the maximum foreseeable consequence [1], [14], [19].

The *global risk level* (N_r) per workplace shall be calculated as a weighted average of the risk levels established for the identified risk factors. In order for the result obtained to reflect as accurately as possible the reality, the risk factor ranking, which is equal to the level of risk, shall be used as a weighting element [6], [20]. In this way, the highest risk factor will also be the highest ranking. Thus, it is eliminated the possibility for the cross-compensation effect, involved by any statistical average, to mask the presence of the highest-risk factor [2], [10], [13].

The formula for calculating the *global risk level* is the following:

$$N_r = \frac{\sum_{i=1}^n r_i \cdot R_i}{\sum_{i=1}^n r_i} \quad (1)$$

where:

N_r - the level of global risk in the workplace;

r_i - risk factor ranking „i”;

R_i - level of risk for the risk factor „i”;

n - number of risk factors identified at the workplace.

The *level of security* (N_g) at workplace is identified on the risk/security level mapping scale, built on the opposite proportionality of risk and security levels. Both the global risk level and the safety level are recorded in the workplace sheet. In the case of macro-systems assessment (sector, section, company), the weighted mean of the average safety levels determined for each workplace analysed in the macro-system component (similar workplace are considered as a single workplace) has to be calculated so that to obtain the *global level of safety at work* for the workshop/section/sector or enterprise under investigation – N_g : [11], [15], [18].

$$N_g = \frac{\sum_{p=1}^n r_p \cdot N_{rp}}{\sum_{p=1}^n r_p} \quad (2)$$

where:

- N_g = the overall risk level of the power substation;

- r_p = workplace rank p , equal to the risk level of the workplace;

- n = number of workplaces;

- N_{rp} = is the level of overall workplace risk.

The authors of the NRDIOS method recommended that the maximum acceptable risk level be 3,5.

2. RISKS ASSESSMENT IN TERMS OF OHS (ACCIDENTS AND OCCUPATIONAL ILLNESS) AT A 400/220/110/20 kV IERNUT POWER SUBSTATION WITHIN NATIONAL POWER SYSTEM

The 400/220/110/20 kV Iernut power substation is located in Iernut commune, Mures county, belonging to the Sibiu Electricity Transport Unit, according to fig. 1., represents an important power node of the Romanian Power System, through which the electricity produced in the Iernut Thermal Power Plant is discharged and the transfer of electricity to the Transylvania and Moldova regions.



Fig.1. Positioning of the 400/220/110/20 kV Iernut power substation
(source:www.transelectrica.ro)

The overall risk levels determined for each workplace at the 400/220/110/20 kV power substation are generally as follows (table 1.):

Table 1. Workplaces at the 400/220/110/20 kV power substation

No.	WORKPLACE	LEVEL OF RISK (Nrp)
1	400, 220 kV, 110 kV OPERATING SERVICE	X
2	20 kV OPERATING SERVICE	X
3	400, 220 kV, 110 kV PRIMARY CIRCUIT MAINTENANCE	X
4	20 kV PRIMARY CIRCUIT MAINTENANCE	X
5	SECONDARY CIRCUIT MAINTENANCE	X

2.1. Risk level assessment for the activity: 400, 220 kV, 110 kV Operational Service

The object of the activity is the operational service of the power installations: *supervision; control; maneuver* [3], [5].

1. Means of production:

400 kV Power Substation:

The 400 kV power substation is of the external type and is equipped with two bussbar systems to which the following power cells (switchgears) are connected next OHL: 400 kV Gadalin and 400 kV South Sibiu.

220 kV Power Substation

The 220 kV power substation is of the external type and is equipped with two bussbar systems to which the following power cells (switchgears) are connected next OHL: 220 kV Ungheni, 220 kV Baia Mare 3 and 220 kV Campia Turzii.

110 kV Power Substation:

The 110 kV power substation is of the external type and is equipped with simple bussbar systems, to which the following power cells (switchgears) are connected all consumers to distribution network.

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).

2. Work load:

According to the operating regulations, the duties of the operational staff are as follows: *performing the handover-receiving operations of the work team; supervision activity; control activity; the activity of executing the electric maneuvers.*

Risk factors specific to the work load:

- *psychic stress* in the 400 kV, 220 kV and 110 kV power substations, when installing shortcircuits by hand.

3. Performer:

The following staff works in the power substation: *manager (s) of the power substations (electrical engineer); shift leaders; shift leaders aides.*

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 [4], [16].

- *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.

4. Work environment:

The operating staff carries out the activity in the control room at the external power substations of 400 kV, 220 kV and 110 kV, where the specific nature of the work assignment requires operation and control activities regardless of climatic conditions and as a result the main risk factor specific to the working environment is

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the air temperature by exposure to high or low temperatures during the performances of the work assignment [7], [9], [17].

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.

Table 2. Workplace assessment sheet 400 kV, 220 kV and 110 kV Operational Service

NATIONAL POWER SECTOR		ASSESSMENT SHEET OF WORKPLACE	NUMBER OF EXPOSED PERSONS			
RESPONSIBLE NATIONAL COMPANY			EXPOSURE TIME: hours/shift			
400 kV, 220 kV and 110 kV OPERATIONAL SERVICE			ASSESSMENT TEAM:			
The composition of the work system	Identified risk factors	Concrete form of manifestation of risk factors	Maximum foreseeable consequence	Class of severity	Class of probability	Risk level
Means of production means of production means of production	Mechanical risk factors: falling from level	1. Falling due to distraction when moving through outside power substations	Temporary Work Incapacity 3–45 days	2	1	1
	Electrical risk factors: electrical shock hazard	2. Not using two mobile short circuits in the working area	DEATH	7	2	2
	Electrical risk factors: electrical shock hazard	3. Not using in working area of capacitive load damper (in case of capacitive currents)	DEATH	7	2	2
	Thermal risk factors: explosion hazard	4. Explosion of power, voltage, and current transformers, discharge	DEATH	7	1	3
Performer	Wrong actions: omission of present operations; not using means of protection	5. Not checking the lack of voltage before mounting the mobile short circuits	DEATH	7	2	2
		6. Failure to use/verify personal protective	DEATH	7	1	3

		equipment, tools and electro-insulating devices provided				
Work environment work environment	Risk factors: air temperature	7. Exposure to adverse weather conditions (high, low temperatures) when operating in outdoor power substations	Temporary Work Incapacity	2	1	1

The global risk level at workplace: 400 kV, 220 kV and 110 kV Operational Service

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

2.2. 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* [8].

1. Means of production:

20 kV Power Substation:

The 20 kV power substation is of the internal type and is equipped with double bussbar systems connected with longitudinal couple, to which the all power cells (switchgears) are connected: 20 kV OHLs; 20 kV Longitudinal Couple; 20 kV Measure; TSI 1 20/0,4 kV – 400 kVA (internal services); TSI 2 20/0,4 kV – 400 kVA (internal services).

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).

2. Work load:

According to the operating regulations, the duties of the operational staff are as follows: *performing the handover-receiving operations of the work team; supervision activity; control activity; the activity of executing the electric maneuvers.*

Risk factors specific to the work load: psychic stress in the 20 kV power substations, when installing short circuits by hand.

3. Performer

The following staff works in the power substation: *manager (s) power substations (electrical engineer); shift leaders; shift leaders aides.*

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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.

4. Work environment:

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.

Table 3. Workplace assessment sheet 20 kV Operational Service

NATIONAL POWER SECTOR		ASSESSMENT SHEET OF WORKPLACE		NUMBER OF EXPOSED PERSONS		
RESPONSIBLE NATIONAL COMPANY				EXPOSURE TIME: hours/shift		
20 kV OPERATIONAL SERVICE				ASSESSMENT TEAM:		
The composition of the work system	Identified risk factors	Concrete form of manifestation of risk factors	Maximum foreseeable consequence	Class of severity	Class of probability	Risk level
MEANS OF PRODUCTION	Mechanical risk factors: Hazard movements: movement under propulsion	1. Short circuit breaker explosions	DEATH	7	1	3
		2. Discharging explosions during operation	DEATH	7	1	3
	Electrical risk factors: electric current	3. Touching of unmarked terminals and installations	DEATH	7	1	3
		4. Touching live installations when connecting short circuits	DEATH	7	1	3
		5. Touching the 20 kV busbars during maneuvers	DEATH	7	1	3
	Thermal	6. Burns due to short circuits	DEATH	7	1	3

WORK LOAD	Inadequate work load content relative to requirements security	7. Mounting short circuits by hand	DEATH	7	1	3
PERFORMER	Wrong actions	8. Failure to respect the neighbouring distances with risk of electric shock by direct contact.	DEATH	7	1	3
		9. Failure to verify the position and/or condition of the components to be operated when maneuvering	DEATH	7	1	3
	Omissions: omission of operations present in the Maneuver Sheet	10. Not checking the lack of voltage before installing mobile short circuiting or closing the grounding knives	DEATH	7	1	3
	Omissions: not using means of protection	11. Failure to use or check personal protective equipment, tools and electro-insulating devices	DEATH	7	1	3

The global risk level at workplace: 20 kV Operational Service

$$N_{20\text{ kV}} = \frac{\sum_{i=1}^{11} R_i \cdot r_i}{\sum_{i=1}^{11} r_i} = \frac{11 \cdot (3 \cdot 3)}{11 \cdot 3} = \frac{99}{33} = 3,00 \quad (4)$$

2.3. Risk level assessment for activity: 400 kV, 220 kV and 110 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.*

1. Means of production:

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.

2. Work load:

Work load of the service and repair team is to: *technical revisions (TR) – annually on all equipment in the power substations; current revisions (RC) – changes in sub-assemblies, replacement of power substation components; accidental interventions – in the event of faults or failures in primary equipment; maintenance of auxiliary installations; maintenance work on the power substation; changes of lighting fittings.*

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.

3. Performer:

The service-repair team the primary equipment is composed of electricians who are led by a master.

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.

4. Work environment: *Risk factors specific to the work environment*

Table 4. Workplace assessment sheet 400 kV, 220 kV and 110 kV Primary Circuit Maintenance

NATIONAL POWER SECTOR		ASSESSMENT SHEET OF WORKPLACE		NUMBER OF EXPOSED PERSONS		
RESPONSIBLE NATIONAL COMPANY				EXPOSURE TIME: hours/shift		
400 kV, 220 and 110 kV PRIMARY CIRCUIT MAINTENANCE				ASSESSMENT TEAM:		
The composition of the work system	Identified risk factors	Concrete form of manifestation of risk factors	Maximum foreseeable consequence	Class of severity	Class of probability	Risk level

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MEANS OF PRODUCTION	Mechanical risk factors: functional movements of technical machinery Mechanical risk factors: functional movements of technical machinery	1. Displacement by means of transport to the workplace – road accident;	DEATH	7	1	3
		2. Hazardous surfaces	Temporary Work Incapacity	2	2	2
	Thermal risk factors	3. Injury by the thermal effect of the electric arc for service and repair personnel when traveling on the area of power substations for fulfilling the work load	1st degree Disability	6	1	3
	Electrical risk factors: indirect touch	4. Touching of metal parts accidentally under voltage, in conditions of: - damage to insulation from the metal housing; - failure of the protective connection	DEATH	7	2	3
WORK LOAD	Improper content in relation to security requirements	5. Improper preparation and/or non-compliance with mandatory steps and measures to secure the work area	DEATH	7	1	3
	Under/oversized workload in relation to the capacity of the performer	6. Dynamic, static effort, forced working positions at ground and height when handling and replacing subassemblies and components of primary equipment, insulators replacement	Temporary Work Incapacity 45-180 days	3	2	2

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WORK ENVIRONMENT	Physical risk factors	7. Inhalation of toxic dust and gases in the while performing painting operations	Temporary Work Incapacity 45-180 days	3	2	2
PERFORMER	Wrong actions	8. Incorrect identification of the installations in which they work, wrong maneuvers when performing functional tests	DEATH	7	1	3
		9. Entering the work area unprepared in terms of work safety	DEATH	7	1	3
		10. Incomplete work permit without specifying all working area insurance conditions	DEATH	7	2	3
		11. Exceeding neighbouring distances of materials to the work area and during the works	DEATH	7	1	3
		12. Displacement, stationing in hazardous areas outside the working area	DEATH	7	1	3
		13. Falling from the same level through imbalance during the transport of materials to the power substation	Temporary Work Incapacity 3-45 days	2	1	1
		Omissions	14. Not using the personal protective equipment provided or use	DEATH	7	1

		of non-certified personal protective equipment	
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The global risk level at workplace: 400 kV, 220 kV and 110 kV Primary Circuit Maintenance

$$\begin{aligned}
 N_{400-220kV} &= \frac{\sum_{i=1}^{14} R_I \cdot r_i}{\sum_{i=1}^{14} r_i} = \\
 &= \frac{1 \cdot (1 \cdot 1) + 3 \cdot (2 \cdot 2) + 10 \cdot (3 \cdot 3)}{1 \cdot 1 + 3 \cdot 2 + 10 \cdot 3} = \frac{103}{37} = \mathbf{2,78} \quad (5)
 \end{aligned}$$

2.4. 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.*

1. Means of production: 20 kV Power Substation:

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.

2. Work load:

Work load of the service and repair team is to:

- *technical revisions (TR) – annually on all equipment in the power substations;*
- *current revisions (RC) – changes in sub-assemblies, replacement of power substation components;*
- *accidental interventions – in the event of faults or failures in primary equipment;*
- *maintenance of auxiliary installations;*
- *maintenance work on the power substation;*
- *changes of lighting fittings.*

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;

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- oversized physical effort when removing the cutting-off switches from the switchgears.

3. Performer:

The primary service-repair team for equipment is composed of electricians who are led by a master.

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.

4. Work environment:

Service activity – primary equipment repair is carried out in the external power substation and very rarely in the mechanical room.

Risk factors specific to the work environment:

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

Table 5. Workplace assessment sheet 20 kV Primary Circuit Maintenance

NATIONAL POWER SECTOR		ASSESSMENT SHEET OF WORKPLACE		NUMBER OF EXPOSED PERSONS		
RESPONSIBLE NATIONAL COMPANY				EXPOSURE TIME: hours/shift		
20 kV PRIMARY CIRCUIT MAINTENANCE				ASSESSMENT TEAM:		
The composition of the work system	Identified risk factors	Concrete form of manifestation of risk factors	Maximum foreseeable consequence	Class of severity	Class of probability	Risk level
MEANS OF PRODUCTION	Mechanical risk factors: - functional movements of technical - machinery and hazardous surfaces	1. Traveling by means of transport to the workplace – road accident	DEATH	7	2	2
		2. Accidents caused by the omission of the MR spring during the adjustment operation (the MRI actuator of the 20-20 kV circuit breaker)	3st degree Disability	4	2	3

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		3. Cutting edges, sting when replacing broken insulators, TT, TC and damaged discharge devices	Temporary Work Incapacity 3-45 days	2	4	2
		4. Hazard of explosion TRBO transformers	DEATH	7	2	2
	Thermal risk factors	5. Injury by the thermal effect of the electric arc of service and repair personnel when traveling on the territory power substations of the work load	1st degree Disability	6	4	3
	Electrical risk factors: indirect touch	6. Touching of accidentally live metal parts under the conditions: - damage to insulation from the metal housing; - failure of the protective connection	DEATH	7	4	3
WORK LOAD	Inadequate content in relation to security requirements	7. Adequate preparation and/or non-compliance with mandatory steps and measures to secure the work area	DEATH	7	3	3
	Under/oversized workload in relation to the capacity of the performer	8. Dynamic, static effort, forced working positions at ground and height when handling and replacing subassemblies and components of equipments, insulating replacement	Temporary Work Incapacity 45-180 days	3	4	3
WORK ENVIRONMENT	Physical risk factors	9. Inhalation of toxic dust and gases in the execution of the operations of painting	Temporary Work Incapacity 45-180 days	3	2	2

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PERFORMER	Wrong actions	10. Incorrect identification of the installations in which they work, wrong maneuvers when performing functional tests	DEATH	7	4	3
		11. Entering the work area unprepared for work safety	DEATH	7	4	3
		12. Incomplete work permit without specifying all working area insurance conditions	DEATH	7	4	3
		13. Exceeding the distances of materials to the work area and during the works	DEATH	7	3	3
		14. Journeys, stationing in hazardous areas outside the working area	DEATH	7	3	3
		15. Falling to the same level through imbalance during the transport of materials to the power substation	Temporary Work Incapacity 3-45 days	2	3	2
	Omission	16. Not using the personal protective equipment provided or use of personal protective equipment non-certified	DEATH	7	3	3

The global risk level at workplace: 20 kV Primary Circuit Maintenance

$$N_{20kV} = \frac{\sum_{i=1}^{16} R_I \cdot r_i}{\sum_{i=1}^{16} r_i} = \frac{5 \cdot (2 \cdot 2) + 11 \cdot (3 \cdot 3)}{5 \cdot 2 + 11 \cdot 3} = \frac{119}{43} = \mathbf{2,76} \quad (6)$$

2.5. 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.*

1. Means of production: 20 kV Power Substation:

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.

2. Work load:

- *protection checks*: during the revisions, all the verifications provided by the technical books of protection are performed; the monitoring of the protection system parameters is done from the 20 kV control room.

- *measurements and verifications performed by the secondary equipments revisions-repair team*:

- at the internal service panels: checking the electrical connections; measurements at internal service cables; measurements at internal service transformers; checking switching devices and current transformers; calibration of fuses on all circuits; checking the ground connections.

- *within the prophylaxis program of the primary equipment from the 20 kV power substations, the following verification are performed*:

- measurements and checks performed on voltage measuring transformers are: measuring the insulation resistance of the windings; measuring the tangent of the dielectric loss angle at the main insulation; measuring the ohmic resistance of the windings; raising the idling characteristic; measuring the secondary load.

- measurements and checks performed on the current measuring transformers are: measuring the insulation resistance of the windings; measuring the tangent of the dielectric loss angle at the main insulation; measuring the ohmic resistance of the windings; raising the idling characteristic; measuring the secondary load; checking the polarity of the windings.

- measurements and checks performed on the circuit breakers are: measuring the insulation resistance; checking the contact resistance; checking the ohmic resistance of the triggering and triggering coil; low voltage operation of the control and automation installation; checking the dielectric strength of the oil.

- measurements and checks performed at power cables are: checking the continuity and identifying the phases; measuring the insulation resistance.

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.

3. Performer:

The team consists of electricians and a team leader or foreman who are authorized in terms of OHS (groups I, II, III, IV, V).

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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 dismantling 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.

4. Work environment:

Revisions – repairs of primary equipments and secondary circuits.

Risk factors specific to the work environment:

- *physical risk factors:* lighting.

Table 6. Workplace assessment sheet 20 kV Secondary Circuit Maintenance

NATIONAL POWER SECTOR		ASSESSMENT SHEET OF WORKPLACE		NUMBER OF EXPOSED PERSONS		
RESPONSIBLE NATIONAL COMPANY				EXPOSURE TIME: hours/shift		
20 kV SECONDARY CIRCUIT MAINTENANCE				ASSESSMENT TEAM:		
The composition of the work system	Identified risk factors	Concrete form of manifestation of risk factors	Maximum foreseeable consequence	Class of severity	Class of probability	Risk level
MEANS OF PRODUCTION	Mechanical risk factors: movement under dynamic effect	1. Traveling by means of transport to the intervention area – road accident	DEATH	7	1	3
	Electrical risk factors: direct touch	2. Explosions of primary equipment, during the movement on the 20 kV substation territory to perform service attributions	DEATH	7	1	3
		3. Touching unmarked terminals and installations	DEATH	7	1	3

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		4. Touching 20 kV busbar during revisions or repairs	DEATH	7	1	3
	- indirect touch	5. Touching of accidentally energized metal parts under the conditions of: - insulation failure; - damage to the protective circuit by grounding; - failure to operate the protection or within the time period before the protection is activated.	DEATH	7	1	3
	Thermal risk factors: flame, explosion of molten metal particles when producing electric arc	6. The capture of personnel by the thermal effect of the electric arc at failure of insulation of primary equipment	1st degree Disability	6	1	3
WORK LOAD	Oversize load in relation to performer's capacity: - psychic stress	7. Psychic stress on decisions in circuit and scheme modification operations in relation to the consequences of mistakes in performing these operations	Territorial Labour Inspectorate 3–45 days	2	2	2
	- physical stress	8. Physical strain, forced working positions during check at the clamp strings.	Temporary Work Incapacity 3–45 days	2	2	2
WORK ENVIRONMENT	- lighting	9. Lighting level in the 20 kV power substation	Temporary Work Incapacity 3–45 days	2	3	2
PERFORMER	Wrong actions:	10. Confusion when working	DEATH	7	1	3

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	defective execution of operations	on the clamp string in the protection system, resulting in loss of the current transformer secondary circuit, clamp and current transformer terminal overvoltage, electrical shock hazard, transformer failure and untimely equipment tripping				
		11. Touching of current paths-conductors, clamps or test machine busbars during high voltage tests, electrical shock hazard	DEATH	7	1	3
		12. Not short circuit of secondary windings at current transformer for carrying out works related to low voltage circuit – hazard of electric shock	DEATH	7	1	3
		13. Touching the terminals of devices, clamps, relays, during voltage checking of secondary circuits under the use of damages personal protective equipment	DEATH	7	1	3
		14. Not short circuit of the secondary	DEATH	7	1	3

		terminals of current transformer when opening current circuits for mounting / dismantling measuring devices				
	Parking, hazard movings	15. Parking or moving outside the work area or outside normal routes	DEATH	7	1	3
	Omission	16. Non use and/or non verification of personal protective equipments.	DEATH	7	1	3

The global risk level at workplace: 20 kV Secondary Circuit Maintenance

$$N_{EP} = \frac{\sum_{i=1}^{17} R_i \cdot r_i}{\sum_{i=1}^{17} r_i} = \frac{13 \cdot (3 \cdot 3) + 3 \cdot (2 \cdot 2)}{13 \cdot 3 + 3 \cdot 2} = \frac{129}{45} = \mathbf{2,87} \quad (7)$$

2.6. Global risk level assessment of the 400/220/110/20 kV power substation

The risk levels, determined for each workplace in the 400/220/110/20 kV power substation are generally the followings:

Table 7. Workplace from 400/220/110/20 kV power substation

No.	WORKPLACE	LEVEL RISK (N _{rp})
1	400 kV, 220 kV and 110 kV Operational service	2,28
2	20 kV Operational service	3
3	400 kV, 220 kV and 110 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 400/220/110/20 kV power substation is:

$$N_{rg} = \frac{\sum_{p=1}^n r_p \cdot N_{rp}}{\sum_{p=1}^n r_p} = \frac{(2,28 \cdot 2,28) + (3 \cdot 3) + (2,78 \cdot 2,78) + (2,76 \cdot 2,76) + (2,87 \cdot 2,87)}{2,28 + 3 + 2,78 + 2,76 + 2,87} = \frac{37,75}{13,69} = \mathbf{2,75} \quad (8)$$

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

3. CONCLUSIONS

After the OHS risk analysis, the following conclusions are generated: global risk level of the 400/220/110/20 kV Urechesi power substation was calculated **2,75 – low – very low risk**, the operative staff of the 400/220/110/20 kV Urechesi power substation complies with the occupational safety and health norms, the maintenance staff of the 400/220/110/20 kV Urechesi power substation complies with the occupational safety and health norms, the danger of injury and professional illness is very low, and the entire 400/220/110/20 kV Urechesi 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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