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ELECTRICAL OCCUPATIONAL RISK ANALYSIS AND SAFETY ASSESSMENT: METHODOLOGY PROPOSAL AND CASE STUDY

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Abstract: The main objective of the article is to evaluate the technical, organizational and other options that can be used in the future in Romanian industrial companies, in order to understand how theory and practice can be integrated to improve the prevention of electrical risks and related economic results. To this end, a complex methodology for electrical risk analysis and occupational safety assessment has been developed, based on a systematic and integrative approach to the issues associated with the components of work systems and those derived from compliance audit tools. The main novelty is related to the definition and consideration of the corrected probability and the corrected gravity, which facilitates a finer and more specialized analysis of the particularities of the investigated system by applying the proposed methodology. The article includes a case study on the application of the methodology in an industrial organization whose object of activity is the distribution of electricity. The results obtained confirmed the validity and usefulness of the tools developed to substantiate occupational safety and health policies aimed at minimizing electrical risks.

Keywords: Electrical Occupational Risk, safety level evaluation, risk analysis, corrected probability, corrected gravity.

1. INTRODUCTION

Traditionally, both scientific research in academia [1, 2] and practitioners have tended to address and analyze electrical hazards by focusing on the technical aspects and looking for the immediate causes of accidents or incidents after they have occurred (a posteriori analysis) [4, 13, 27, 28]. However, major accidents have highlighted the need for a proactive approach to safety. In addition to the perpetuation of events with severe consequences and as a direct consequence of them, the emergence of new

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regulations and international standards has required organizations to improve their safety performance [5, 6, 11, 12, 23, 24, 25]. As a result, companies have been forced to move from a prescriptive, regulatory, flexible, tailored, to a more dynamic approach to analyzing, evaluating, and, most importantly, managing operational risks that can affect important components of the activity, including electrical risks to the safety and health of workers [15, 19].

Electrical risk differs from other technological risks in that sensory perception is not sufficient to detect electrical hazards. Regarding the typology of the forms of manifestation of electrical risks, the potential risk factors can materialize in the activities of isolation and access of electrical networks and installations, when working in the vicinity of electric arc sources, when modifying or repairing high, medium and low voltage electrical installations, when testing and finding faults in high, medium and low voltage equipment and installations, when working with high fault currents - operation, testing or fault identification, as well as in many other areas and types of industrial and, in general, economic activity [18, 20]. The evolution of the statistical indicators regarding the collective work accidents produced in Romania in the last two decades according to the records of the National Institute of Statistics, in section 35 - Production and supply of electricity at national level, indicates that there is a decrease in the number of accidents [18]. However, the number of accidents caused by electrical risks continues to remain unacceptably high, with all the associated human, economic and social consequences, which attests to the importance of the topic addressed.

Existing, applied and validated approaches to occupational risk minimization may be a necessary and useful step in the concerted effort to effectively manage the safety and health of workers, but may not be comprehensive to properly address all complex issues related to occupational risk management, in the complex context of the current challenges posed by the major changes in the dynamic reality of emerging work environments [7, 8, 21]. With increasing relevance, it is necessary to identify, develop and implement a new pragmatic approach, realistic and adapted to the conditions, but - at the same time - systemic, with applicability in the area of manifestation of electrical risks [9, 10, 16].

The need for such an approach to electrical hazards may facilitate the development of a systemic model of occupational safety and health management, in the context of attempting to interpret events as a whole and to "see" events, including technical failures and human error, as "*products*" of a system operation and, in this regard, to analyze the consequences of scenarios as a result of the operation of the systems [17, 22]. The ultimate goal of such research is to maintain risk in an acceptable field in the operations of any industrial organization, regardless of the internal, external and risk management context in which it is located [26].

A methodology for the analysis of electrical risks in medium and high voltage installations has been proposed and applied. A logical sequencing of the stages regarding the proposed methodology was carried out, the priority areas for assessing compliance with safety requirements were defined, structured on the components of the investigated work system - ENS module, a set of tools for assessing risks used for quantification; an assessment of the level of safety and quantification of the risk was also carried out in a real organization, generically referred to as "*Electrical Risk*".

The methodology adapted and applied for the analysis of electrical risks within the organization allowed the investigation of work systems taking into account the dynamics of development and the existing inter-conditioning between the components of the system.

2. MATERIAL AND METHODS: RESEARCH METHODOLOGY

The role of the audit or assessment of compliance is to assess the degree of compliance with the provisions of the legislation and to assess qualitatively the efficiency of the elements of the OHS management system. The safety level is one of the performance indicators on the basis of which the OHS management analysis is performed [3].

In order to take into account the influences generated by the interdependencies of the human operator or the workload with the other elements of the system, the applied method introduced a series of correction coefficients determined based on the level of safety associated with the two human components (performer and work task). To assess the risk level associated with the material components of the work system (in this case, equipment and the work environment), the instrument uses a combination of the corrected severity of the probable consequences, the corrected probability of an undesirable event and the exposure to the risk factor of the target - staff [14].

The risk analysis completed with the conformity assessment carried out is an important first step in terms of the possibilities to make a coherent radiography, to develop a "landscape" as realistic as possible, systematic and coherent of the nature and magnitude of the risks in an organization that has as main object of activity work systems and processes that frequently involve the existence of electrical risks [1].

The methodological investigation tool adapted and applied in this paper for the analysis of electrical risks in the investigated organization, generically called "Electrical Risk", is based on the logic and essential structure of the general method [14], which is characterized by flexibility and best suited to the purpose of the study. By combining the tools / stages of the safety level assessment technique with those corresponding to the risk assessment method per microsystem / workplace / functional unit, there are performed, according to the methodology described in figure 1, the following analysis steps:

i. **Structural and functional description of the investigated system**;
ii. **Identification of electrical hazards / risks in medium and high voltage installations, with the important feature of the prior assessment of the system’s safety level**; the evaluation criteria (essential safety conditions) are not pre-established, the checklists that constitute the analysis tools, being built according to the particularities of the investigated system, so as to best define its safety level.

Thus, the methodology becomes very flexible and easy to customize for each work system / organization. For the assessment of compliance, the checklist used in the safety level assessment (ENS) method was used for each checklist criterion by using a six-level scale (0-5). The identification of the risk factors within each component of the work system is done by comparing an ideal situation, provided by legislative acts (laws, norms, norms, standards, instructions) with the real situation found in the investigated system.

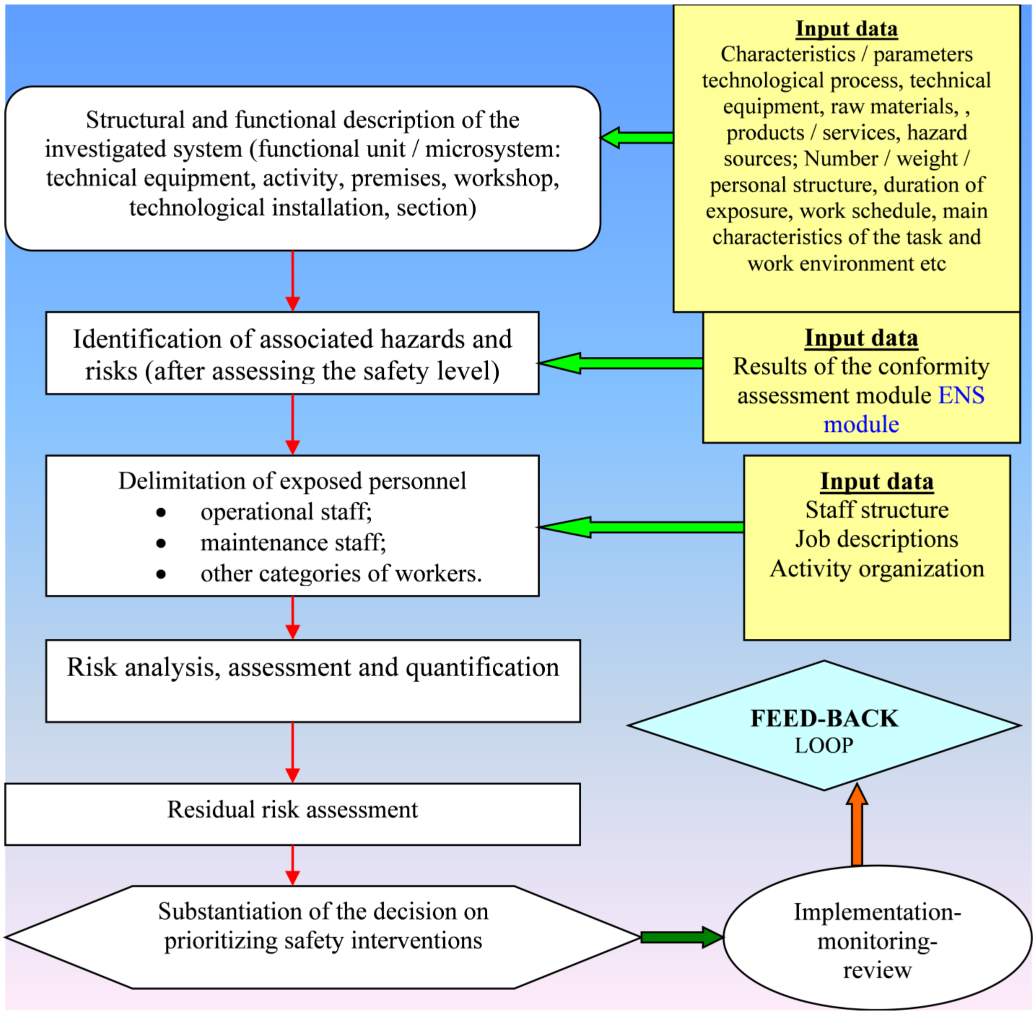


Fig.1. Proposed methodology for the analysis of electrical risks in medium and high voltage installations: logical sequencing of stages

In order to better identify the occupational risks present in the analyzed system and to be able to establish a more exhaustive list of the applicable essential safety requirements, the components of the work system are divided into several priority areas, according to figure 2. In order to establish the criteria (indicators) on the basis of which the risk factors are identified, a development is proposed in which, for each area of the components of the work system that may present non-conformities (work equipment and work environment), in parallel with establishing the criteria to determine the risk factors, the minimum safety requirements imposed on the respective domain are also identified, which are thus constituted in criteria for evaluating the safety level of the analyzed domain. Based on them, the questions that make up the checklists for assessing the level of safety for each area were established.

E01	Degree of training and professional competence
E02	Professional skills and abilities
E03	Attitude towards workload
E04	Ability to identify risks
E05	Attitude towards occupational risks

a. Defining priority areas for the "HUMA N FACTOR" component

SM01	First aid organization
SM02	Fulfilling the forms of work or arranging works
SM03	Admission to work
SM04	Organizing and securing work area
SM05	Supervision of the work team's activity

b. Defining priority areas for the "WORK LOAD" component to reduce the severity of the consequences (protection)

SM06	Execution of works without de-energizing power in installations
SM07	Execution of de-energized works
SM08	Execution of intervention works in case of damages, disturbances and incidents
SM9	Operational maintenance (supervision) of electrical installations
SM10	Execution of works at height specific to electrical installations
SM11	Physical overload - generated by microclimate and work environment
SM12	Mental overload coupled with factors external to load and work environment

c. Defining priority areas for the "WORK LOAD" component to reduce likelihood (prevention)

ET 01	Electrical insulating means
ET 02	Means of protection for earthing and short circuit
ET 03	Means of protection for the material delimitation of the work area
ET 04	Risks related to old SEN energy installations and equipment
ET 05	Personal work and protection devices and equipment including for working at heights
ET 06	Tools, devices and equipment for work under voltage
ET 07	Special vehicle, special devices and equipment (cranes, trolleys stepper, OHL, hoists, chainsaw)
ET 08	Mechanical risk
ET 08	Thermal risk
ET 10	Chemical risk

d. Defining priority areas for the "WORK EQUIPMENT" component

MM01	Working microclimate;
MM02	Noise;
MM03	Natural ultraviolet or infrared radiation.

e. Defining priority areas for the "WORK ENVIRONMENT" component

Fig.2. Defining the priority areas for assessing compliance with safety requirements, structured on the components of the investigated work system-ENS module

At the same time, depending on the importance given to each criterion for assessing the level of safety, a weighting is achieved by coefficients that can vary from 0.5 to 2, in order to establish a relative balance regarding the importance of that criterion in the risk management process. The specific coefficients required in the calculation of the parameters "***corrected severity***" and "***corrected probability***" related to the areas that assess the level of risk generated by technical non-conformities characteristic of "*means of production / work equipment*" and "*work environment*", respectively, are established, in this way their influence on the level of risk of the analyzed system, as follows:

- e_1 **-** probability correction coefficient, directly proportional to the safety level;
- SM_1 – severity correction coefficient, determined by the level of safety presented by the organizational measures to reduce the severity ;
- SM_2 – probability correction coefficient directly proportional to the level of safety, determined by the level of safety presented by the technical and organizational measures to reduce the probability.

iii. **Delimitation of the categories of exposed personnel;**

iv. **Analysis, evaluation and quantification of the risk level:** it is performed exclusively for the material components of the investigated system (figure 3);

v. The assessment and quantification of the risk level is based on the combination of the exposure, the maximum severity of the most likely consequences and the probability of materialization of the risk. The semantic value of the notion of risk level, within the concept of the proposed methodology, defines the level of residual risk as representing the level of residual risk **depending on the safety level of the system existing at the time of evaluation**. A summary table is used in which are listed: staff structure, number of workers per category of participants in the work process, weight in relation to the total number of workers in the system, exposure, severity of consequences and probability of occurrence (figure 4);

vi. **Residual risk assessment**; in order to assess the residual risks in terms of acceptability / unacceptability, the methodology uses a criticality of risks; In this sense, the occupational risk assessment form, for each analyzed field, is completed with a grid of risk classes, in which the corrected probability classes were written on the ordinate and the corrected severity classes were written on the abscissa. The inscription on this diagram of the values of the severity-probability couple determined for a risk factor allows the appreciation of the character of acceptability / unacceptability. The grid used is divided into three areas of risk classes: a) the field of acceptable risks; b) the field of acceptable risks with the taking of additional organizational measures; c) the field of unacceptable risks. The transposition on this grid of the pair of values of corrected gravity / corrected probability characteristic of each category of participants in the work process allows a global assessment of the area of occupational risks to which they are subjected (figure 4);

Class	Probability Simbols	Frequency of manifestation
class 6	FF (very frequent)	$P>1^{-1}$/lună.
class 5	F (frequent)	1^{-1}/an<$P<1^{-1}$/lună.
class 4	PF (low frquency)	$2^{-1}<P<1^{-1}$/an.
class 3	R (rare)	5-1<P<2-1/an.
class 2	FR (very rare)	$10^{-1}<P<5^{-1}$/an.
class 1	ER (extremely rare)	$P<10^{-1}$/an.

a. Probability rating: depending on the safety level of the material components of the work system (means of production, work environment), reliability of technical equipment, length of service of technical equipment, share in the staff structure of representatives of sensitive groups

b. Corrected probability

Consider the influences of "a posteriori" statistical analysis of accidents and elements of characterization of the staff structure / seniority of the ET in the form of correction coefficients and the influence of the level of safety determined by the human factor and the workload in the form of the coefficients e_1 and sm_2, thus:

$$P_c = P \times E \times k_2 \times k_3 \times k_4 \times e_1 \times sm_2$$ where:

E – probability correction coefficient depending on the level of exposure;

k_2 - probability correction coefficient depending given by the ratio between the frequency index of the analyzed system and the frequency index of the industrial branch to which the analyzed system belongs;

k_3 - correction coefficient given by the seniority of the technical equipment in service;

k_4 - correction coefficient given by the share in the personnel structure of workers with less than 4 years of employment and of workers with more than 20 years of employment.

c. Hazard exposure classes

- analyzing the photo-schedule for each category of workers, standard operating procedures:
- by direct observation of the work process;
- through direct discussions with workers / line management.

Exposure	Interpretation value
ER (extremely rare)	exposure of up to one hour per month;
R (rare)	exposure of up to one hour per week;
A (incidental)	exposure of up to one hour per day;
T (temporary)	exposure between one and four hours a day;

Class	Symbol	Meaning
class 1	N (negligible)	minor reversible consequences of foreseeable inability to work up to 3 calendar days - healing without treatment;
class 2	Mc (low)	reversible consequences with a foreseeable incapacity for work of 3-45 days, requiring medical treatment;
class 3	Md (average)	reversible consequences with a predictable incapacity for work between 45 and 180 days requiring medical treatment and hospitalization;
class 4	M (high)	irreversible consequences with a decrease in work capacity of maximum 50% - degree III disability;
class 5	G (serious)	irreversible consequences with the loss between 50 - 100% of the work capacity but with possibility of self-service - degree II disability
class 6	FG (very serious)	irreversible consequences with total loss of work capacity and self-service capacity degree I disability;
class 7	Ma (maximal)	death.

d. Severity (gravity) of consequences: rating grid

e. Corrected severity (gravity): $GCc = GC \times k_1 \times sm_1$; where:

k_1 - severity correction coefficient given by the ratio between the severity index of the analyzed system and the severity index of the industrial branch to which the analyzed system belongs ;

sm_1 - severity correction coefficient, determined by the level of safety presented by the organizational measures to reduce the severity

Fig.3. Research methodology: risk assessment tools used for quantification

a. Indicator rating grid from checklists

Score	Explanation
0	there is no evidence that the requirement of the indicator is met - (answer no or yes without interpretation)
1	totally insufficient evidence of the requirement of the indicator
2	existing evidence regarding the partial satisfaction of the requirement provided by the indicator - (missing or incomplete documentation, incomplete solutions regarding the elimination of non-compliance)
3	existing evidence regarding the almost complete satisfaction of the requirement of the indicator - (existing documentation, almost complete solutions regarding the elimination of non-compliance)
4	existing evidence of good satisfaction of requirement set out in the indicator (complete documentation, good solutions to eliminate non-compliance)
5	very good evidence of excellent satisfaction of the requirement of the indicator - (complete documentation, very good solutions to eliminate non-compliance; answer no or no without interpretation)

b. Safety/ conformity level calculation

$$\text{Conformity index} = \frac{\text{Obtained score}}{\text{Maximum possible score}} \times 100 \quad [\%]$$

where: The ***score obtained*** is the sum of the products between the score given for each criterion (valid) and the weighting coefficient of the indicator, ie = Σ (individual score given x weighting coefficient); ***Maximum possible score*** = the sum of the products between the maximum score (5) for each indicator (valid) and the weighting coefficient of the indicator, ie = Σ (5 x weighting coefficient)

c. Estimating the safety level (ENS-IC)

91%-100%	→ excelent;
81% - 90%	→ very good;
71%-80%	→ good;
61% - 70%	→ average;
51% - 60%	→ low;
sub 50%	→ unsatisfactory.

d. Risk level cuantification

The results of the assessments of the **corrected severity** and of the **corrected probability** are identified in the grid of risk levels, which is a summary of all combinations of the severity and the probability of their occurrence ordered by **risk levels**.

Risk level	Severity - probability coupling
1. Minimal	(1,1) (1,2) (1,3) (1,4) (1,5) (1,6) (2,1)
2. Very low	(2,2) (2,3) (2,4) (3,1) (3,2) (4,1)
3. Low	(2,5) (2,6) (3,3) (3,4) (4,2) (5,1) (6,1) (7,1)
4. Average	(3,5) (3,6) (4,3) (4,4) (5,2) (5,3) (6,2) (7,2)
5. High	(4,5) (4,6) (5,4) (5,5) (6,3) (7,3)
6. Very high	(5,6) (6,4) (6,5) (7,4)
7. Maximal	(6,6) (7,5) (7,6)

$$N_r = \frac{\sum_{i=1}^{n} r_i \times R_i}{\sum_{i=1}^{n} r_i}$$

e. Global rik cuantification

where: N_r - the level of global risk at work; r_i -the rank of the risk factor "i"; R_i - represents the partial level of risk for the risk factor "i"; n - the number of risk factors identified at work place.

Fig.4. Research methodology: Safety level assessment and risk quantification

Hazard level	The priority of implementing the prevention measure
NP > 3,5	Immediate correction. The activity is interrupted until the risk is eliminated.
3,5 > NP > 2,5	Urgent situation. Action is required as soon as possible.
2,5 < NP	The risk must be eliminated without delay, but situation is not an emergency.

a. Prioritization of preventive intervention according to the calculated hazard level

Priority no.	Explanatory criteria
1	• the risk factors analyzed can seriously affect the physical and mental integrity of the workers; • the values of the measurements of chemical, physical or biological noxious substances exceed • the maximum allowed limits; • medium consequences (ITM 45 and 185 days), large (grade III disability), severe (grade II disability), very severe (grade 1 disability) or severe (death); • probability of infrequent manifestation (1-2 times every 2 years), frequent (1 / year - 1 / month); • small investments; • corrective actions of an organizational nature.
2	• the risk factors analyzed may affect the physical and mental integrity of workers; • the values of the measurements of chemical, physical or biological noxious substances are close to the maximum limits; • small consequences (temporary incapacity for work between 3 and 45 days); • probability of rare manifestation (2-3 times every 10 years); • large investments.
3	• the risk factors analyzed affect to a small extent the physical and mental integrity of the workers; • there are exceedances of the maximum permissible limits only extremely rarely; • negligible or minor consequences (temporary incapacity for work between 3 and 45 days); • probability of very rare manifestation (1-2 times every 10 years); • large investments.
4	• the risk factors analyzed do not affect the physical and mental integrity of the workers; • there are no exceedances of the maximum admissible limits provided by the regulations in force; • negligible consequences (incapacity for work less than 3 days); • extremely rare probability of manifestation (less than once every 10 years); • very large investments, financially onerous, technology change.

b. The degree of priority and the hierarchical order of OSH interventions, explainedbased on criteria of severity, probability and associated macro-estimated costs

For measures deriving from the conformity assessment sheets		For measures deriving from risk assessment sheets		
NC	Priority	NRR	NC	Priority
95 ÷ 100%	4	1	Indifferent IC	4
91 ÷ 95%	4	2	NS>80%	4
85 ÷ 90%	3		NS<80%	3
81 ÷ 85%	3	3	NS>85%	3
75 ÷ 80%	2		NS<85%	2
71 ÷ 75%	2	4	NS>90%	2
65 ÷ 70%	1		NS<90%	1
61 ÷ 65%	1	5	Indifferent NC	1
55 ÷ 60%	1	6	Indifferent NC	1
50 ÷ 55%	1	7	Indifferent NC	1

c. Grid for assessing the priority degree allocated to safety interventions

Fig.5. The tools for substantiating the decision on the allocation of resources for prevention and protection

vii. Substantiation of the decision regarding the prioritization of safety interventions (prevention - protection)

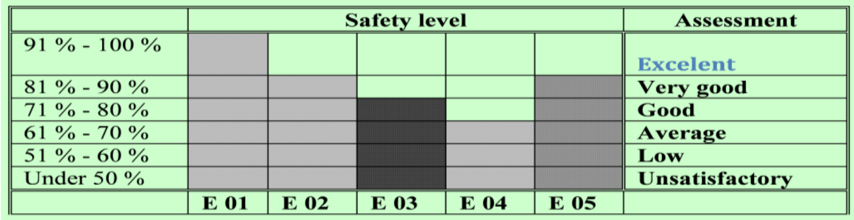
The classification of acceptable / unacceptable risks in the area resulting from the grid, correlated with the analysis of the answers to the minimum occupational safety and health requirements found in the checklists and the calculated hazard level allow the substantiation of the decision-making priorities, feasible, pragmatic and that will have the potential to ensure an optimal cost-benefit ratio. The content elements that ensure the substantiation of the decisions regarding the treatment of risks, in case of application of the proposed methodology are systematized and presented in figure 5. In order to establish the prevention / protection measures necessary to improve the level of compliance of the analyzed work system, it is also necessary to take into account the hierarchy of assessed risks, according to the scale of risk / safety levels.

3. RESULTS AND DISCUSSION

3.1. Analysis/interpretation of safety level induced by the human factor

The results of the synthesis regarding the level of safety induced by "Human Factor", on the 5 pre-established priority areas, are presented in figure 6, highlighting values of the safety level (compliance index) ranging from 60.95% (average) to 94.66% (excellent). The calculated average value of the global safety level induced by the human factor is NSG = 80.74% (very good level).

Work system component: HUMAN FACTOR	Priority area analyzed	Safety Level
E 01	Degree of training and professional competence	94,66%
E 02	Professional skills and abilities	88,95 %
E 03	Attitude towards workload	74,12 %
E 04	Ability to identify risks	60,95 %
E 05	Attitude towards occupational risks	85,00 %



NSG = 80,738% e_1 = 1,00

Fig.6. Results of the analysis regarding safety level induced by the "Human factor", on 5 priority areas

3.2. Analysis/ interpretation of the safety level induced by the work task

3.2.1. The component of reducing the consequences severity

The results of the synthesis regarding the level of safety induced by the component of diminishing the gravity of the consequences of the “Work task”, on the 6 pre-established priority areas, are presented in figure 7, highlighting values of the safety level (compliance index) ranging from 61.54% (average) to 85% (very good). The calculated average value of the overall safety level induced by this component of the work task is NSG = 75.53% (good level).

3.2.2. Probability reduction component

The results of the synthesis regarding the level of safety induced by the probability reduction component of the “Work task”, on the 6 pre-established priority areas, are presented in figure 8, highlighting values of the safety level (compliance index) ranging from 66.00% (average) to 84.55% (very good). The calculated average value of the global safety level induced by this component of the work task is NSG = 74.17% (good level).

Work system component: WORK TASK	Priority area analyzed	Safety Level
SM 01	First aid organization	80,00 %
SM 02	Fulfilling the forms of work or arranging works	85,00 %
SM 03	Admission to work	70,71 %
SM 04	Organizing and securing work area	61,54 %
SM 05	Supervision of the work team's activity	72,63 %
SM 06	Execution of works without de-energizing power in installations	83,31 %

NSG = 75,532%

Safety level							Assessment
91 % - 100 %							Excelent
81 % - 90 %							Very good
71 % - 80 %							Good
61 % - 70 %							Average
51 % - 60 %							Low
Under 50 %							Unsatisfactory
	SM 01	SM 02	SM 03	SM 04	SM 05	SM 06	

SM_1 = 0,695

Fig.7. Results of the analysis on the safety level induced by the "Work task", the component of diminishing the consequences severity

Work system component: WORK TASK	Priority area analyzed	Safety Level
SM 06	Execution of works without de-energizing power in installations	70,86 %
SM 07	Execution of de-energized works	84,55 %
SM 08	Execution of intervention works in case of damages, disturbances and incidents	70,77 %
SM 09	Operational maintenance (supervision) of electrical installations	80,00 %
SM 10	Execution of works at height specific to electrical installations	74,55 %
SM 11	Physical overload - generated by microclimate and work environment	72,50 %
SM 12	Mental overload coupled with factors external to load and work environment	66,00 %

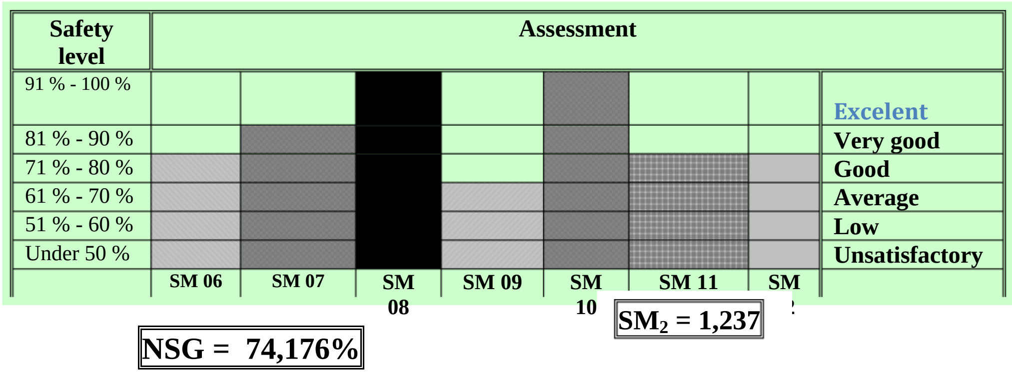


Fig.8. Results of the safety level analysis induced by the "Work task", the component of probability reduction

3.3. Residual risk resulting from assessment sheets and overall safety level

In order to assess the residual risks in terms of acceptability / unacceptability, based on the calculated values of the corrected probability and the corrected severity, the risk criticality grid was used, according to the described methodology. In this sense, the occupational risk assessment sheet, for each area analyzed, was completed with a grid of risk classes.

The transposition on this grid of the pair of values of corrected gravity / corrected probability characteristic of each category of participants in the work process allowed an estimate of the area of occupational risks to which they are subjected (figure 9.a).

Crt. no.	Assessment card code	NRR
1	ET 01.	5
2	ET 02.	4
3	ET 03.	2
4	ET 04.	3
5	ET 05.	4
6	ET 06.	5
7	ET 07.	3
8	ET 08.	1
9	ET 09.	2
10	ET 10.	2
11	MM 01	3
12	MM02.	1
13	MM03.	2

a)

For measures deriving from the conformity assessment sheets		*For measures deriving from risk assessment sheets*		
NSG	Priority	NRR	NSG	Priority
95 ÷ 100%	4	1	Indifferent NSG	4
91 ÷ 95%	4	2	NSG>85%	4
85 ÷ 90%	3		NSG<80%	3
81 ÷ 85%	3	3	NSG>85%	3
75 ÷ 80%	**2**		NSG<85%	**2**
71 ÷ 75%	2	4	NSG>90%	2
65 ÷ 70%	1		NS<90%	1
61 ÷ 65%	1	5	Indifferent NSG	1
55 ÷ 60%	1	6	Indifferent NSG	1
50 ÷ 55%	1	7	Indifferent NSG	1

b)

Fig. 9. Results of the residual risk analysis and the level of global safety.
a) Residual risk values; b) Framing the global safety level

The calculation of the global residual risk level (relation in figure 4.e) leads to the following result, using the residual risk values related to the 10 areas associated with "**Work Equipment**" and the three predefined and investigated areas of the "**Work Environment**" component:

$$N_{rg} = \frac{\sum_{i=1}^{13} r_i \cdot R_i}{\sum_{i=1}^{13} r_i} = \frac{2(5x5)+2(4x4)+3(3x3)+4(2x2)+2(1x1)}{(2x5)+(2x4)+(3x3)+(4x2)+(2x1)} = \frac{102}{31} = 3{,}29 \qquad (1)$$

The calculation of the global safety level is performed using a mathematical relationship that makes the percentage ratio between the sum of the actual safety levels, for each applicable criterion (human factor, work task) and the sum of the maximum possible level (theoretical):

$$NS = \frac{80{,}738 + 75{,}532 + 74{,}176}{300} = 76{,}82 \qquad (2)$$

according to the table is a good level

Priority grade 2 corresponding to the case study performed, according to the table in fig. 9.b, indicates the following: i) the analyzed risk factors may affect the physical and mental integrity of the workers; ii) a prevalence of low level consequences (temporary incapacity for work between 3 and 45 days); iii) the most frequent probability class of manifestation is the so-called generic rare (2-3 times every

10 years); iv) the values of the measurements of chemical, physical or biological noxious substances are close to the maximum allowed limits provided by the regulations in force; v) prevention / protection measures associated with priority class 2 generally involve significant investments.

4. CONCLUSIONS

The methodology adapted and applied for the analysis of electrical risks in the organization allows the investigation of the work system taking into account the dynamics of development and the existing inter-conditions between the components of the system.

In order to take into account the influences generated by the interdependencies of the human operator and / or the workload with the other elements of the system, the applied method introduced a series of correction coefficients determined based on the level of safety associated with the two human components (worker and work task).

The correction coefficients for the severity of the consequences and the probability of occurrence, respectively, were determined by:

- the exposure level;
- the ratio between the frequency index of the analyzed system and the frequency index of the industry to which the analyzed system belongs;
- the ratio between the severity index of the analyzed system and the severity index of the industry to which the analyzed system belongs;
- average length of service of technical equipment;
- the positioning in the personnel structure of the workers belonging to the groups sensitive to specific risks;
- the level of global safety presented by the areas of work task aimed at increasing the safety level;
- the level of global safety presented by the areas of work task aimed at reducing the severity of the consequences.

To assess the level of risk associated with the material components of the work system (in this case, equipment and the work environment), the instrument uses a combination of the corrected severity of the probable consequences, the corrected probability of an undesirable event and the exposure to the risk factor of the target staff members.

The residual risk fell within the acceptable risk range, and the overall safety level in the “GOOD” category (70% <NSG <80%).

The risk analysis, completed with the conformity assessment that has been performed, is an important first step in terms of the possibilities to achieve a coherent radiography, to develop a "landscape" as realistic, systematic and coherent as possible of the nature and magnitude of risks in an organization whose main object of activity is work systems and processes that frequently involve the existence of electrical risks.

Given the capacity / potential for improvement detected, the next stage of the research will logically be directed to the human and managerial components involved in these activities. It is considered imperative to develop a statistical study on the perceptions of workers / managers on how to achieve and - implicitly - the effectiveness of the operation of the occupational safety and health system.

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