

# Assessing the Professional Risk of Electricians Who Service Substations at The Karagandy Zharyk LLP

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**Abstract.** Electricians perform a wide range of work, from maintenance of electrical equipment to elimination of accidents. They are daily exposed to numerous harmful and dangerous production factors, including electric current, high voltage, electromagnetic fields, unfavorable parameters of the microclimate of the working area, chemicals and noise. The article deals with the assessment of the professional risk of electricians who service electrical substations of the Karagandy Zharyk LLP. The purpose of the study is to conduct a quantitative assessment of the professional risk of electrical personnel with the development of risk reduction measures. In the process of risk assessment, hazards were identified, taking into account the specifics of the work of electricians at substations. The analysis and assessment of the probability and consequences were carried out using the Fine-Kinney method. Based on the risk assessment results, organizational measures were proposed aimed at reducing the risk level and ensuring safe working conditions for electricians who service substations.

**Keywords:** electrician, professional risk, Fine-Kinney method, electric current, electromagnetic field, hazards, harmful and dangerous production factors, risk assessment.

## Introduction

Substations, their maintenance and repair play an important role in the energy complex. Electrical substations are designed to receive, to transform, and to distribute electrical power. Operation and maintenance of substations is a complex and responsible process that requires highly qualified and experienced personnel. Electricians perform a variety of functions, from scheduled equipment inspections to emergency response. The profession of an electrician is associated with numerous production risks that workers face on a daily basis. When performing their job duties, electrical personnel are exposed to various harmful and hazardous production factors, such as electric current, high voltage, electromagnetic field, high and low ambient temperatures, chemicals, noise [1-6]. Thus, the problem of the presence of hazardous and harmful production factors when servicing substations of the Karagandy Zharyk LLP is relevant, since these factors has

a negative impact on the health of workers.

In many developed countries, worker safety is ensured by managing industrial risks, which is becoming an increasingly popular and widely used approach. This is due to the fact that in the context of modern scientific and technological progress, the number and types of risks continue to grow, the technologies and equipment used are becoming more complex, and the capacity and productivity of technological systems are constantly increasing. As a result, the likelihood of incidents and accidents in various sectors of the economy increases which leads to significant material and social damage.

The purpose of the study is to analyze the working conditions of electricians, to perform a quantitative assessment of the professional risk of electrical personnel using the Fine-Kinney method, and to develop risk reduction measures.

### Research methods

The professional risk assessment was carried out in three standard stages: hazard identification, risk analysis and risk assessment. The Fine-Kinney method was used to analyze and to assess professional risk that allows to take into account the probability of hazardous situations, exposure to them and possible consequences. This approach allows obtaining substantiated risk assessment results and developing effective measures to reduce it. Its advantage is the simplicity of calculations, the ability to obtain a quantitative assessment of the risk level and clarity. The risk assessment was carried out based on the analysis of three factors: the degree of the harmful and hazardous production factor impact on an employee, the probability of its occurrence in the workplace and the consequences for human health as a result of the hazard.

### Hazard identification

The process of hazard identification is based on the results of analyzing the regulatory and technical documentation governing the activities of electricians who service substations at the Karagandy Zharyk LLP, as well as safety regulations for the operation of electrical installations. The results of workplace certification and the instructions for safety and labor protection of an electrician were also a source of information for hazard identification. An electrician who services electrical substations performs the key work at servicing and monitoring equipment at substations with voltage of up to 35 kilovolts. His responsibilities include ensuring stability of substation operating parameters, such as voltage, load and temperature, as well as performing operational switching in distribution devices. In addition, an electrician carries out regular inspections of equipment and troubleshoots in various parts of the substation. These responsibilities require high qualifications and attentiveness, since the work is associated with a number of hazardous factors.

When servicing equipment at 35-kilovolt substations of the III complexity level, an electrician directly interacts with live parts of the equipment under high voltage. In addition, during the inspection of the substation, an electrician can detect equipment malfunctions. Thus, when performing his duties, an electrician is exposed to the risk of electric shock. The danger comes from live parts of the equipment that do not have insulation or have damage to it. Contact with live parts of the equipment is mainly possible in emergency situations. For example, in 2021, a case of electric shock was registered at the Karagandy Zharyk LLP during operational switching. Cases of electric shock are also registered at the other power enter-

prises in Kazakhstan [7, 8]. Most accidents at power enterprises occur due to neglecting measures related to technical and organizational aspects of safety when performing work.

There is a risk of electric arcing during switching operations. Electric arcing can occur as a result of the following:

- worn, damaged or contaminated insulation;
- faulty connection diagram (e.g. broken wires on a power line, current-carrying elements blocked by animals or birds);
- equipment malfunction;
- high humidity;
- corrosion;
- increased voltage;
- erroneous actions of service personnel during operational switching operations in electrical installations.

The source of electric arcing is increased voltage in the network with a faulty connection diagram. Electric arcing is accompanied by a high temperature, intense radiation and a shock wave, which can lead to burns, eye damage (electrophthalmia).

In the process of monitoring and regulating the parameters of the mains, an electrician servicing the substations is exposed to the electromagnetic field. The sources of the electromagnetic field of industrial frequency at substations are power transformers, high-voltage disconnectors, switches, flexible and rigid busbars, overhead lines. When inspecting the territory of open switchgears during the operation of high-voltage equipment, the main source of the electromagnetic field is the busbar running through the territory of open switchgears.

In addition, when performing their duties, electricians are exposed to harmful production factors that include the following:

- an increased or decreased air temperature of the working environment;
- an increased noise level;
- insufficient illumination of the work area.

An electrician walks around a substation in all the weather conditions. Thus, he can be affected by both high and low air temperatures. When working outdoors without head protection during high temperatures, an electrician can get heat stroke. When working during low temperatures, there is a risk of frostbite. These factors can negatively affect the health of the worker. Thus, the source of these harmful production factors is work in adverse weather conditions.

An electrician can be affected by the noise level at the substation. High noise levels are present when operating closed switchgear. Noise is also present when operating open switchgear but its level is significantly lower.

The main sources of noise at substations are transformers and the other process equipment, ventilation equipment, and equipment elements.

When inspecting the substation area, a maintenance electrician is exposed to the risk of falling, since surfaces become especially slippery in winter or in adverse weather conditions (rain or fog). In addition, the risk of falling can increase in conditions of insufficient lighting of the work area. Falling from a height is also a danger but it is less common, since electricians rarely work at significant heights. Therefore, when carrying out an inspection, an electrician can encounter the risk of falling at the workplace.

When eliminating accidents, electricians often face severe working conditions. This can include lifting weights that exceed the permissible weight and working in awkward positions. Lifting weights that exceed the established standards leads to increased strain on the spine, joints and muscles, which can lead to injuries and disorders of the musculoskeletal system. Working in awkward positions, such as bending over or sitting for long periods, also has a negative impact on health since it causes circulatory problems, back, neck and shoulder pain. Together, these factors increase the risk of serious injury and impair the overall performance of an electrician.

Based on the analysis of sources of harmful and hazardous production factors, the following types of hazards were identified: electric shock, electric arc, exposure to electromagnetic fields and unfavorable microclimate parameters of the working area, falling in the workplace, exposure to physical overload, exposure to increased noise levels. Based on these types of hazards, the professional risk of electricians who service substations at the

Karagandy Zharyk LLP was assessed.

### Assessing the professional risk of electricians

To analyze the probability of occurrence of a hazard and its consequences for the employee, assessing the professional risk is carried out using the Fine-Kinney method. This method is based on the analysis of three factors: the probability of occurrence of a hazard in the workplace, the employee exposure to harmful and dangerous production factors, and the health consequences in the event of the hazard being realized. The result of assessing the professional risk for each identified hazard is a calculated indicator: the professional risk index determined by the formula [9]:

$$R = V \times P \times C, \quad (1)$$

where  $R$  is the professional risk;

$V$  is the probability of hazard occurrence;

$P$  is the employee exposure to a harmful and dangerous production factor;

$C$  is the consequence for the human health.

Table 1 presents the scales by which the probability of the hazard occurrence, exposure to a hazard and consequences for human health are assessed. The scale presented in Table 2 is used to assess the level of professional risk (five levels of risk): low, moderate, significant, high and extremely high.

Using Tables 1 and 2, an assessment of the professional risk of electricians who service substations of the Karagandy Zharyk LLC was carried out. The results of the obtained risk assessment are presented in Table 3.

Based on the inspection of workplaces and analysis of working conditions of electricians who service substations of the Karagandy Zharyk LLP, it was found that the probability of occurrence for all the types of hazards could be assessed as 3, i.e. not typical but possible.

**Table 1 – Scales for determining the probability, exposure and consequences**

Probability, V	Points	Exposure, P	Points	Consequences, C	Points
Almost improbable	0,2	Very rare (up to 1 time per year)	0,5	Minor injury, first aid is sufficient	1
May be but little probable	0,5	Rare (annual up to 11 times per year)	1	Cases of temporary incapacity for work, injury	3
Improbable	1	Sometimes (monthly up to 3 times a month)	2	Loss of ability to work, disability, occupational disease	7
Not typical but possible	3	Occasional (weekly up to 6 times a week)	3	Very severe, one fatal case	15
Very probable	6	Regularly (daily)	6	Destruction, there are victims	40
Expectable	10	Constant (more than 1 time per day or > 50% of shift time)	10	Catastrophe, many victims	100

**Table 2 – Scale to assess the level of professional risk**

Professional risk index	Risk level
0-20	Low
21-70	Moderate
71-200	Significant
200-400	High
Свыше 400	Extremely high

Exposure to electric shock from faulty current-carrying parts is assessed as 6, i.e. is regular, since the electrician's work is directly related to equipment where there is a constant risk of contact with electric current.

An electrician inspects the substation every shift. When walking, especially on uneven or slippery surfaces, due to inattention, they are regularly exposed to the danger of tripping over cables, wires, boxes, tools, etc. and, accordingly, falling in the workplace. When eliminating an accident, electricians can perform work at height. Thus, exposure to falling is assessed as 6, i.e. is regular. Exposure to electromagnetic fields and high noise levels is assessed as regular, since these harmful production factors are present on every shift.

Exposure to electric arc is rated as 3, i.e. is occasional. The worker is not regularly exposed to electric arcs but only in isolated cases, such as insulation failure or the other equipment malfunctions. Exposure to physical overload is also rated as 3, i.e. is occasional

that occurs mainly in emergency situations. When eliminating an accident, an electrician often works in an uncomfortable position or is forced to move equipment elements that exceed the permissible weight. Exposure to unfavorable microclimate parameters of the work area is rated as 3 (occasional). Microclimate parameters are usually assessed on the basis of specific conditions and depend on environmental factors such as weather conditions, which makes them probabilistic and variable depending on the time of year.

The consequences of electric shock are rated as 15, since the outcome can be very severe or even fatal, with possible damage to internal organs, burns and disruption of the vital systems functions. The consequences of electric arc injury are rated as 7, as they can lead to loss of working capacity due to damage to vision, requiring long-term treatment and rehabilitation, as well as a significant deterioration in the quality of life. Implementation of the other types of hazards is rated as 3, as they can lead to a temporary disability or injury.

The risk components are assessed according to the scale for determining probability, exposure and consequences. Multiplying these three factors according to formula 1 allows calculating the professional risk index. Assessing the resulting product according to the scale presented in Table 2, high and moderate risk levels for a substation maintenance electrician were obtained.

The danger of electric shock from faulty current-carrying parts represents a high level of risk. The following measures are recom-

**Table 3 – Results of assessing the professional risk of electricians who service substations of the Karagandy Zharyk LLC**

Hazard	Probability of the hazard occurrence, V	Exposure to the hazard impact, P	Consequences for human health, C	Professional risk index, R	Professional risk level
Electric shock	3	6	15	270	High
Electric arc shock	3	3	7	63	Moderate
Exposure to electromagnetic field	3	6	3	54	Moderate
Falling in the workplace	3	6	3	54	Moderate
Exposure to unfavorable microclimate parameters of the work area	3	3	3	27	Moderate
Exposure to physical overload	3	3	3	27	Moderate
Exposure to elevated noise levels	3	6	3	54	Moderate

mended to reduce it:

- training employees in first aid in case of electric shock;
- conducting an audit and inspection of electrical equipment before starting work;
- restricting access to substation maintenance for untrained persons;
- timely troubleshooting of equipment;
- conducting an express test of employees' knowledge before starting work.

For the other types of hazard, moderate risk levels were obtained. The following measures are recommended to minimize them:

- using a suit made of aramid fabric to provide protection from the effects of an electric arc;
- providing workers with protective glasses with filters that protect against bright flashes due to the occurrence of an electric arc;
- reducing the time spent in areas with high levels of electromagnetic radiation and industrial noise;
- providing production sites with non-slip surfaces to ensure safe movement of workers when performing their work duties;
- conducting regular inspections of work premises and remove obstacles that can cause falls;
- using lifting mechanisms to move heavy loads;

- providing workers with headlamps if it is impossible to install lighting lamps.

These organizational measures will help to form safer conditions for electricians and to reduce the level of professional risk in the workplace.

### Conclusion

In the course of the study, hazards for electricians who service substations at the Karagandy Zharyk LLP were identified, and the following types of hazards were identified: electric shock, electric arc shock, exposure to electromagnetic fields, exposure to unfavorable microclimate parameters of the working area, falling in the workplace, exposure to physical overload, exposure to increased noise levels.

Based on the results of the professional risk assessment using the Fine-Kinney method, high and moderate risk levels were identified. Organizational measures were proposed to reduce the likelihood of hazards and negative consequences for the health of electricians who service substations.

A systematic approach to solving the safety issues and implementing the proposed measures to comply with labor discipline will significantly reduce the likelihood of injuries and diseases, providing safer working conditions for electricians at substations.

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### **«Қарағанды Жарық» ЖШС қосалқы станцияларына қызмет көрсету бойынша электромонтерлердің кәсіби тәуекелін бағалау**

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**Аңдатпа.** Электромонтерлер электр жабдықтарына техникалық қызмет көрсетуден бастап апаттарды жоюға дейін көптеген зиянды және қауіпті өндірістік факторларға, соның ішінде электр тогына, жоғары кернеуге, электромагниттік өрістерге, жұмыс аймағының қолайсыз микроклимат параметрлеріне, химиялық заттарға және шуға ұшырайтын кең ауқымды жұмыстарды орындайды. Мақала «Қарағанды Жарық» ЖШС электр қосалқы станцияларына қызмет көрсететін электромонтерлердің кәсіби тәуекелін бағалауға арналған. Зерттеудің мақсаты-қауіпті азайту шараларын әзірлей отырып, электртехникалық персоналдың кәсіби тәуекелін сандық бағалау. Тәуекелді бағалау процесінде қосалқы станциялардағы электромонтерлер жұмысының ерекшелігін ескере отырып, қауіптерді сәйкестендіру жүргізілді. Ықтималдық пен салдарды талдау және бағалау Файн-Кинни әдістемесі бойынша жүргізілді. Тәуекелді бағалау нәтижелері бойынша қосалқы станцияларға күтім жасайтын электромонтерлер үшін қауіпсіз еңбек жағдайларын қамтамасыз етуге және тәуекел деңгейін төмендетуге бағытталған ұйымдастырушылық шаралар ұсынылды.

**Кілт сөздер:** электромонтер, кәсіби тәуекел, Файн-Кинни әдісі, электр тогы, электр доғасы, электромагниттік өріс, қауіптер, зиянды және қауіпті өндірістік факторлар, тәуекелді бағалау.

### **Оценка профессионального риска электромонтеров по обслуживанию подстанций на ТОО «Қарағанды Жарық»**

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**Аннотация.** *Электромонтёры выполняют широкий спектр работ, от технического обслуживания электрооборудования до устранения аварий, ежедневно подвергаясь воздействию многочисленных вредных и опасных производственных факторов, включая электрический ток, высокое напряжение, электромагнитные поля, неблагоприятные параметры микроклимата рабочей зоны, химические вещества и шум. Статья посвящена оценке профессионального риска электромонтеров, обслуживающих электрические подстанции ТОО «Қарағанды Жарық». Целью исследования является проведение количественной оценки профессионального риска электротехнического персонала с разработкой мероприятий по снижению риска. В процессе оценки риска, проведена идентификация опасностей, с учетом специфики работы электромонтеров на подстанциях. Анализ и оценка вероятности и последствий проведены по методике Файна-Кинни. По результатам оценки риска предложены мероприятия организационного характера, направленные на снижение уровня риска и обеспечение безопасных условий труда для электромонтеров обслуживающих подстанции.*

**Ключевые слова:** *электромонтер, профессиональный риск, метод Файна-Кинни, электрический ток, электрическая дуга, электромагнитное поле, опасности, вредные и опасные производственные факторы, оценка риска.*

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