Electric power supply management of the construction site in the interests of facilitating electrical safety

Maxim Polyukhovich[1,*], *Vyacheslav* Burlov[1], *Victor* Mankov[1] and *Amangeldy* Bekbayev[2]

[1]Higher School of Technosphere Safety, Peter the Great St. Petersburg Polytechnic University, 29 Polytechnicheskaya str., St. Petersburg, 195251, Russia
[2]Satbayev University, 22a Satpaev str., Almaty, 050013, The Republic of Kazakhstan

Abstract. A critical resource in construction work is electricity. Various problems that can lead to a breakdown of the electric power supply to the construction site can arise during its active operation. The basis of the activity is the decision of the person. Activity is based on the model. The dependence of human activity on electrical energy has formed the need to ensure uninterrupted electric power supply. To solve the complex problem of electric power supply, it is necessary to develop a theory. A properly constructed theory has three levels, three components: methodology, methods, technology. The decision maker (DM) perceives the world around him and carries out his activities through processes. A process is an object in action at a fixed purpose. A constructive methodology should form the condition for the existence of a process with which the DM works. The goal of research is to select and justify the conditions for the existence of the electric power supply process in the interests of guaranteed achievement of the goal of the industrial safety.

1 Introduction

Currently, in many regions of the country, a steady increase in electrical loads has resumed. Electricity consumption in the domestic sector has a steady growth trend [1].

The stability of the functioning of the construction industry cannot be imagined without reliable and high-quality power supply [2].

The task of power supply construction objects: uninterrupted supply of electricity to electric receivers, optimization of the parameters of power supply systems by the correct choice of nominal voltages, conditions of connection to the power system, selection of electrical equipment based on the calculation of electrical loads, reactive load compensation, rational distribution of electricity, ensuring protection of electrical installations.

The task of power consumption is the organization of safe (electrical safety) [3] and economical modes of operation with minimal financial costs [4] and reduction of electric power losses.

The type of construction, the volume of construction work, the technology and organization of production [5] largely determine the nature of consumers of electrical energy, electrical loads and electricity. At construction sites, electricity is used to drive operation of various mechanisms and machines. The main consumers of electrical energy at the construction site include tower cranes, various lifting mechanisms, hand power tools, electrical equipment for concrete mixing rooms, electric welding equipment, electric lighting, electrical equipment for heating concrete mixtures and soil, etc.

Thus, a critical resource for the construction site is electricity.

In scientific publications, individual problems of power supply are usually considered: reducing economic losses, energy saving, and the search for alternative sources of electricity [6]. Constructive methodological foundations in the form of the condition of the existence of the process with which the DM works are not presented in the publications. But without a methodological basis for solving energy supply problems in the form of a process condition, it is impossible to guarantee the achievement of an activity goal. Therefore, the tasks of power supply are solved on the basis of the necessary conditions. That is, on the assumption that the proposed solution exists. A fundamental problem arises: “The results of activity in solving energy supply problems do not meet the expectations of the decision maker” [7].

Adequate and uninterrupted power supply is provided only under the condition of safe operation of the electrical installation. In regulatory documents [8] security is defined as a degree of protection. But then we can conclude that the maximum protected electrical grid is one that does not work. Scientific and pedagogical school [9] offers and uses a broader concept of “security”. Security is a property that characterizes the ability of a system to retain its purpose during the life cycle.

* Corresponding author: mpolyukhovich@gmail.com

The considered set of factors determines the relevance of this research. The purpose of the article is to select and justify the conditions for the existence of the power supply process in the interest of ensuring the achievement of the goal of the DM's activities.

A person solves problems based on three categories: system, model, purpose.

The activity is carried out in 3 systems: social, economic, technical and technological. Power supply safety is based on the impact on the processes occurring in these systems. Social and economic systems are destroyed through individual and mass consciousness. Technical and technological system is destroyed through technical means. For the successful solution of power supply problems, it is necessary to solve two problems of a methodological level.

The first problem. To develop a system, two approaches are known: development of a system based on analysis (enumeration of possible options), development of a system based on synthesis (knowledge of the law of construction and operation of the system is necessary).

The first approach is usually used. However, he does not guarantee the achievement of the goal. The authors of this paper to solve problem 1 proposed to use for the synthesis of the object integrity maintenance law (OIML). The OIML is a stable, objective, repetitive connection of the properties of an object and the properties of its action with a fixed purpose. OIML ensures the achievement of the purpose of the activity.

The second problem. The DM solves problems based on the model. Therefore, it is necessary to be able to synthesize adequate models. There are three known approaches to assessing adequacy: testing in practice, comparison with a standard, completeness of accounting for the basic laws of the subject area. The third approach is suitable for solving the problems of power supply security. But for its implementation it is necessary to know such a law. In known publications, such a law was not considered. The authors propose to assess the adequacy of the model on the basis of the OIML.

2 Methods

In the process of power supply, the DM works with two groups of systems. This is a social and economic system and a technical-technological system. In this regard, the methodology for solving problems of power supply has two areas of application. These two spheres of activity are influenced by three groups of factors: social, economic, technical.

1. Socio-economic sphere. The synthesis of the formation of adequate models of social behavior as an individual, as a state as a whole. The basis of activity is the decision. A solution is a condition for the realization of the purpose of a control or self-management object. The activity is implemented through management.

2. Technical and technological sphere. Synthesis of an adequate model of the process of power supply under conditions of destructive influences. The second area of activity has been called “Electric Power Supply Safety”. The basis of activities in ensuring the safety of power supply is the preservation of the purpose of the process of functioning of an electrical installation. The impact of threats destroys the process of electrical installation in the interests of achieving the goal of the activity.

To solve these problems, the methodology for solving electrical power supply problems should give the DM a condition for the existence of the activity process. The decision is based on the system integration of the properties of human thinking, the properties of objects of the world and the general connection of phenomena.

For the formation of conditions that guarantee the achievement of the goal of activity, a Natural Science Approach (NSA) to the management of power supply is used.

The model of the electrical installation should be presented in the form of a graph with two states: initial (1) and final (2) (figure 1). The average time to complete the target task is given as “T ”:

$$T = f_0(æ_1, æ_2, \ldots æ_n), \tag{1}$$

where $æ_1, æ_2 \ldots æ_n$ - the parameters of the electrical installation.

The power supply system of construction objects is a combination of electrical installations and devices intended for the production, transmission and distribution of electricity, its accounting and control of quality indicators.

Electrical installation is a set of machines, devices, lines and auxiliary equipment (together with the facilities and premises in which they are installed) intended for the production, transmission, distribution of electrical energy and its transformation into another type of energy [10, 11].

The solution is implemented with human activity and the operation of electrical installations. The electrical installation implements the decision of the chief designer, the activity of a man - his itself decision. A decision is a process with which a person works.

Electrical safety should be considered in the following aspect. The main task is to preserve the purpose of the process of functioning of the object (electrical installation), namely, continuous operation within 24 hours. Security is the ability of an object to retain its purpose during the life cycle.

The level of security is the probability that each emerging threat is recognized and neutralized within the limits imposed on information, activity, and environmental resources [12, 13].

During operation, the solution to the target problem may be unsatisfactory. “ζ^-” - the failure rate. “ζ^+” is the frequency of satisfactory supply of electricity to consumers (the reciprocal of the average execution time of the target task). There is a problem: how to connect the process of electrical installation with the activities of the security system. A block diagram of the security process management is presented in figure 1.

As a result of the application of the methods of decomposition, abstraction and aggregation, the concept of “managerial decision” was transformed into an aggregate - a mathematical model of a managerial solution of the following type:

$$P = F(\Delta t_{PM}, \Delta t_{PI}, \Delta t_{PN}, T_E), \quad (2)$$

where Δt_{PM} - an average time of hazard occurrence (problem manifestation); Δt_{PI} - an average problem identification time; Δt_{PN} - an average time to neutralize the problem; T - the average time to complete the target task; P- an indicator of the effectiveness of the implementation of management decisions.

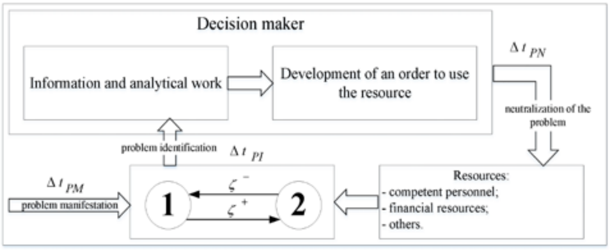

Fig. 1. Security process management framework.

The sign of the threat action (appearance of a problem) is a change in the characteristics of the object. The integral characteristic of an electrical installation is its power. One of the basic laws of electrical engineering is Ohm's law:

$$I = U/R \quad (3)$$

where I is the current strength, A; U - voltage, V; R - electrical resistance, Ω.

In Ohm's law does not depend on us electrical resistance.

Action is voltage - characterizes the process of manifestation of energy. Electrical resistance is an object that exists outside of us. They must match each other. The matching criterion is the passage of the required current strength.

For distribution lines of 0.4 kV class, the main limiting factor is the permissible voltage loss in the line section from the transformer substation to the consumer.

The solution of the problem is to ensure that the actual greatest voltage loss from the power source to the most remote node ΔU_1 is not more than acceptable ΔU_2.

Voltage loss can be represented as [14]:

$$\Delta U_1 = \sum^{n}_{i=1}(P_{iL}R_{iL}+Q_{iL}X_{iL})/U_{nom} =$$

$$= \sum^{n}_{i=1}(P_{iL}R_{iL})/U_{nom} + \sum^{n}_{i=1}(Q_{iL}X_{iL})/U_{nom} = \Delta U_a + \Delta U_r \quad (4)$$

where P_{iL}, Q_{iL} - active and reactive power, respectively, on the i-th segment, determined by the specified loads at the network nodes; R_{iL}, X_{iL}- active and reactive resistances of the i-th network segment; n is the number of consecutive sections; ΔU_a, ΔU_r - accordingly, voltage losses in active and reactive resistances.

Taking into account above, it is necessary to distinguish four basic states (figure 2). State "1" is the normal (initial) state of the electrical installation (the control object is located at the beginning of the process in question). State "2" is an established safe operation of an electrical installation that provides the required power supply to consumers (the control object fulfills its purpose). In the management process, regular situations are possible, which are characterized by proven schemes [15]. And abnormal situations when a problem arises in the management process (such a situation in which the capabilities of the staff do not correspond to the situation and have to find resources to resolve the problem that has arisen). In this connection, a third basic state of the system (process) appears, which is characterized by the fact of the problem (task) manifestation - the state "3". When the control process is in state "3", the electrical personnel must identify the problem that has arisen. At this stage, preparations are underway to attract additional resources to solve the problem. Thus, during the analysis of the solution, the management process goes to state "4". State "4" - analysis of the need to use specific resources to achieve the goal of management and the development of priority actions. The frequency of the transition of the system from state "1" to state "2" "ζ^+" is equivalent to the inverse of the average delivery time of a certain amount of energy to consumers (T). The frequency "ζ^-" characterizes the average frequency of power supply failure.

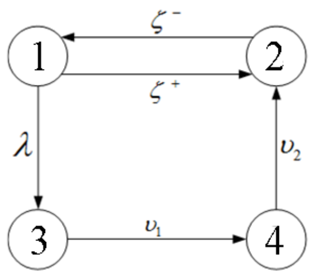

Fig. 2. State graph of the process of forming a management decision.

The transition from state "1" to state "3" is characterized by an intensity equal to the value: $\lambda=1/(\Delta t_{PM})$ (Δt_{PM} - an average time of hazard occurrence (problem manifestation)). The frequency of transition from state "3" to state "4" is equal to the value: $\upsilon_1=1/(\Delta t_{PI})$ (Δt_{PI} - average time of problem identification). The frequency of transition from state "4" to state "2" is equal to the value: $\upsilon_2=1/(\Delta t_{PN})$ (Δt_{PN} - the average time to neutralize the problem).

The process of forming a solution can be considered as a Markov chain. This approach does not allow to sufficiently take into account the dynamics of the process. Therefore, in the present research it is advisable to use continuous Markov chains. To implement this approach, it is necessary to create a system of Kolmogorov-Chapman differential equations.

3 Results

The solution of this linear algebraic system of equations is the following relations:

$$P_1=(\zeta^-\cdot\upsilon_1\cdot\upsilon_2)/(\lambda\cdot\zeta^-\cdot\upsilon_1+\lambda\cdot\zeta^-\cdot\upsilon_2+\zeta^+\cdot\upsilon_1\cdot\upsilon_2+\lambda\cdot\upsilon_1\cdot\upsilon_2+\zeta^-\cdot\upsilon_1\cdot\upsilon_2), \quad (5)$$

$$P_2=(\zeta^+\cdot\upsilon_1\cdot\upsilon_2+\lambda\cdot\upsilon_1\cdot\upsilon_2)/(\lambda\cdot\zeta^-\cdot\upsilon_1+\lambda\cdot\zeta^-\cdot\upsilon_2+\zeta^+\cdot\upsilon_1\cdot\upsilon_2+\lambda\cdot\upsilon_1\cdot\upsilon_2+\zeta^-\cdot\upsilon_1\cdot\upsilon_2), \quad (6)$$

$$P_3=(\lambda\cdot\zeta^-\cdot\upsilon_2)/(\lambda\cdot\zeta^-\cdot\upsilon_1+\lambda\cdot\zeta^-\cdot\upsilon_2+\zeta^+\cdot\upsilon_1\cdot\upsilon_2+\lambda\cdot\upsilon_1\cdot\upsilon_2+\zeta^-\cdot\upsilon_1\cdot\upsilon_2), \quad (7)$$

$$P_4=(\lambda\cdot\zeta^-\cdot\upsilon_1)/(\lambda\cdot\zeta^-\cdot\upsilon_1+\lambda\cdot\zeta^-\cdot\upsilon_2+\zeta^+\cdot\upsilon_1\cdot\upsilon_2+\lambda\cdot\upsilon_1\cdot\upsilon_2+\zeta^-\cdot\upsilon_1\cdot\upsilon_2). \quad (8)$$

Having obtained relationships that determine the probabilities of finding the system in states “1”, “2”, “3”, “4”, we can work out requirements for the properties of the process of recognizing a problem that has arisen in the system and the properties of the process of neutralizing this problem in the electrical safety system:

$$P_2=P_{INP}=(\zeta^+\cdot\upsilon_1\cdot\upsilon_2+\lambda\cdot\upsilon_1\cdot\upsilon_2)/$$
$$/(\lambda\cdot\zeta^-\cdot\upsilon_1+\lambda\cdot\zeta^-\cdot\upsilon_2+\zeta^+\cdot\upsilon_1\cdot\upsilon_2+\lambda\cdot\upsilon_1\cdot\upsilon_2+\zeta^-\cdot\upsilon_1\cdot\upsilon_2) \quad (9)$$

There are three parameters in this relationship. Thus, the analytical dependence of the generalized characteristics of the situation ($\Delta\ t_{PM}$), information-analytical activity ($\Delta\ t_{PI}$) and neutralization of the problem ($\Delta\ t_{PN}$) arising in the management of electrical safety was established. A system-forming factor was obtained to create a process control system for ensuring the safety of electrical installation operation in the form of a ratio (9).

4 Discussion

Relation (9) is considered as a condition for the existence of an electrical safety management process. Indicator of the level of electrical safety is set in the form of P_{INP} , and $\Delta t_{PM}=f_x\ (x_1,x_2,\ldots,x_n)$ - the characteristic of the situation. Based on the condition of ensuring the electrical safety indicator, it is possible to form the required indicator of the process of recognizing the situation $\Delta t_{PI}=f_y\ (y_1,y_2,\ldots,y_n)$ and the required indicator of the result of the electrical safety management activity $\Delta t_{PN}=f_z\ (z_1,z_2,\ldots,z_n)$. Here, vector X characterizes the process of problem formation, vector Y is the process of recognizing the situation, and vector Z is the process of neutralizing the problem in managing electrical safety. Identification of the situation is based on the qualified training of labor force.

In general, the research proposed the basics of building a process control technology to ensure the safety of electrical installations and the industrial safety.

References

1. V.B. Yakovlev and M.V. Rastorguev, Vestnik RGAZU. **3**, pp. 122–124 (2007)
2. D. Tarasova, K. Andreev and S. Lakić, MATEC Web of Conferences. **53** (2016)
3. A.P. Byzov, S.V. Efremov and F.A. Gomazov, Proceedings of the 2018 IEEE International Conference "WASTE 2018". pp. 10–13 (2018)
4. J.I. Idrisova, V.N. Myasnikov, A.I. Uljanov and N.V. Belina, International Conference on Information Networking. pp. 586-588 (2018)
5. J.I. Idrisova, T.T. Kaverzneva, N.V. Rumyantseva, I.L. Skripnik, IOP Conference Series: Earth and Environmental Science. **302** (2019)
6. N. Vatin and O. Gamayunova, Applied Mechanics and Materials. **672-674**, pp. 550-553 (2014)
7. E. Tuchkevich, A. Rechinsky, A. Vysotskiy, J. Zolotova and V. Tuchkevich, Procedia Engineering. **117 (1)**, pp. 1137-1142 (2015)
8. I.V. Aladyshkin, S.V. Kulik, and S.V. Efremov, IOP Conference Series: Earth and Environmental Science. **272** (2019)
9. Register of leading scientific as well as research and educational schools in Saint Petersburg. Available at: http://is.ifmo.ru/aboutus/2013/science-schools.pdf
10. O.K. Nikol'skij and N.I. CHerkasova, Vestnik AGAU. **7 (105)**, pp. 86-90 (2013)
11. S.V. Smolovik and F.Kh. Khalilov, Proseedings of the Kola Scientific Center of the RAN. **5**, pp. 155-163 (2011)
12. M. Lu and H. Li, Journal of Construction Engineering and Management. **4**, pp. 412-420 (2003)
13. W.P. Simpson III, J.H. Patterson, European Journal of Operational Research. **3**, pp. 525-542 (1996)
14. E.F. SHCHerbakov, Ul'yanovsk: UlGTU, 404 (2011)
15. Ju.S. Vasiliev, V.V. Elistratov, V.I. Maslikov and V.P. Breusov, 2005 IEEE Russia Power Tech. Paper № 4524811 (2005)