Safety management of the electric power supply process of the construction site, taking into account the qualification of the manager

Vyacheslav Burlov, Victor Mankov and Maxim Polyukhovich

1Higher School of Technosphere Safety, Peter the Great St.Petersburg Polytechnic University, 29 Polytechnicheskaya str., St. Petersburg, 195251, Russia
E-mail: polyuhovich_ma@spbstu.ru

Abstract. Sustainable development in the construction industry is hard to imagine without proper electric power supply. The fulfillment of the target by the control object (electric power networks, sources of electricity) can be achieved only if it’s safe. Safety management system should be developed based on synthesis. Only such an approach guarantees the achievement of the goal of activity (timely and high-quality electric power supply of the construction site). The basis of human activity is the decision of the person (decision maker). There is a need to take into account the qualifications of the manager. Human makes a decision based on a model. Therefore, it is advisable to introduce a manager’s qualification indicator into the mathematical model of managerial decision. The manager’s presence of knowledge and skills appropriate to the current situation allows timely response to emerging threats during the operation of the control object. The methodological foundations of creating a model of the managerial decision in managing the safety of the electric power supply process guarantee sustainable development in the field of construction of residential and industrial facilities.

Keywords: sustainable development, managerial decision, manager’s qualification, electric power supply.

1 Introduction

Socio-technical construction and civil engineering are some of the most material-intensive and basic sectors of the national economy, which consumes a huge amount of electricity. The state of the construction industry characterizes the sustainable development of the society. Construction is the engine of the socio-economic sphere of the state and produces a tangible comprehensive effect both on the development of industries associated the construction, and on all other aspects of society’s life, including social [1-2].

Most types of construction work require the availability of electricity: the use of electric power tools, external and internal lighting of workplaces, technological needs (heating of concrete, heating of soil, brickwork, etc.). Thus, without preliminary electrical work and laying electrical wiring, it does not make sense to begin construction of facilities.

Qualitatively completed design work while ensuring comprehensive electrification of facilities, including the wiring of individual systems and elements, will help to achieve significant savings in material and labor resources [3]. High-quality development of the electric power supply project will reduce the time of commissioning of the facility and increase quality indicators during its further
operation [4], while maintaining the reliable functioning of the technological processes of industrial enterprises, and the vital provision of electricity to social facilities [5].

When managing the electric power supply of the construction site, the following principles should be followed:

– electric power supply reliability;
– safety of builders and auxiliary staff during work [6];
– profitability of electric power supply process [7].

The electric power supply of the construction site is provided either by a stationary source or by a temporary one. Stationary sources include transformer substations, overhead transmission line and ground distribution devices, temporary ones include diesel (gasoline) generators.

Intermediate links in the electric power supply system are cable underground and overhead transmission lines. In case if underground power lines cannot be further used on an ongoing basis, it is recommended to use overhead transmission lines. Cable underground lines are used when the operation of overhead transmission lines can be dangerous.

When designing an electric power supply system, the necessary amount of electricity is first calculated [8]. After collecting the necessary data, experts determine the power of the transformer, select a source of electricity and design the power grid [9].

Despite the fact that the electric power supply of the construction site belongs to the category of temporary engineering services, in the design process it is necessary to carry out a whole list of very important tasks [10-14]:

– to calculate loads on lighting and electric power networks;
– to determine the total power consumption of a structure under construction;
– to calculate the electrical power of auxiliary sources of electric power supply (diesel generators, backup transformers, etc.);
– to design reserve line;
– to determine the layout of the main energy consumption points at the facility, etc.

The specific of electric power supply of the construction sites is such that the supply of such facilities with electricity is carried out through the use of rather non-traditional sources of electricity. These can be mobile electric power plants, or stationary diesel generators, which should also be commissioned by specialized organizations. It can be electrical substations, which are managed by a local power supply company, or there can be other sources of electricity (for example, low voltage), the power and basic characteristics of which corresponds to the level of energy consumption at the construction site.

The key requirement that specialists who connect electricity to the building under construction must comply is the need to ensure the proper level of electrical safety [15]. Electrical safety in this case involves the following conditions:

– the possibility of using combustible lubricants and explosive materials at the construction site;
– the safety of the environment from the negative factors effects [16] that may arise during the operation of the electric power supply system of the construction site;
– the safety of the system itself from the human factor.

The main problems of sustainable development of socio-technical construction and civil engineering arise in connection with the low qualification of specialists [17-18] who provide electric power supply of the construction site, design, construction and repair work. Sustainable development of any branch of human activity implies the existence of a fault-tolerant system that is stable functioning under the influence of threats (problems) [19-20]. Only the professional with a sufficient level of knowledge and relevant qualifications is able to manage such a system effectively [21]. In this regard, this study is devoted to the development of an indicator of the effectiveness of a managerial decision in the electric power supply of the construction site, taking into account manager or responsible specialist qualification indicator.
2 Methods

A person carries out his activities on the basis of the model [19]. As far as this model is adequate to the socio-economic environment, so successfully the person carries out his movement in life. By the facility model the description or representation of the facility corresponding to the object and allowing to obtain characteristics about this object is made [19].

The basis of the activity is always the decision of the person (decision maker – DM). Thus, a person makes a decision based on a model. By decision the condition for the implementation of the target purpose of the control object is meant. The process is the object in action with a fixed purpose. A person in his activity works with four processes:

– target process (fulfillment by the control object of its purpose – electric power supply of the construction site);
– problem manifestation process;
– problem identification process;
– process to neutralize the problem.

The stable operation of the electric power supply process of the construction site cannot be imagined without the organization of its safety, which includes a set of measures aimed at identifying the main threats and dangerous situations, assessing damage in the course of implementing these threats, and creating a site safety management system. Threats (problems) are manifested through the design, action model and resources in the system.

To create a site safety management system restrictions are imposed on the following resources:

– information resources (aimed at recognizing threats);
– activity resources (aimed at eliminating / preventing threats);
– resources of situation.

To synthesize a site safety management system a natural-scientific approach based on the object integrity maintenance law (OIML) is used [20].

OIML is a stable repeating relationship between the properties of the site and the properties of the action under a fixed purpose. OIML is manifested in the mutual transformation of the properties of the site and the properties of its action for a fixed purpose (figure 1) [20].

To develop a theory of correctly constructed systems modeling, you need to understand:

– methodology (doctrine of the principles of construction, forms and methods of scientific knowledge);
– methods (a way to achieve a goal, solve a specific problem; a set of techniques or operations of practical or theoretical knowledge of reality);
– technology (the science of ways of influencing raw materials or materials with appropriate tools).

![Figure 1. The object integrity maintenance law.](image-url)
The first level (1) characterizes the abstract level of representation of the theory and describes its methodology.

The second level (2) characterizes the abstract-concrete level of presentation of the main provisions of the theory, which include various methods.

The third level (3) characterizes a specific level of representation of the theory main provisions using algorithms or technologies.

The results of the application of the OIML are intended to theoretically substantiate the use of a set of measures that ensure safety and maintain the effectiveness of the control object operation.

Since the decision is the basis of human activity, it is necessary to form a managerial decision to ensure security.

Management is the targeted action of the subject to change the spatial and temporal states of the object, corresponding to the purpose of its functioning.

Managerial decision is a condition ensured by the subject the conditions for the implementation of the control object purpose in an appropriate situation in the interests of achieving the activity goal.

Situation is a set of factors and conditions in which activities are carried out.

Info-analytic work is continuous search, collection, study, display and analysis of data on the situation.

To form an adequate model of managerial decision, it is necessary to decompose the concept of "managerial decision" into three basic elements: "situation", "information-analytical work" and actually "decision" (figure 2) [20].

Figure 2. The structural scheme of formalization of managerial decision.

At the first level, the decomposition method is applied. The solution is divided into three elements: “situation”, “decision” and “info-analytical work”, which correspond to “object”, “purpose” and “action”.

At the second level abstraction is applied. A person perceives facts correlated in time [20], therefore it is advisable to characterize the “situation” (“object”) by the average time the person faced the problem $- \Delta \rho_\ell$. “Purpose” (“decision”) is identified with the frequency of neutralization of the problem (the average time is an adequate response to the problem) by a person $- \Delta \rho_\ell$. “Action” (“Info-analytic work”) is identified with the frequency of identification of the problem (average time to recognize the situation) $- \Delta \rho_\ell$.

Temporal characteristics are justified by the fact that only temporary resources for people are irreplaceable [19]. To obtain new results, the old developments are used, namely the results of research in the theory of functional systems of the academician of the Academy of Science of USSR.
P.K. Anokhin. They showed that a person’s decision is formed in the “excitation” ($\Delta_{\text{PM}}$), “recognition” ($\Delta_{\text{PI}}$), “reaction to the situation” ($\Delta_{\text{PN}}$) scheme. Therefore, it is assumed in the work that these time intervals are random variables, and the following diagram of the change in the basic components of the solution model formation is used (figure 3) [19].

![Diagram](image)

**Figure 3.** The manifestation of the basic elements of the formation of the decision model.

At level 3, an aggregate – a mathematical model of the decision (basic pattern) is created [19] (Eq. (1)).

$$P = F(\Delta_{\text{PM}}, \Delta_{\text{PI}}, \Delta_{\text{PN}}, T).$$

Eq. (1) is a condition for the existence of a management process of the control object safety without taking into account the manager’s qualification indicator.

### 3 Results

Using the state graph obtained in [19], the manager’s qualification influence on the management process is considered.

In [19], the following notations were adopted:

- $\lambda = 1/\Delta_{\text{PM}}$ – problem manifestation frequency;
- $\nu_1 = 1/\Delta_{\text{PI}}$ – problem identification frequency;
- $\nu_2 = 1/\Delta_{\text{PN}}$ – frequency of problem neutralization;
- $\zeta^+ = 1/T$ – frequency of solving management targets;
- $\zeta^-$ – frequency of failure to complete the target.

If the control object (process) is in state 3 (figure 4), then the need to complete the task requires identification of the problem that has arisen. Obviously, a certain time for managerial decision by DM is required to fulfill this requirement ($\Delta_{\text{PI}}$). During the problem identification process, measures are developed for the use of additional resources to resolve the problem. Electric power supply safety management system goes to state 4. The DM forms the necessary requirements, according to which it is determined what additional resources should be used to eliminate the problem and achieve the goal of the activity (electric power supply of the construction site). When the control system is in state 4, there are two scenarios:

1. The DM is not ready to solve the problem. In such a situation, the control system from state 4 goes into state 1 (initial state) – the target purpose is not solved.
2. The DM eliminates the problem within a certain time, the control system goes from state 4 to state 2, and i.e. the target purpose is done.
When the control system is in state 4, there are also two scenarios:

1. When solving the problem, the DM exceeds the permissible time limit for solving the task. As a result, the target purpose is not performed by the control object. This case is represented by the transition of the control system from state 2 to state 1.

2. The DM eliminates the problem within an acceptable time interval. The control object performs the target purpose.

The transition of the electric power supply management system of the construction site to its required state characterizes the presence of the required qualification level DM acquired as a result of appropriate training [21]. The frequency of the transition of the system from state 1 to state 2 \((\zeta^-)\) is equal to the reciprocal of the average time to complete the target purpose (electric power supply to the objects). This frequency characterizes the degree of preparedness for solving target tasks. Frequency \(\zeta^-\) characterizes the average frequency of non-fulfillment of the target purpose (interruptions in the electric power supply of sections of the construction site). The frequency of transition from state 4 to state 2 is a quantity \(\nu_2\) – the average time to neutralize the problem. The degree of preparedness for solving unknown problems depends on the ratio of the above frequencies.

The frequency of transition from state 4 to state 1 is a value \(\nu_1\) (the frequency of processes disruptions of eliminating the problem by the manager due to the inability to recognize the situation). Thus, the manager’s qualification indicator is expressed by the value \(\nu_1\).

In a previous study [19], a network model taking into account the DM’s qualification indicator is developed (figure 4).

![States graph of the management system](image)

**Figure 4.** States graph of the management system, taking into account the disruption of the target activity (electric power supply of the construction site) and the failure to solve the problem by the manager.

The following assumptions and suppositions were identified to describe the transition processes of the electric power supply management system of the construction site.

1. Information and management system (electric power supply management system) is analyzed.
2. The time intervals for identifying attributes of problems are random variables.
3. Attributes of problems are a stream in nature similar to a Poisson stream.
4. The time of data analyzing for the required attributes of problems is random value.
5. Information about the attributes of problems is distributed among the fixed resources providing the solution of the corresponding target tasks for the electric power supply of the construction site.
6. The case explored when the time and the presence of the required attributes of problems in the scope of the management system (person) are strictly limited and comparable with the time required for their identification, data analysis and approval of the relevant actions on these attributes.
7. The object safety management system is prepared to identify and neutralize problems that have arisen.
8. The object safety management system is designed to eliminate the potential threats influencing the electric power supply process (stable operation of the control object) depending on the current situation.
Based on the assumptions and suppositions above, the Kolmogorov system of differential equations is used. To solve this system, it is necessary to go to stationary processes. The following restriction is introduced in the form Eq. (2).

\[ P_1 + P_2 + P_3 + P_4 = 1. \] (2)

The probabilities of finding an electric power supply management system in certain states are no longer time-dependent. The solution of a linear algebraic system of equations is presented in the form of the relations Eq. (3), (4), (5) and (6).

\[ P_1 = \frac{\zeta^{-1} u_1 + \zeta^{1} u_1 + \zeta^{2} u_1 + \zeta^{3} u_1 + \zeta^{4} u_1 + \zeta^{5} u_1 + \zeta^{6} u_1 + \zeta^{7} u_1}{\lambda + \zeta^{1} u_1 + \lambda + \zeta^{2} u_1 + \lambda + \zeta^{3} u_1 + \lambda + \zeta^{4} u_1 + \lambda + \zeta^{5} u_1 + \lambda + \zeta^{6} u_1 + \lambda + \zeta^{7} u_1}, \] (3)

\[ P_2 = \frac{\zeta^{-1} u_2 + \zeta^{1} u_2 + \zeta^{2} u_2 + \zeta^{3} u_2 + \zeta^{4} u_2 + \zeta^{5} u_2 + \zeta^{6} u_2 + \zeta^{7} u_2}{\lambda + \zeta^{1} u_2 + \lambda + \zeta^{2} u_2 + \lambda + \zeta^{3} u_2 + \lambda + \zeta^{4} u_2 + \lambda + \zeta^{5} u_2 + \lambda + \zeta^{6} u_2 + \lambda + \zeta^{7} u_2}, \] (4)

\[ P_3 = \frac{\zeta^{-1} u_3 + \zeta^{1} u_3 + \zeta^{2} u_3 + \zeta^{3} u_3 + \zeta^{4} u_3 + \zeta^{5} u_3 + \zeta^{6} u_3 + \zeta^{7} u_3}{\lambda + \zeta^{1} u_3 + \lambda + \zeta^{2} u_3 + \lambda + \zeta^{3} u_3 + \lambda + \zeta^{4} u_3 + \lambda + \zeta^{5} u_3 + \lambda + \zeta^{6} u_3 + \lambda + \zeta^{7} u_3}, \] (5)

\[ P_4 = \frac{\zeta^{-1} u_4 + \zeta^{1} u_4 + \zeta^{2} u_4 + \zeta^{3} u_4 + \zeta^{4} u_4 + \zeta^{5} u_4 + \zeta^{6} u_4 + \zeta^{7} u_4}{\lambda + \zeta^{1} u_4 + \lambda + \zeta^{2} u_4 + \lambda + \zeta^{3} u_4 + \lambda + \zeta^{4} u_4 + \lambda + \zeta^{5} u_4 + \lambda + \zeta^{6} u_4 + \lambda + \zeta^{7} u_4}. \] (6)

4 Discussion

As a result of the research, an indicator of the effectiveness of the implementation of managerial decisions in the electric power supply of the construction site was obtained taking into account the indicator of manager's qualification.

Thus, the indicator of the effectiveness of the electric power supply management system can be represented as Eq. (7).

\[ P_5 = P_{SP} = \frac{\zeta^{-1} u_5 + \zeta^{1} u_5 + \zeta^{2} u_5 + \zeta^{3} u_5 + \zeta^{4} u_5 + \zeta^{5} u_5 + \zeta^{6} u_5 + \zeta^{7} u_5}{\lambda + \zeta^{1} u_5 + \lambda + \zeta^{2} u_5 + \lambda + \zeta^{3} u_5 + \lambda + \zeta^{4} u_5 + \lambda + \zeta^{5} u_5 + \lambda + \zeta^{6} u_5 + \lambda + \zeta^{7} u_5}. \] (7)

A synthesis-based approach solves inverse problems. To achieve the required indicator of the effectiveness of the safety system, measures should be developed to establish the necessary values for the indicators of manifestation, identification, neutralization of the problem and qualification of the manager.

The methodological foundations of creating a model of managerial decision in managing the safety of the electric power supply process guarantee sustainable development in the field of socio-technical construction and civil engineering.

Sustainable electric power supply of the construction site allows for timely and high-quality supply of electricity to the objects of the construction industry. The safety of such a process depends on the manager’s ability to act in the face of various threats (problems), for example, in the influence of extreme values of meteorological conditions.

In general, the study obtained a model of managerial decision in managing the safety of the electric power supply process with an indicator of manager's qualification.

References

[1] Levina E, Pyrkova G, Zakirova C, Semikova O, Nabiullina K, Ishmuradova I & Yakovlev S 2015 Socio-economic systems strategic development managing. Journal of Sustainable Development 8(6), pp 76-82. doi: 10.5539/jisd.v8n6p76

[2] Nabiullina K, Bystrova D, Torria R, Kovaleva N, Borisova L, Nesmeianova I & Kirakosyan S 2020 Managing innovation in complicatedly organized facilities. Journal of Environmental Treatment Techniques 8(1), pp 225-230.

[3] Murty V & Kumar A 2020 Multi-objective energy management in microgrids with hybrid energy sources and battery energy storage systems. Protection and Control of Modern Power Systems 5(1). doi: 10.1186/s41601-019-0147-z
[4] Arens S, Schlüters S, Hanke B, von Maydell K & Agert C 2020 Sustainable residential energy supply: A literature review-based morphological analysis. Energies 13(2). doi: 10.3390/en13020432

[5] Tang R, Wang S & Li H 2019 Game theory based interactive demand side management responding to dynamic pricing in price-based demand response of smart grids. Applied Energy 250, pp 118-130. doi: 10.1016/j.apenergy.2019.04.177

[6] Rumyantseva N, Primak E, Uljanov A & Kiss V 2019 Assessment of an occupational risk using injury safety indicators. In: International Scientific-Practical Conference on Quality Management and Reliability of Technical Systems 2019. St. Petersburg, Russian Federation. doi: 10.1088/1757-899X/666/1/012090

[7] Piacentini R, Vega M, Morabito J & Rene Estevez M 2019 Academic buildings as a substantial part of the teaching system. the case of the new building design at the school of engineering, national university of rosario, argentina. In: 4th World Multidisciplinary Civil Engineering-Architecture-Urban Planning Symposium, WMCAUS-2019. Prague, Czech Republic. doi: 10.1088/1757-899X/603/3/032036

[8] Soluyanov Y, Fedotov A & Ahmetshin A 2019 Calculation of electrical loads of residential and public buildings based on actual data. In: International Scientific Electric Power Conference 2019, ISEPC-2019. Peter the Great Saint Petersburg Polytechnic University, Saint Petersburg, Russian Federation. doi: 10.21869/2223-1560-2017-21-1-57-68

[9] Tronchin L, Manfren M & Nastasi B 2018 Energy efficiency, demand side management and energy storage technologies – A critical analysis of possible paths of integration in the built environment. Renewable and Sustainable Energy Reviews 95, pp 341-353. doi: 10.1016/j.rser.2018.06.060

[10] Kuehn I, Cordier J, Carafa L, Darbour R, Giuseppe G D, Jeannoutot T, ... Zhang Y 2018 Status on design and construction of the ITER buildings and plant systems. IEEE Transactions on Plasma Science 46(7), pp 2647-2652. doi: 10.1109/TPS.2017.2774861

[11] Hariharan S, Borders K & McCrea B 2019 A case study of a remote line powered small cell network. In: 2018 IEEE International Telecommunications Energy Conference, INTELEC 2018. Torino, Italy.

[12] Kuscu L, Hand D, Rose C, Mink R & Kuscu I 2018 Development of a low temperature, low flow hot spring for demonstration of a distributed energy resource unit in surprise valley, cedarville, California. The Transactions - Geothermal Resources Council 42, pp 289-304.

[13] Gray A, Pisica I, Taylor G & Whitehurst L 2017 Exploiting granular electrical energy data and the challenges a utility company faces with an ageing asset base. In: 52nd International Universities Power Engineering Conference, UPEC 2017. Heraklion, Crete, Greece. doi: 10.1109/UPEC.2017.8231900

[14] Schneider C, Braun S, Klette T, Härtelt S & Kratzsch A 2016 Development of integration methods for thermal energy storages into power plant processes. In: The ASME 2016 10th International Conference on Energy Sustainability, ES 2016, Collocated with the ASME 2016 Power Conference and the ASME 2016 14th International Conference on Fuel Cell Science, Engineering and Technology. Charlotte, United States. doi: 10.1115/ES2016-59266

[15] Liu M, Tang P, Liao P & Xu L 2020 Propagation mechanics from workplace hazards to human errors with dissipative structure theory. Safety Science 126. doi: 10.1016/(ASCE)ME.1943-5479.0000690

[16] Vodolazhskaya E, Kiseleva O, Kharisova R, Sutyagin S, Kurbanov R, Lushchik I, ... Zhandarova L 2019 Preventive management of industrial enterprise environmental risks. Ekologiya 28(107), pp 317-324.

[17] Khairutdinov R, Safin R, Korchagin E, Mukhameztyanova F, Fakhirutdinova A & Nikishina S 2019 The content of educational programs in technical universities: Quality of applying the modern professional standards. International Journal of Instruction 12(1), pp 357-360. doi: 10.29333/iji.2019.12124a
[18] Wong T, Man S & Chan A 2020 Critical factors for the use or non-use of personal protective equipment amongst construction workers. *Safety Science* **126**.

[19] Polyukhovich M, Burlow V, Mankov V & Bekbayev A 2019 Electric power supply management of the construction site in the interests of facilitating electrical safety. In: 2019 International Scientific Conference on Energy, Environmental and Construction Engineering, *EECE 2019*. Congress Center of Peter the Great St. Petersburg Polytechnic University, Conference hall of the Ambassador Hotel 5-7 Rimsky-Korsakov str. Saint-Petersburg, Russian Federation. doi: 10.1051/e3sconf/201914008006

[20] Burlow V, Andreev A, Gomazov F & Somga-Bichoga N 2018 System integration of security maintenance processes in knowledge management. *The Proceedings of the European Conference on Knowledge Management, ECKM 1*, pp 112-122.

[21] Mitrofanova E, Simonova M & Tarasenko V 2020 Potential of the education system in Russia in training staff for the digital economy. *Advances in Intelligent Systems and Computing* vol. **908**, pp 463-472. doi: 10.1007/978-3-030-11367-4_46