MODELS OF THE COMPUTER INTELLECTUALIZATION OPTIMAL STRATEGY OF THE POWER SUPPLY FAST-FLOWING TECHNOLOGICAL PROCESSES OF THE RAILWAYS TRACTION SUBSTATIONS

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Resume

Based on analysis of the problem of the power supply networks of railways innovative transformation, the direction of research is substantiated related to organization of the optimal strategy of computerized intellectualization of the power supply processes to the railways traction substations. The logical structure of a distributed computer environment developed in the form of graph, which adequately reflects the topology of the organization of the power supply system. A differential mathematical model of the computer architecture of the power supply control is proposed. An intelligent method for finding the optimal strategy for the intellectualization of the power supply processes was proposed to guarantee the specified indicators of the optimal functioning of individual nodes and segments of the power supply management computer network.

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1 Introduction

Computer systems and networks are the main component in functioning of business, government organizations, military institutions, health systems, education and science. In the process of managing the complex energy and social systems that operate in normal and abnormal modes, there is a need for registration, storage and processing of large amounts of information and formation of the control actions. National competitiveness depends, first of all, on the procedures for conducting, in real time, information analysis and decision-making of flexible management of production or social facilities.

The experience of using information technology in the management of complex systems has shown that many of the limitations in solving the real problems are significantly reduced by adding intelligence to computer systems, or modelling intelligent control procedures [1-2]. Moreover, in many cases, classical methods are ineffective for many practical problems of production and business since it is impossible to accurately describe reality when creating a management model.

A study of evolution of the computer networks and systems development for managing complex objects showed that the maximum efficiency of their functioning can be achieved by mutual integration of the intellectual resources of managers and modern capabilities of almost unlimited performance of distributed computing [3].

This fact led to creation of a new class of mathematical models and methods of intelligent information processing, as a basis for creation of the intelligent computer systems [3-6]. For example, in [7] a method was proposed based on use of simplified calculations of state of a train as a controlled system without the use of differential equations of motion, which can significantly increase the speed of calculations. This, in turn, will solve the problem of finding the optimal control in real time, taking into account the changing conditions during the movement of the train. To implement this method of calculation, a simplified model of the train was used as a controlled system.

2 Separation of previously unresolved parts of a common problem

Many authors' works are dedicated to the complex problem of the innovative transformation of traction electric lines by organizing energy-saving technologies and optimizing the processes of power supply in railway

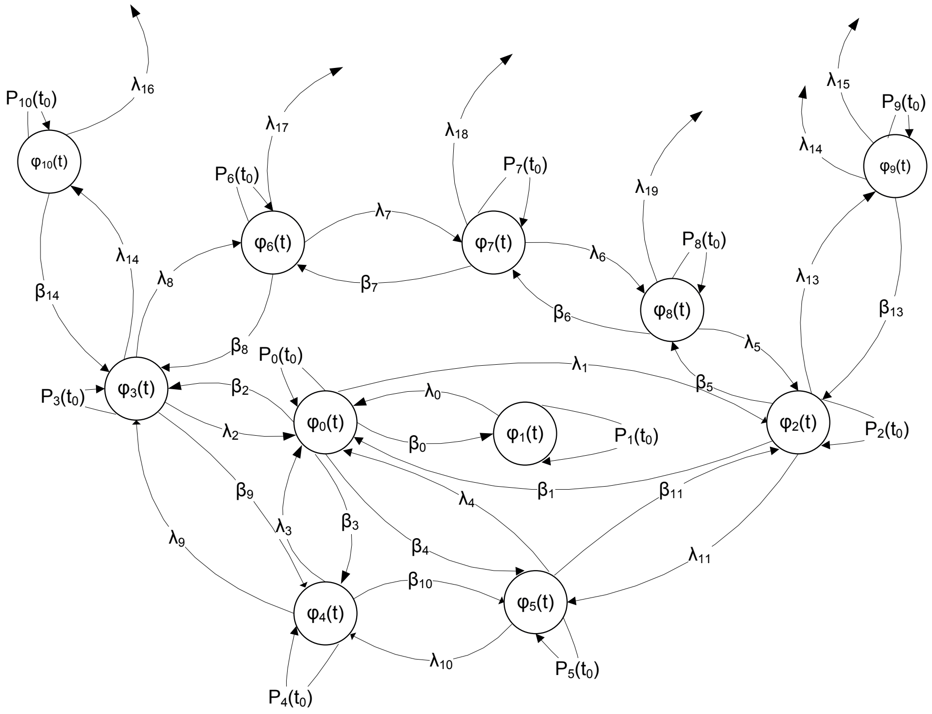

Figure 1 *Graph of the architecture of the local computer network of the traction substation*

transport [1, 6]. In [8], to improve energy efficiency, the possibility of using Smart Grid in urban transport conditions was considered. Thanks to the Smart Grid solutions, traction power systems are no longer passive energy consumers. They become a dynamic link in the power system. In electric transport systems, energy islands can be created that serve as elements of modern smart power systems [9]. In work [10], the solution to the scientific problem of increasing the energy efficiency of DC traction systems by the development of distributed power systems that fit into the existing infrastructure to ensure high-speed traffic, which is necessary for electric transport, is considered. Thus, in the scientific works there is a promising direction of research aimed at developing mathematical models for the traction power supply systems and methods that combine human intelligence and the computer environment. A new class of computer intelligent systems has appeared that is focused on the integrated intellectualization of a set of procedures for the operational and strategic management of the fast-flowing technological processes of energy supply and power consumption. This fact stimulated the emergence of new analytical and intelligent technologies, which, based on certain models, algorithms, and mathematical theorems, allow, according to known data, to estimate the values of unknown characteristics and parameters of a complex object of study [6, 11-13]. It became apparent that a qualitatively new set of intelligent traction power supply systems could be obtained by forming a deep mutual integration of topology of the power grid infrastructure of the power supply system and architecture of a distributed computer network. At the same time, truly little attention is paid to the previously unresolved parts of the problem of innovative transformation of traction electric lines - creation of mathematical models and methods for analyzing and evaluating the optimal functioning of individual nodes and segments of intelligent computer networks for controlling the fast-flowing power supply technological processes.

3 Aim formulation

The aim of the work is the organization of an optimal computerization strategy for the fast-flowing technological processes of power supply lines by developing mathematical models and methods of increased intellectual complexity and dimensionality of analysis and assessment of the conditions for optimal functioning of individual nodes and segments of a distributed computer-based power management network.

4 The main research material

Distributed railway power supply systems represent a hierarchical system, the basic level of which is the level of traction substations as the basis for minimizing the system-wide costs, optimizing power consumption and transportation reliability. The emergence of promising areas of innovation and investment transformation of railway power supply systems has contributed to development of a new class of intelligent computer networks for optimal control of power supply systems. The organization of intelligent systems requires comprehensive research in the subject area, to create a new model of the optimal strategy for intellectualization of a wide range of technological processes of the power supply systems. The implementation of an adequate reflection of the distributed architecture of the computer environment and the topology of the power supply system of the traction substation opens up the possibility of maximizing the managing efficiency of the fast-flowing technological processes of power consumption. The important issue in this case is the ability of computer architecture to control the electrical systems of traction substations in real time. To form models and criteria for computer intellectualization of technological processes for managing energy systems, the architecture of a local area network of power supply management at the level of traction substations is presented in the form of a graph, which reflects adequately the topology of the electric system.

Graph of the logical architecture of the local computer network (Figure 1) includes two types of topologies - a star and a circle. A fragment of a star topology includes a node φ_0(t) - which is the central server of a computer network of a traction substation, a node φ_1 (t) - to organize a unified information environment for primary information and maintaining a database, a node φ_2(t) - to exchange information within a corporate computer network railway power supply control, node φ_3(t) - to exchange the information on Internet, node φ_4(t) - is a server operational management and maintenance of a set of automated workstations for power supply management, monitoring of traction transformers, high-voltage circuit breakers and power equipment, as well as a φ_5(t) node for organizing microprocessor and relay protection of the traction power line.

A segment of the circle graph topology includes a series of joint nodes φ_0(t) φ_1(t) φ_2(t) φ_3(t) φ_4(t) φ_5(t) considered above, as well as node φ_6(t) - organization of commercial electricity metering at commercial tariffs differentiated by zones of the day, φ_7(t) is the node for monitoring the parameters of the traction power supply system, node φ_8(t) is for the intellectual processing of commercial and technological information. In addition, the topology under consideration includes nodes φ_9(t), φ_{10}(t) - a distributed local power management network at the highest level, that is the department of the railway power supply.

Assume that in the process of exchanging information between components of a computer network, the flow rate of applications is represented by the value $\lambda_i(t)$ and the intensity of the service flow of applications is determined by the following value $\beta_i(t)$. To analyse the computer architecture of the local network and determine the values of the probabilities $P_0(t)$, $P_1(t)$, $P_2(t)$, $P_3(t)$, $P_4(t)$, $P_5(t)$, $P_6(t)$, $P_7(t)$, $P_8(t)$, $P_9(t)$, $P_{10}(t)$ the graph is presented in the form of a Kolmogorov differential equation system with the corresponding initial conditions, which can be written in the following form [1-2]:

$$
\begin{aligned}
&\frac{dP_0(t)}{dt} = \lambda_0 P_1(t) + \beta_1 P_2(t) + \lambda_2 P_3(t) + \\
&+ \lambda_3 P_4(t) + \lambda_4 P_5(t) - (\beta_0 + \beta_2 + \beta_3 + \beta_4 + \lambda_1) \cdot \\
&\cdot P_0(t), \\
&\frac{dP_1(t)}{dt} = \beta_0 P_0(t) + \lambda_0 P_1(t), \\
&\frac{dP_2(t)}{dt} = \lambda_1 P_1(t) + \lambda_5 P_8(t) + \lambda_2 P_3(t) - \\
&-(\beta_1 + \beta_5 + \lambda_{11} + \lambda 13) \\
&P2(t) + \beta_{11} P_5(t) + \beta_{13} P_9(t), \\
&\frac{dP_3(t)}{dt} = \lambda_9 P_4(t) - (\lambda_2 + \lambda_8 + \lambda_{14} + \beta_9) P_3(t) + \\
&+ \beta_2 P_0(t) + \beta_8 P_6(t) + \beta_{14} P_{10}(t), \\
&\frac{dP_{10}(t)}{dt} = \lambda_{14} P_3(t) - \beta_{14} P_{10}(t),
\end{aligned} \tag{1}
$$

with the corresponding initial conditions written as follows:

$P_0(t) + P_1(t) + P_2(t) + \ldots + P_9(t) + P_{10}(t) = 1$, with $t = 0, P_0(t) = t$, $P_0(t) + P_1(t) + P_2(t) + \ldots + P_9(t) + P_{10}(t) = 1$.

5 Differential mathematical models

Based on the system of Equations (1), a differential mathematical model is synthesized for calculating, first of all, probability values $P_0(t)$, $P_1(t)$, $P_2(t)$, $P_3(t)$, $P_4(t)$, $P_5(t)$, $P_6(t)$, $P_7(t)$, $P_8(t)$, $P_9(t)$, $P_{10}(t)$. In this regard, the principles of the theory of differential transformations of Pukhov are applied, the fundamental concepts of which are represented by the following mathematical equations [14]

$$
\begin{aligned}
&P_i(k) = \frac{H^k}{k!}\left[\frac{d^k P_i(t)}{dt^k}\right]_{t=0} \equiv P_i(t) = \\
&= \sum_{k=0}^{k=\infty} \left(\frac{t}{H}\right)^k P_i(k),
\end{aligned} \tag{2}
$$

where:

$P_i(t)$ is the initial function that can be differentiated n-times and which has a number of corresponding restrictions, including its derivatives;

$P_i(k)$ - differential T-images of the original function $P_i(t)$;

H - a scale factor, the dimension of which coincides with the dimension of the argument t, as a rule, is selected on conditions on $0 \leq t \leq H$ the entire range of the function - the original $P_i(t)$;

$\equiv$ - a symbol of correspondence between the function - the original $P_i(t)$ and its differential T - image Pi(k).

Based on the direct differential transformation, which is to the left of $\equiv$, a differentiated T-image of the function-original is formed - $P_i(t)$ as a discrete function $P_i(k)$, with integer argument $k = 0,1,2,$ ....Based on the set of the T-discrete values of the integer argument function $P_i(k)$ $k = 0,1,2..$, using the inverse differential transformation, which is located to the right of the symbol $\equiv$, one obtains the original functions $P_i(t)$. Note that for $k = 0$, according to Equation (2), for any instantaneous value t of each i-th parameter $P_i(t)$, the corresponding equality $P_i(t) = P_i(k)$ holds. $P_i(t)$ - $P_i(k)$. Using the direct differential transformation $P_i(k) = \frac{H^k}{K!}\left[\frac{d^k P_i(t)}{dt^k}\right]_{t=0}$, one synthesizes a differential mathematical model focused on the study of network computing architecture [14]:

$$P_0(k+1)=\frac{H}{k+1}\begin{bmatrix}\lambda_0P_1(k)+\beta_1P_2(k)+\lambda_2P_3(k)\\+\lambda_3P_4(k)+\lambda_4P_5(k)-\gamma_1P_0(k)\end{bmatrix}.$$
$$\cdot P_1(k+1)=\frac{H}{k+1}[\beta_0P_0(k)+\lambda_0P_1(k)],$$
$$P_2(k+1)=\frac{H}{k+1}\begin{bmatrix}\lambda_1P_0(k)+\lambda_5P_8(k)-\\\gamma_2P_2(k)+\beta_{11}P_5(k)+\beta_{13}P_9(k)\end{bmatrix},$$
$$P_3(k+1)=\frac{H}{k+1}\begin{bmatrix}\lambda_9P_4(k)+\gamma_3P_3(k)+\\\beta_2P_0(k)+\beta_8P_6(k)+\beta_{14}P_{10}(k)\end{bmatrix},$$
$$P_{10}(k+1)=\frac{H}{k+1}[\lambda_{14}P_3(k)+\beta_{14}P_{10}(k)], \qquad (3)$$

where:

$$\gamma_1=(\beta_0+\beta_2+\beta_3+\beta_4+\lambda_1);$$
$$\gamma_1=(\beta_1+\beta_5+\lambda_{11}+\lambda_{13});\gamma_3=(\lambda_2+\lambda_8+\lambda_{14}+\beta_9);$$
$$\gamma_4=(\lambda_3+\lambda_9+\beta_{10});\gamma_5=(\lambda_4+\lambda_{10}+\beta_{11});$$
$$\gamma_6=(\lambda_7+\beta_8);\gamma_7=(\lambda_6+\beta_7);\gamma_8=(\lambda_5+\beta_6).$$

The initial conditions, under $t = 0, k = 0$ are represented $P_0\ (t = 0) = P_0\ (0) = 1$, respectively $P_i\ (t = 0) = P_i\ (0) = 0$.

The differential mathematical model in Equation (3) is the basis for the formation, in an analytical form, of probabilities $P_0(t)$, $P_1(t)$, $P_2(t)$, $P_3(t)$, $P_4(t)$, $P_5(t)$, $P_6(t)$, $P_7(t)$, $P_8(t)$, $P_9(t)$, $P_{10}(t)$ state of nodes of a traction substation computer network.

Making the substitution of the initial conditions: $P_0\ (t = 0) = P_0\ (0) = 1$m $P_i\ (t = 0) = P_i\ (0) = 0$, $t = 0$, $k = 0$, $i = 1,2,...10$ in the differential mathematical model in Equation (3) and for $k = 0$, one obtains the discrete spectrum in the form:

$$\begin{aligned}&P_0(1)=-\gamma_1H;P_1(1)=\beta_0H;P_2(1)=\lambda_1H;\\&P_3(1)=\beta_2H;P_4(1)=\beta_3H;P_5(1)=\beta_4H;\\&P_6(1)=0;P_7(1)=0;P_8(1)=0;P_9(1)=0;\\&P_{10}(1)=0.\end{aligned} \qquad (4)$$

Values of $P_0(1)=-\gamma_1H$ the T-discrete $P_1(1)=\beta_0H$, ... $P_{10}(1)=0$ are substituted in the differential model in Equation (3) and for $k = 1$ one obtains the following set of discrete in the form:

$$P_0(2)=\frac{H^2}{2}\begin{pmatrix}\lambda_0\beta_0+\lambda_1\beta_1+\lambda_2\beta_2+\\+\lambda_3\beta_3+\lambda_4\beta_4+\gamma_1^2\end{pmatrix}.$$
$$\cdot P_0(2)=-\frac{H^2\beta_0}{2}(\gamma_1+\lambda_0);$$
$$P_2(2)=\frac{H^2}{2}[\beta_4\beta_{11}-\lambda_1(\gamma_1+\gamma_2)];$$
$$P_3(2)=\frac{H^2}{2}[\lambda_9\beta_3-\beta_2(\gamma_1+\gamma_3)];$$
$$P_4(2)=\frac{H^2}{2}[\lambda_{10}\beta_4-\beta_3(\gamma_1+\gamma_4)+\beta_2\beta_9]; \qquad (5)$$
$$P_5(2)=\frac{H^2}{2}[\lambda_1\lambda_{11}-\beta_4(\gamma_1+\gamma_5)+\beta_3\beta_{10}];$$
$$P_6(2)=\frac{H^2}{2}\lambda_8\beta_2;P_7(2)=0;P_8(2)=\frac{H^2}{2}\lambda_1\beta_5$$
$$P_9(2)=\frac{H^2}{2}\lambda_1\lambda_{13};P_{10}(2)=\frac{H^2}{2}\lambda_{14}\beta_2.$$

Acting by analogy with $k = 2$, $k = 3$ ... $k = n$ one obtains, respectively, the set of discrete $P_i(0)$; $P_i(1)$; $P_i(2)$, ..., $P_i(k)$ $(i = 1,2,...10)$ the number of n, which is determined from the conditions of necessary accuracy.

Obtained in this way, at $n = 2$, the set of discrete $P_i(0)$; $P_i(1)$, $P_i(2)$ $i = 1,2,...10$ is substituted into the inverse differential transformation $P_i(t)=\sum_{k=0}^{k=\infty}\left(\frac{t}{H}\right)^kP_i(k)$, mathematical dependence in Equation (2) is obtained in an analytical form, the probability values $P_0(t)$, $P_1(t)$, $P_2(t)$, $P_3(t)$, $P_4(t)$, $P_5(t)$, $P_6(t)$, $P_7(t)$, $P_8(t)$, $P_9(t)$, $P_{10}(t)$, the state of the nodes of the local computer network of power supply control at the level of traction substations, i.e.

$$P_0(t)=1-\gamma_1t+\begin{pmatrix}\lambda_0\beta_0+\lambda_1\beta_1+\lambda_2\beta_2+\\+\lambda_3\beta_3+\lambda_4\beta_4+\gamma_1^2\end{pmatrix}\frac{t^2}{2};$$
$$P_1(t)=\beta_0t-\beta_0(\gamma_1+\lambda_0)\frac{t^2}{2};$$
$$P_2(t)=\lambda_1t+[\beta_4\beta_{11}-\lambda_1(\gamma_1+\gamma_2)]\frac{t^2}{2};$$
$$P_3(t)=\beta_2t+[\lambda_9\beta_3-\beta_2(\gamma_1+\gamma_3)]\frac{t^2}{2};$$
$$P_4(t)=\beta_3t+[\lambda_{10}\beta_4-\beta_3(\gamma_1+\gamma_4)+\beta_3\beta_9]\frac{t^2}{2}; \qquad (6)$$
$$P_5(t)=\beta_4t+[\lambda_1\lambda_{11}-\beta_4(\gamma_1+\gamma_5)+\beta_3\beta_{10}]\frac{t^2}{2};$$
$$P_6(t)=\lambda_8\beta_2\frac{t}{2};P_7(t)=(\lambda_7\lambda_8\beta_2+\beta_6\lambda_1\beta_5)\frac{t^3}{3!};$$
$$P_8(t)=\lambda_1\beta_5\frac{t^2}{2};P_9(t)=\lambda_1\lambda_{13}\frac{t^2}{2};$$
$$P_{10}(t)=\lambda_{14}\beta_2\frac{t^2}{2}.$$

6 Models of optimal computer intellectualization strategy

Represented by Equations (6), the probability values $P_0(t)$, $P_1(t)$, $P_2(t)$, $P_3(t)$, $P_4(t)$, $P_5(t)$, $P_6(t)$, $P_7(t)$, $P_8(t)$, $P_9(t)$, $P_{10}(t)$ conditions of each node of the graph can be used to formulate a criterion for the optimal strategy of power supply control procedures, which can be written as [14]

$$\Theta_i(t)=\frac{1}{T}\int_{t=t_0}^{T}P_i(t)dt,\ i=0,1,2\ldots. \qquad (7)$$

Since each node of the local computer network operates in a conflict between the intensity of the application flow $\lambda_i\ (t)$ and the intensity of the application flow β_i (t), the dominance in such conditions is the observance by the conflict subjects of the minimax principle [2, 4]. Achievement of optimal functioning in each node of the computer network is possible by rational adherence to the strategy of formation of such values of service flow intensity $\beta_i(t)$ that minimize the fee $\Theta_i(\lambda_i,\beta_i)$ at the maximum flow rate of service flow $\lambda_i(t)$, i.e.

$$\Theta_i{}^*(\lambda_i\beta_i)=\min_{\beta_i\in E\beta}\ \max_{\lambda_i\in E\lambda}\Theta_i(\lambda_i,\beta_i),\ i=0,1,2\ldots. \qquad (8)$$

In the process of modelling the optimal strategy, it is likely to proceed from the condition for formation of such $\lambda_i(t)$ that maximize the fee $\Theta_i(\lambda_i,\beta_i)$, provided it is minimized by the application service system $\beta_i\ (t)$, i.e.

$$\Theta_i{}^*(\lambda_i\beta_i)=\min_{\lambda_i\in E\lambda}\ \max_{\beta_i\in E\beta}\Theta_i(\lambda_i,\beta_i),\ i=0,1,2\ldots. \qquad (9)$$

Obviously, subject to the fulfilment of mathematical dependencies in Equations (8), (9)

$$\min_{\beta_j \in E\beta} \max_{\lambda_i \in E\lambda} \theta_i(\lambda_i, \beta_i) = \min_{\lambda_i \in E\lambda} \max_{\beta_j \in E\beta} \theta_i(\lambda_i, \beta_i) = \theta_i^{*opt}(\lambda_i^{opt}, \beta_i^{opt}), \tag{10}$$

search strategies λ*i(t)* $\lambda i(t)^{opt}$ i $\beta_i(t)^{opt}$ are called optimal [3, 11-12].

The strategy is to select the law of change in the flow of customer service intensity *βi (t)*, which implements minimization of functional in Equation (10) with the stochastic intensity of the customer service flow λ_i *(t)*, within the appropriate limits. Therefore, in connection with the antagonism of the goals of the subjects of the information conflict, the dominant strategy for the optimal intellectualization of the fast technological processes will be a strategy based on the minimax principle, i.e. [3]

$$\min_{\beta_j \in E\beta} \max_{\lambda_i \in E\lambda} \Theta_i(t, P_i, \lambda_i, \beta_i). \tag{11}$$

The minimax strategy in Equation (11) allows to minimize functional in Equation (7) even in the cases of the worst combination of flow intensities λ_i *(t)* and $\beta_i(t)$. Using the direct differential transformation in Equation (2), the criterion $\theta_0(t) = \frac{1}{T}\int_{t0}^{T} P_0(t)dt$ takes the form [14]

$$\Theta_i^* \sum_{k=0}^{k=\infty} \frac{p_i(k)}{k+1}. \tag{12}$$

Based on calculations of the corresponding set of T-discrete, $P_i(0)$; $P_i(1)$, $P_i(2)$, …, $P_i(k)$, according to Equation (3), the optimization procedure based on the differential spectrum can be implemented as follows. After substituting the aggregate discrete $P_i(0)$; $P_i(1)$; $P_i(2)$, …, $P_i(k)$ in Equation (12), the state model for the $\varphi_i(t)$-th node of the local network, for $i = 0$, that is $P_0(k)$ $k = 0,1,2,...$, takes the form:

$$\Theta_{i=0}^*(\lambda_i, \beta_i) = 1 - (\beta_0 + \beta_2 + \beta_3 + \beta_4 + \lambda)t + \\ +(\lambda_0\beta_0 + \lambda_1\beta_1 + \lambda_2\beta_2 + \lambda_3\beta_3 + \lambda_4\beta_4 + \gamma_1^2)\frac{t^2}{2}. \tag{13}$$

The procedure for selecting the optimal strategies for the intensity of application flows λ_i^{opt} and the flow of service intensity of applications β_i^{opt} of a functional Θ_i^* is linked with studying it to an extremum by substituting values of the corresponding discrete into Equation (12) $P_i(0)$; $P_i(1)$; $P_i(2)$;...(i = 1,2,...,10). It is known that the necessary conditions for existence of an extremum of a functional, according to the Kuhn-Tucker theorem, are conditions that allow us to determine the optimal strategy in the form [3, 8]

$$\begin{cases} \frac{d}{\lambda_0}(\Theta_0^*(\lambda_i, \beta_i)) = 0, \\ ..... \\ \frac{d}{\lambda_{10}}(\Theta_0^*(\lambda_i, \beta_i)) = 0, \end{cases} \begin{cases} \frac{d}{\beta_0}(\Theta_0^*(\lambda_i, \beta_i)) = 0, \\ ..... \\ \frac{d}{\beta_{10}}(\Theta_0^*(\lambda_i, \beta_i)) = 0, \end{cases}. \tag{14}$$

Implementing the substitution $\Theta_i^{*opt}(\lambda_i, \beta_i)$, according to Equation (13), into the system of Equations (14) and taking partial derivatives, one obtains a system of linear algebraic equations, solving of which gives the optimal strategies λ_i^{opt} and β_i^{opt}. The signs of extremes in strategies λ_i^{opt} are β_i^{opt}, determined based on checking the sufficient conditions by:

$$\begin{cases} \frac{d^2}{\lambda_0^2}(\Theta_0^*(\lambda_i, \beta_i))\rangle 0, \\ ..... \\ \frac{d^2}{\lambda_{10}^2}(\Theta_0^*(\lambda_i, \beta_i))\rangle 0, \end{cases} \begin{cases} \frac{d^2}{\beta_0^2}(\Theta_0^*(\lambda_i, \beta_i))\rangle 0, \\ ..... \\ \frac{d^2}{\beta_{10}^2}(\Theta_0^*(\lambda_i, \beta_i))\rangle 0, \end{cases} \tag{15}$$

Carrying out studies analogically or substituting values of $\Theta_{i=0}^{*opt}(\lambda_i, \beta_i)$ from Equation (13) into the system of Equations (15) and taking the second derivatives, one obtains a system of algebraic equations, the solution of which indicates the fulfilment or non-fulfilment of sufficient conditions. Calculating the value of optimal strategies λ_i^{opt} and β_i^{opt} according to Equation (14), corresponding to conditions in Equation (15) and substituting them into Equation (13) the optimum functioning of the $\varphi_0(t)$-th node of the graph is determined, which represents the local area network of controlling the power supply of traction substation.

7 Conclusions

1. Research was conducted on the problem of innovative transformation of railway power supply systems to create promising energy-saving technologies for the power consumption and the formation of the new knowledge. This direction of research is justified, related to formation of a qualitatively new set of intelligent power supply systems, which is achieved through deep mutual integration of the topology of the power grid infrastructure and the architecture of the distributed computer network for power supply management.
2. Based on the modern concept of the intelligent traction power supply systems' synthesis, a research direction has been formulated related to organization of an optimal strategy for computer intellectualization of the fast-flowing technological processes of power supply in traction substations of railways, by creating mathematical models and methods for determining the optimal functioning of individual nodes and segments of an intelligent computer network power management.
3. The logical structure of a distributed computer environment that adequately reflects the topology of the organization of the electric power supply system at the level of traction substations is proposed in the form of a graph, based on which a differential mathematical model of the computer architecture of the power supply control is formed and methods for determining, in an analytical form, the set of values of

the probabilities of node states graph.

4. Due to the antagonism in each node or segment of the intelligent computer network for the power supply management, between the intensities of the application flow $\lambda_i(t)$ and the application service flow $\beta_i(t)$, an optimal computerization strategy for the fast power supply technological processes based on the minimax principle is proposed, which allows to minimize function even in the cases of poor combination of intensity of application flows and every law of service flow intensity.
5. An intelligent method has been developed for finding the optimal strategy for computer intellectualization of the power supply process to provide specified indicators for the optimal functioning of individual nodes and segments of an intelligent computer control network.

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