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AUTOMATIED WORKSTATION FOR CALCULATING RATIONAL MODE OF TRACTION POWER SUPPLY SYSTEMS

Introduction

Increasing of the competitiveness and efficiency of the Ukrainian railway transport is impossible without solving a number of priority issues, including [1]: ensuring efficient railway technology taking into account energy, economic and environmental criteria, development of railway infrastructure for high-speed traffic, improving the rolling stock, planning of energy consumption resources, introduction of effective control methods for railway transport at all levels of the production cycle. In this problem list is very important problem - the energy saving in traction power supply systems. In [2] it is shown that this problem has complex, multi-level and multi-factor nature.

The definition of rational modes of traction power supply DC systems has previously been performed without taking into account the realities of nowadays, when there is a market economy, there are different options for electricity payment (by flat-rate tariffs, differentiated tariffs or wholesale prices). Now, the energy component in the transportation tariff has reached 20 % [3], and taking into account global trends this component will continue to rise. During decisions process we need firstly to take into account not only technical indicators, but also economic (cost of electricity consumed). In [4] it's discussed a method for calculation of rational modes of traction power supply system, based on genetic algorithms.

Purpose of this article is **to describe** the created software for the calculation of rational modes of traction power supply system.

In the context of the definition of rational modes of electric power supply systems power system can be considered as a combination of different processes, combined solution of the continuous supply of electric rolling stock with appropriate quality. Thus must be a cost-effective consumption of energy and reduction of losses emerging during transmission and transformation. During control process of the power supply system along with optimal power supply problems in the automated control system of power supply (ACSPS) are also solved the problem of collecting, processing, planning and forecasting of technology process and equipment state. Like any complex system, power traction system has a hierarchical structure consisting of individual subsystems (Fig.1), having their own objectives and one common goal for all automated system. These subsystems are located at different levels of hierarchy, interact, and have an external connection with district power systems and other railway subsystems. Each subsystem is a part of automated system according to certain parameters, corresponding to the specific objectives and tasks of control. In these tasks subsystem can be considered as an independent system.

Control within power supply distance includes three levels: the first control level implements manual and automated equipment and decentralized control modes, the second control level involves local operating (remote) and automatic centralized hardware control of traction substations, sectioning point, etc., and the third level of control implements automated supervisory system (SCADA). Here it's carrying a centralized control of traction substations, sectioning points and other elements.

The information goes from higher points of the fourth and fifth control levels , respectively (the power supply department of railway and the main power control department of Ukrzaliznycia). The operational control information goes to the distance energy dispatcher for coordinating modes of power distance of given railway. Energy controller takes into account the main electric parameters of traction subsystem, that performs all types of planning for railways, and communicates with the power supply department of Ukrzaliznycia and energy systems. Automated dispatch control system (ADCS) provides automated collection and processing of necessary information for continuous monitoring and centralized control.

The mode of the power supply system is determined by operational control tasks to be solved.

We can define the mode of power supply system as a set of processes that determine at any time the state of power supply system. And parameters of the power supply system modes are indicators of the mode of the system and the conditions of operation: power, voltage, power flows on the traction lines, frequency, and so on.

Power supply system is characterized by parameters, i.e. parameters that are depended on the properties of the system equipment, its configuration and determine the value of the coefficients, which is established by the interconnection and interdependence of the modes.

In **normal mode**, it's carrying regulation of power supply system, its adjustment for providing the requirements of power quality and reliability of its supply, maintenance and repair, collection, processing all documents on power supply distance. In this mode we can calculate the rational modes.

In **emergency mode**, the devices of protection are triggered (relay protection). In this case, the operational control staff makes necessary disconnections for disabling failure devices. However, due to the low performance of control system the quality of control can worsens.

In **post-emergency** mode personal solves the problem of restoring normal power supply scheme with given quality of electricity, inputing to the work the failed equipment, taking measures to eliminate the causes of the accident and repair damaged equipment.

Solving tasks of operational control it's nessesery envisages maximum use of the energy controller experience. Depending on the situation, energy dispatcher have different time to make decisions that taken by him. In emergency situations amount of information increases and the time for decision is reduced to a few seconds or minutes.

The subsystem of the 3-rd level provides centrally managed dispatching of elements, objects and modes of supply, exchange of information with power dispatcher points of power systems and service management.

Electric power supply system in the normal mode moves from one state to another, the mismatch between the actual and desired states of the power supply system in the operational thinking is regarded as a problem. In man-machine systems is very important to study the problem of states and conditions analysis, and making decisions.

By analyzing the problems of the states we understand the problems associated with the tasks of identifying such conditions that define the problems of decision-making.

The decision-making problems are the problems of finding alternatives. The person who makes decisions (DM) selects a specific alternative (from set of alternatives) having knowledge of object state, control systems, decision rules.

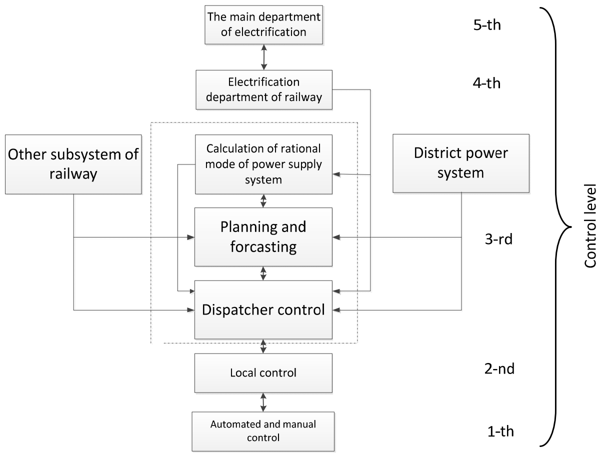

Fig. 1. Block diagram of the power supply control system of Ukrzaliznytcia

The above problems can be considered as a sequence of steps.

Stage 1 - evaluation of traction power supply system state. In general, we can talk about collection a certain amount of information by control system about a state of the power system and about environment. Here we catch the mismatch between the desired and actual parameters of modes. If there is no mismatches, we can assume that there is no decision-making problem.

Step 2 - defining the objectives and performance criteria of rational modes definition. At this stage should be determined the necessity of changing (or saving) the current state of the power supply system, i.e. we establish some control target. This is done by analyzing the current mode disadvantages. As a result, can be formed a representation of the rational mode in general. Providing rational mode in these conditions is a goal of control in this context.

3rd stage - development of solutions. It's developing existing methods for achieving the goal. It's necessary to ensure the completeness of possible states of the system power supply.

Stage 4 - making decisions about rational mode. Here it's defined a the set of possible solutions in the context of efficiency of our goals. As a result, there is one solution for poviding a rational mode.

Stage 5 - introducing solutions into action. In this stage it's producing a regulation of control parameters of electric power supply system for ensuring the rational mode.

On the basis of the above principles of rational modes of power supply system can be set up the monitor system for ensuring the rational modes of the system, which for each time point could evaluate the system mode and propose measures to ensure the most advantageous mode.

The block diagram of that system is shown in Fig. 2.

The system includes the following elements:

– power traction system model;
– train flow model;
– model of electricity praces;
– reliability analysis block of switching devices;
– model of non traction consumers receiving power from tire traction substations;
– model of selection of energy saving measures for ensuring rational modes of power supply system;
– power system model.

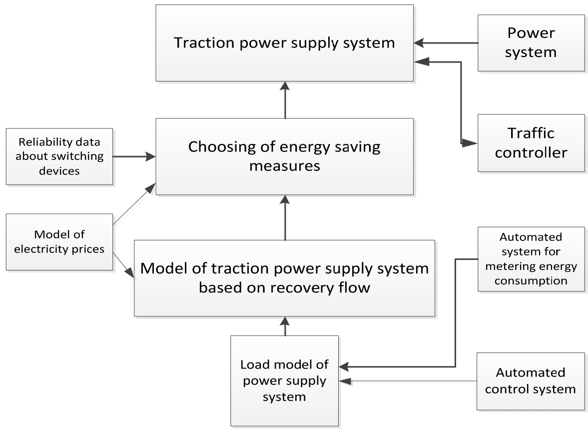

Fig. 2. System of providing the rational modes of traction power supply system

To find the rational modes of traction power supply system we proposed a program complex His block diagram is shown on Fig. 3.

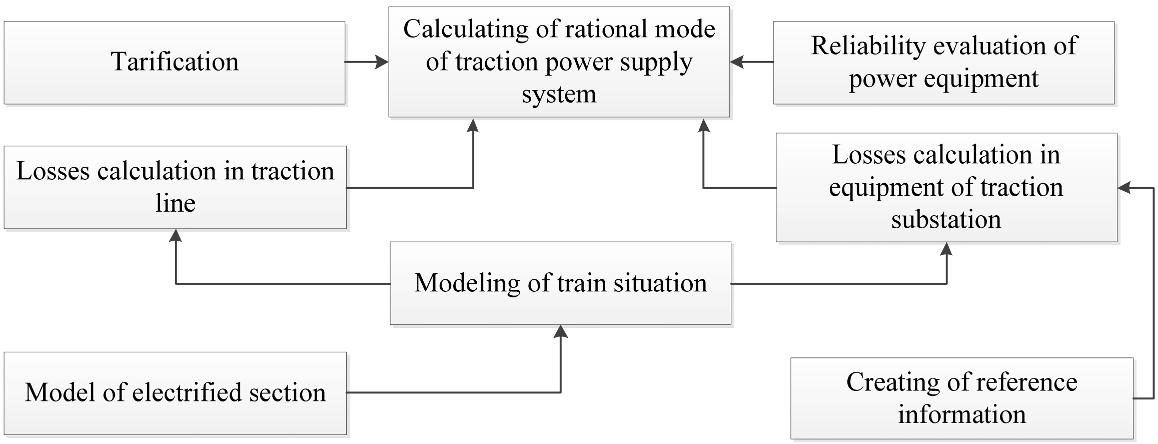

Fig. 3. Elements of software complex

It is assumed that the flow of trains on the railway is a steady stream of ordinary homogeneous events with limited after-effect [4,5]. Stationarity of flow is a property when the probability of a particular number of events in time length depends only on the size and length of interval and not depends of the position of interval on the time axis. Ordinary of flow is property when probability of getting two or more events on the elementary interval Δt is negligible compared with the probability of getting a single event.

The purpose of described in this article software complex is evaluation of rational modes of power supply traction system, namely – determination of the optimal number of power and traction transformers at each substation, the level of voltage on the fiders of traction substations, rational schemes of contact lines (taking into account the variable cost of electric energy and reliability of the equipment). Described software system minimizes the following objective function

$$C = [\sum_{m=1}^{T} Ce(t_m) t_m \sum_{i=1}^{N-1} (\Delta P_{Ti} + \Delta P_{yi}) + \sum_{i=1}^{N} \Delta P_{\Pi i} + Y] \to \min , \quad (1)$$

where *Ce(t)* – rates for electricity that is consumed by the transportation process (single-rate, wholesale, multi-rate); ΔP_{Ti} - power losses in traction line on *i*-th zone without countervailing currents; ΔP_{yi} – power losses in the traction line on the *i*-th zone, caused by the inequality of the voltage on substations; $\Delta P_{\Pi i}$ – losses of power in the equipment of *i*-th traction substation; *Y* – damage from reduced reliability of transformers and switching devices; *T* – period of time for which the costs are determined.

The structure of the program. To describe the structure of the program it was was selected component diagram (Fig. 4), which describes the features of the physical system representation.

The peculiarity of the proposed component diagram is the fact that one of the modules (Dmodule.cpp) uses a third party program (Interbase Server) to access the database files (Energ, Profil, Poezdka).

The input data for the software package are:

- $C_e(t)$ – electricity tariff;;
- *T* – period of time for which the power losses are calculated;
- $P_{XX\_ПТi}$, $P_{XX\_ТТi}$ – load losses for power and traction transformers respectively;
- C_i – the cost of the *i*-th operation of resource restoring;
- $\omega(t)$ – the total failures rate;

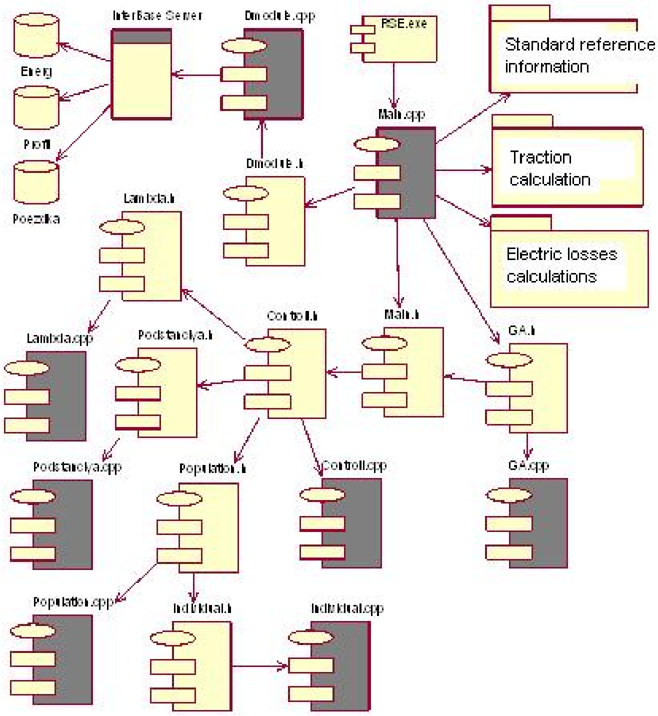

Fig. 4. Component Diagram

- $r_0(S)$ – resistance of traction line in section *S*, Om;;
- $\psi(s,x)$ – current distribution function;
- *NP* – number of substations;
- $\Delta P_{КЗПТi}$, $\Delta P_{КЗТТi}$ – load losses, respectively for power transformers and traction ones for *i*-th traction substation, kW;
- $I_{НОМ\_ТТi}$, $I_{НОМ\_ПТi}$ – rated currents, respectively for power transformers and traction ones in *i*-th substation, KA;
- $f(t)$ – density of intervals between train;
- Q_{ij} – mass of the *j*-th train that runs along the *i*-th sector, t;
- $I_{дн\ i}$ – rated current of *i*-th traction transformer, KA;
- r_{1pi}, r_{2pi} – active resistance of reactors 1 and 2 of the smoothing device of *i*-th traction substation (TS), Om;
- *ND* – number of sector;
- NK_i – the number of tracks on the *i*-th sector;
- NV_i – the number of nodes in the *i*-th sector;
- α_{ij} – the unit energy consumption of *j*-th train that runs along the *i-th* sector, kWh/10 ^{4} · t · km;
- v_{ij} – the average speed of the *j*-th train that runs along the *i*-th sector, km / h;
- u – the average voltage kV;
- L_i – the length of the *i*-th section, km;
- ΔE_{1i} – the step of voltage regulation on the primary transformer *i*-th TS, kV;
- ΔE_{1maxi} – maximum traction transformer primary voltage of the *i*-th TS, kV;
- ΔE_{2i} – regulation step by primary voltage of power transformer *i*-th TS, kV;

- ΔE_{2maxi} – the maximum primary voltage of power transformer *i*-th TS kV;
- l_{0i} – position of RUL (regulation under load) of traction transformer of *i*-th substation;
- k_{0i} – RUL position of i-th substation.

After starting the program executable file it's displayed the main window. This window allows to perform the following operations:

- on the tab "System ELS" section choose traction line for which you want to calculate rational modes of operation, to enter information about TS for given section (Fig.5);
- on the tab "Zone" enter information about sections between TS, the number of tracks and nodes in each zone (Fig.6);
- on the tab "Results" - view the results of traction calculations;
- on the tab "Train" - enter information about the trains that move along selected section;
- on the tab "equipment of TS" - enter information about the power substation equipment.

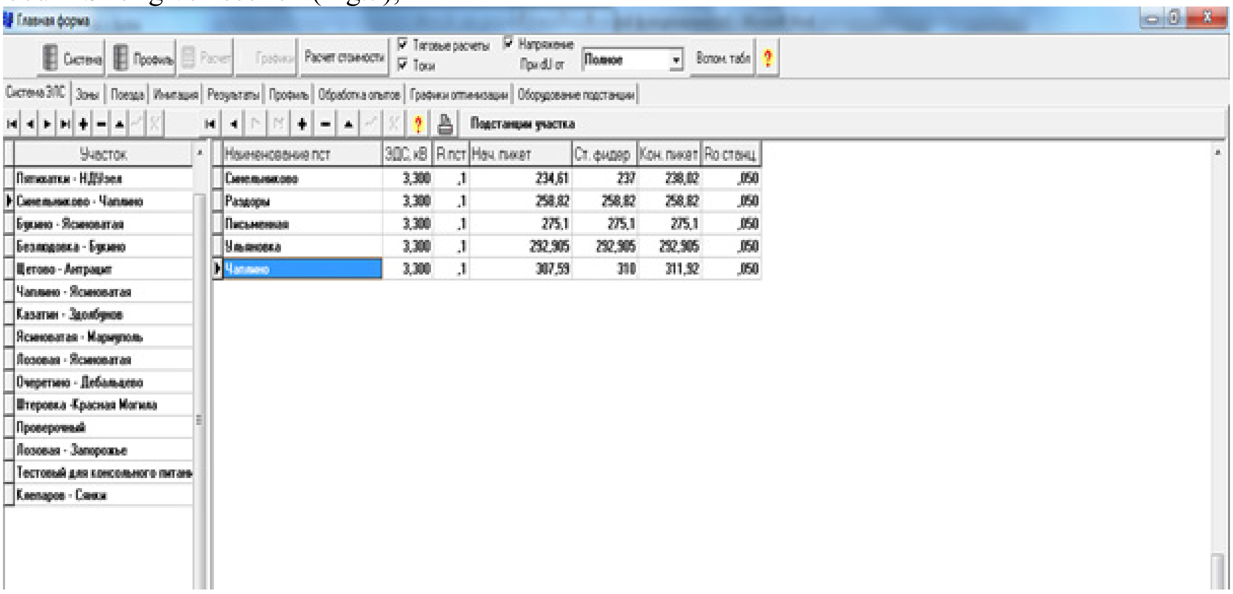

Fig.5. The tab "System ELS 'main window

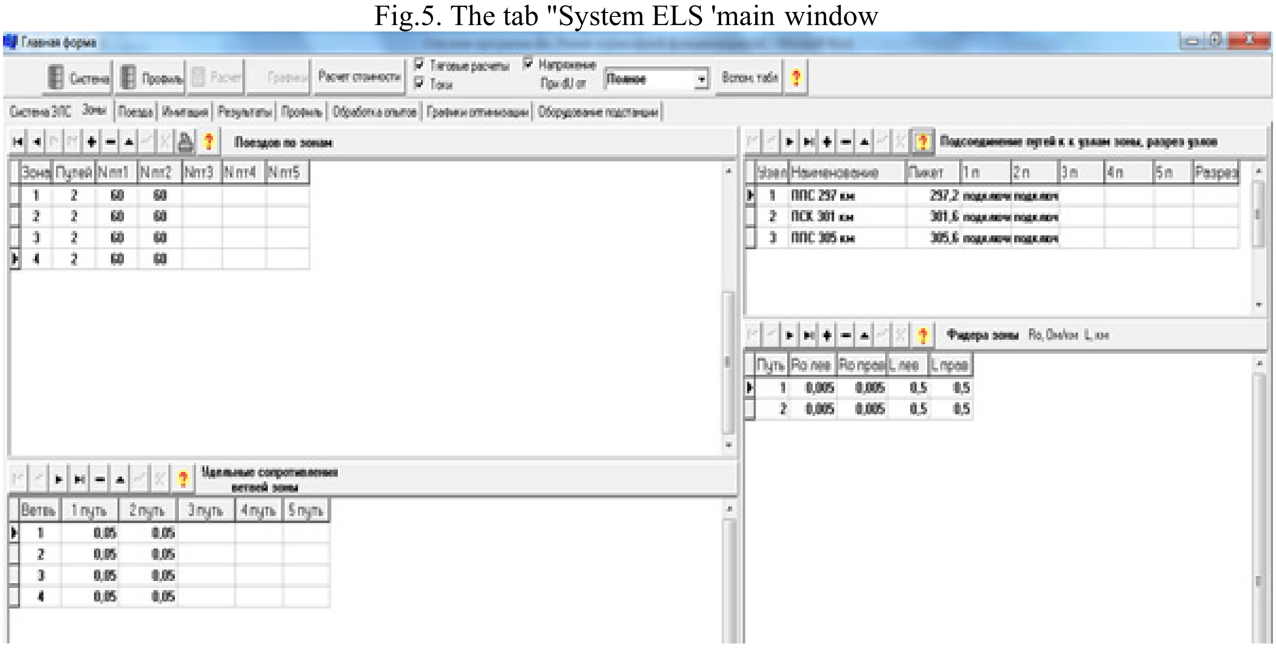

Fig. 6. Tab "Zone" in the main program window

The window "Constant data" (Fig. 7) can be displayed by using the buttom "Aux. table." It contains the scientific background information, which is situated on options "Electric locomotives", "Characteristics of electric locomotives," "Transformers substations", "Converters of substations", "cost", "Parameters of GA", "intensity", "Substation equipment", " damage ".

Option "Cost of electricity losses" shows the graph of the cost of existing electricity losses in the section of traction line and the cost of losses for rational modes of power supply system.

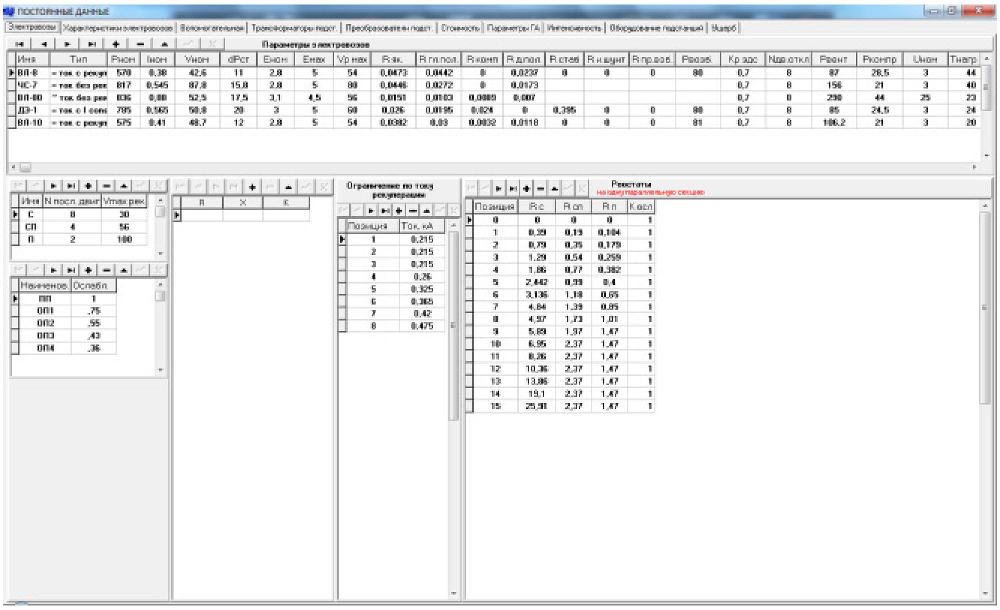

Fig. 7. The window "Constant Data"

In the "Schemes of contact line' displays the existing schemes and rational ways of connecting to the nodes for each zone between TS.{0On the "voltage levels on substations" displays the real and rational levels of voltage for each given substation.On the "Transformers" is displayed an existing and rational number of power and traction transformers for each given substation."Charts" displays graphs of the cost of electricity and the intensity of the flow of trains.

As a result of the software work system calculated the following indicators:

- *C* – the cost of power losses;
- l_i – Traction transformer RUL position of *i*-th TS;
- k_i – power transformer RUL position for i-th TS;
- *m* – the total number of switching power equipment;
- γ_{uv} – *u*-connection of the way to the *v-th* node (1 - connected, 2 - not connected);
- X_{1i}, X_{2i} – the number of simultaneously working power transformers and traction transformers for i-th TS (1 or 2).

This software package has been evaluated on the Pridneprovskaya i Doneckaya railways.Due to the modes optimization on Krasnoarmejskaya power supply distance on the basis of the discussed software package it's reduced electricity consumption by 474 million kWh for month. ·

Conclusions:

1. The problem of definition of rational modes of traction power supply system has multi-level and multi-purpose nature.

2. It's possible to reduce energy losses in the elements of the contact line by switching to the different contact line scheme and by regulating the voltage on the traction power substations (by switching the RUL or by using other devices) and the power and traction transformers, making a rational switching to the parallel scheme.

3. It's described a specialized program complex for finding rational mode of traction power supply system.

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AUTOMATIED WORKSTATION FOR CALCULATING RATIONAL MODE OF TRACTION POWER SUPPLY SYSTEMS

Improving the competitiveness and efficiency of railway transport of Ukraine is impossible without solving a number of priority issues, including: providing a rational railway technology taking into account energetic, economic and environmental criteria, infrastructure development for high-speed motion, improving consumption energy planning, the implementation of effective management at all levels of the production cycle. This list very important problem is energy saving in power supply traction systems. This problem is complex, multi-level and multi-factor in nature.

The definition of rational modes of traction power supply DC systems has previously been performed without taking into account the realities of our time, when there is a market economy, there are different options for electricity payment (by flat-rate tariffs, differentiated tariffs or wholesale prices for electricity). Now, the energy component in the transportation tariff has reached 20%, and taking into account global trends will continue to rise. When making decisions in firstly we need to take into account not only technical indicators, but also economic (cost of electricity consumed).

The paper presents the principles of rational modes of the power supply systems. This make a basis for creation a monitoring system for ensuring the rational modes, which could for each time point evaluate the power supply system mode and propose the measures to ensure the most profitable mode.

It's done the description of the specialized software that allows you to define rational modes of traction power supply system. The discussed program uses a genetic algorithm to determine the rational modes. This article contains screenshots of developed software.

Keywords: power supply system, genetic algorithm, energy savings, the program complex.

Prof. *V. G. Sichenko*, D. Sc. recommended this article to be published.

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АВТОМАТИЗИРОВАННОЕ РАБОЧЕЕ МЕСТО ПО ОПРЕДЕЛЕНИЮ РАЦИОНАЛЬНЫХ РЕЖИМОВ СИСТЕМ ТЯГОВОГО ЭЛЕКТРОСНАБЖЕНИЯ

Повышение конкурентоспособности и экономичности работы железнодорожного транспорта Украины невозможно без решения ряда первоочередных проблем, среди которых: обеспечение рациональной технологии перевозочного процесса по энергетическим, экономическим и экологическим критериям; развитие инфраструктуры железнодорожного транс-порта для обеспечения скоростного движения; совершенствование подвижного состава; планирование потребления энергетических ресурсов; внедрение эффективных методов управления железнодорожным транспортом на всех уровнях производственного цикла. В этом перечне особенно выделяется проблема энергосбережения в системах электроснабжения тяги поездов. Эта проблема носит комплексный, многоуровневый и многофакторный характер.

Определение рациональных режимов систем электроснабжения магистральных железных дорог постоянного тока ранее осуществлялось без учёта реалий сегодняшнего дня, когда в условиях рыночной экономики существуют различные варианты расчётов за потреблённую электроэнергию (по одноставочным тарифам, дифференцированным тарифам или оптовым ценам за электроэнергию). Сегодня доля энергетической составляющей в тарифе за перевозки достигла 20 %, и с учётом мировых тенденций будет повышаться и далее. При принятии решений на первое место выходят не технические показатели, а экономические (например, стоимость потреблённой электроэнергии).

В статье приведены принципы обеспечения рациональных режимов в системе электроснабжения, на основе которых может быть создана в система контроля и обеспечения рациональных режимов, которая бы для каждого момента времени могла бы оценить режим системы элеткроснабжения и предложить меры по обеспечению наивыгоднейшего режима.

Приведено описание специализированного программного комплекса, который позволяет определять рациональные режимы систем тягового электроснабжения. Приведенный программный комплекс использует генетический алгоритм для определения рациональных режимов. Статья содержит скриншоты разработанного программного комплекса.

Ключевые слова: система электроснабжения, генетический алгоритм, энергосбережение, программный комплекс.

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АВТОМАТИЗОВАНЕ РОБОЧЕ МІСЦЕ ПО ВИЗНАЧЕННЮ РАЦІОНАЛЬНИХ РЕЖИМІВ СИСТЕМ ТЯГОВОГО ЕЛЕКТРОПОСТАЧАННЯ

Підвищення конкурентоспроможності та економічності роботи залізничного транспорту України неможливе без вирішення ряду першочергових проблем, серед яких: забезпечення раціональної технології перевізного процесу з енергетичних, економічних та екологічних критеріїв; розвиток інфраструктури залізничного транспорту для забезпечення швидкісного руху; вдосконалення рухомого складу; планування споживання енергетичних ресурсів; впровадження ефективних методів управління залізничним транспортом на всіх рівнях виробничого циклу. У цьому переліку особливо виділяється проблема енергозбереження в системах електропостачання тяги поїздів. Ця проблема носить комплексний, багаторівневий і багатофакторний характер.

Визначення раціональних режимів систем електропостачання магістральних залізниць постійного струму раніше здійснювалося без урахування реалій сьогоднішнього дня, коли в умовах ринкової економіки існують різні варіанти розрахунків за спожиту електроенергію (по одноставочному тарифу, за диференційованими тарифами або оптовими цінами за електроенергію). Сьогодні частка енергетичної складової в тарифі за перевезення досягла 20%, і з урахуванням світових тенденцій буде підвищуватися й далі. При прийнятті рішень на перше місце виходять не технічні показники, а економічні (наприклад, вартість спожитої електроенергії).

У статті наведено принципи забезпечення раціональних режимів в системі електропостачання, на основі яких може бути створена в система контролю і забезпечення раціональних режимів, яка б для кожного моменту часу могла б оцінити режим системи елеткроснабженія і запропонувати заходи по забезпеченню найвигіднішого режиму.

Наведено опис спеціалізованого програмного комплексу, який дозволяє визначати раціональні режими систем тягового електропостачання. Наведений програмний комплекс використовує генетичний алгоритм для визначення раціональних режимів. Стаття містить скріншоти розробленого програмного комплексу.

Ключові слова: система електропостачання, генетичний алгоритм, енергозбереження, програмний комплекс.

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