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RESEARCH OF INFORMATION FLOWS IN THE CONTROL OF INTELLIGENT POWER SYSTEM REGIMES

The purpose of this work is to solve the problem of optimizing the management of maintenance and repair equipment at large enterprises. In a unified management system, the operational collection, consolidation and transfer of indicators about the state of all numerous power equipment allows solving and sometimes avoiding many problems. It is about reducing the time for repair work (equipment downtime), offloading personnel, optimizing logistics chains, and reducing material costs. The general problems of creating intelligent energy systems from the point of view of information and telecommunication technologies have been studied. A way to process information flows in the monitoring and management of intelligent energy systems modes is proposed, which involves combining information and mathematical technologies and the use of international data standards. The approach to the development of a new information and technological infrastructure of intelligent energy systems is considered. After conducting the analysis, the optimal system is seen as a multi-level control system for intelligent electric power systems. The technology combines intelligent tools for situation analysis and software systems for mode modeling and control. The use of IT infrastructure allows to create a single information space that includes data and knowledge, as well as a set of mathematical models and methods for solving the problems of the electric power industry in the conditions of active adaptive management. In the conclusions, a detailed classification of the types of information about mode parameters is provided and the relationship between the quality of mode information and the application of various mathematical models is determined.

Keywords: *information flows, intelligent power systems (IPS), Smart Grid, management, monitoring, information and technological infrastructure, power system modes, power transmission and distribution, signals, mathematical model, dispatch control.*

Introduction

Operational management of electricity infrastructure is crucial. Energy companies face the need to introduce new standards of operation and maintenance to continuously improve the relationship between security of energy supply and costs. Management of electricity consumption regimes is an integral condition for ensuring the sustainable operation of modern industrial enterprises. Given the steady increase in the cost of energy, including electricity, which increases the cost of production, management of electricity consumption regimes seems to be one of the most effective ways to save energy costs at the enterprise, increase profitability and gain additional competitive advantage. These measures are aimed at ensuring the possibility of building electricity balances of electricity supply companies and, ultimately, creating conditions for building a common electricity balance of Ukraine. In network companies, there is a low information security, which is associated both with the insufficiency of electricity metering tools and their unacceptable error. Also, one of the key tasks in the energy sector is the management of maintenance and repair of equipment. This is due to the huge number of pieces of equipment that are distributed over a large area and that require constant maintenance and repair. Consolidation of information on the state of equipment in a single management system with the ability to quickly provide it to different consumers on the ground can reduce downtime, reduce the cost of spare parts and materials, optimize logistics and relieve staff.

Today in the modern world the direction called Smart Grid (intelligent power systems or intelligent electric networks) is actively developing. These are electric power systems using new technologies both in electric power equipment and in the field of information support economic indicators. In Ukraine, although a little late, work is also underway in this area. The attention of specialists is focused primarily on improving the technological infrastructure of energy, without which the introduction of modern information technologies is impossible. At the same time, it is necessary to develop a methodology and new information and telecommunication technologies that should become the basis of "smart" energy systems. Currently, an approach to the processing of information flows in the monitoring and management of intelligent energy systems is proposed, which involves the integration of information and mathematical technologies and the use of international data standards.

Smart grid creation issues

Smart Grid includes all the main traditional components of power systems: generation, transmission and conversion systems, as well as consumers, but those that have a qualitatively new level of technology and are characterized by close interconnection. In fact, the Smart Grid concept provides for the development of power systems in three main areas:

- infrastructure improvement;
- informatization of an electric network (imposing of a digital layer on an electric network);
- modernization of business processes, which makes a "smart" network profitable.

Smart Grid should increase the reliability and efficiency of electricity generation through the use of modern highly intelligent control and management tools, integration of renewable energy sources, as well as distributed energy generation and storage, large-scale monitoring and control of modes using new tools and technologies.

General problems of creation of intelligent energy systems (IES) from the point of view of information and telecommunication technologies are synthesized: 1 – the need to develop information and communication technologies that would create qualitatively new systems for monitoring and managing energy systems; 2 – limited range of proposals in this segment from information technology (IT) suppliers: solutions from foreign developers are quite expensive, high-quality domestic developments are insufficient or they are simply absent.

At the present stage of intellectualization of electric power systems (EPS) the most important issues are the development of automated control system (DACS) IT infrastructure, which will ensure the construction of a multilevel management system taking into account the reliability, efficiency and effectiveness of the EPS. In addition, the implementation of new systems for collecting, transmitting and processing the flow of information requires the development of technologies and methods for modeling the processes and events under study in the management of IES. Therefore, it is possible to consider the issue of solving the following tasks relevant: 1) collection, transmission and processing of data streams; 2) development of new generation software packages (distributed, exchanging information or using common information resources); 3) development of intelligent components to support decision-making in mode control.

It infrastructure of the IES

For the creation and further development of IES, it is proposed on the basis of experience to identify the following main components of IT infrastructure: intelligent infrastructure, information infrastructure, calculation infrastructure, telecommunication infrastructure.

The *telecommunication* infrastructure is built on the basic generally accepted principles, taking into account the needs of computer and information security. As part of the *intellectual infrastructure* includes intelligent components (for example, intelligent components of decision support in regime management). The *information infrastructure* includes technologies and tools for data description, storage and processing. The *calculation infrastructure* integrates software packages (for example, for modeling and control of IES modes). The same infrastructure may include automated energy management systems.

Elements of the IT infrastructure of dispatch management are:
- information collection and transmission system (ICTS);
-dispatching and technological control communication network;
-supervisory control and data acquisition (SCADA);
-object-oriented data model (CIM);
-information display system;
-electricity generation and transmission management system (EMS);
-electricity and power market management system (MMS);
-power transmission and distribution management system (DMS).

Approach to the processing of information flows in the monitoring and management of IES regimes

Information flow means a set of measured regime variables in a certain period of time [1]. In the monitoring and automated control of IES modes, first of all, the analysis and processing of information flows is necessary. Recently, power systems have been provided with means of measuring complex PMU values, which allows together with the information received from SCADA (telemetry parameters of the EPS mode , condition of means and systems of dispatching control), to measure complexes of nodal loading and complexes of currents in branches incident to this knot [2]. Given the fact that one of the most important stages of management of EPS regimes is operational and emergency management, when processing information flows, it is advisable to use CEP and CIM models.

The CEP (Complex Event Processing) model [3] proposes to use for real-time processing of many events from different sources (event streams) in order to detect global events based on one or more event streams or to detect a number of events over time.

The CIM (Common Information Model), based on the ODM data format, allows you to create models of any complexity, which can then be converted to any known energy data format or to any new data format using optional modules. ODM (Open Model for Exchanging Power System Simulation Data) – it is an open model for data exchange when modeling power systems. ODM, in turn, is an international open data exchange standard for modeling and computing power systems that supports dynamic computing. CIM and ODM models, in general, are used in an open integration environment to solve energy problems [4].

From all the above we can conclude that there is a need for real-time processing of large amounts of information of different quality and the formation of such information flows that would provide the necessary accuracy of solving regime problems. The scheme of the process of processing information flows in the monitoring and control of regimes in the IES is shown in Fig.1.

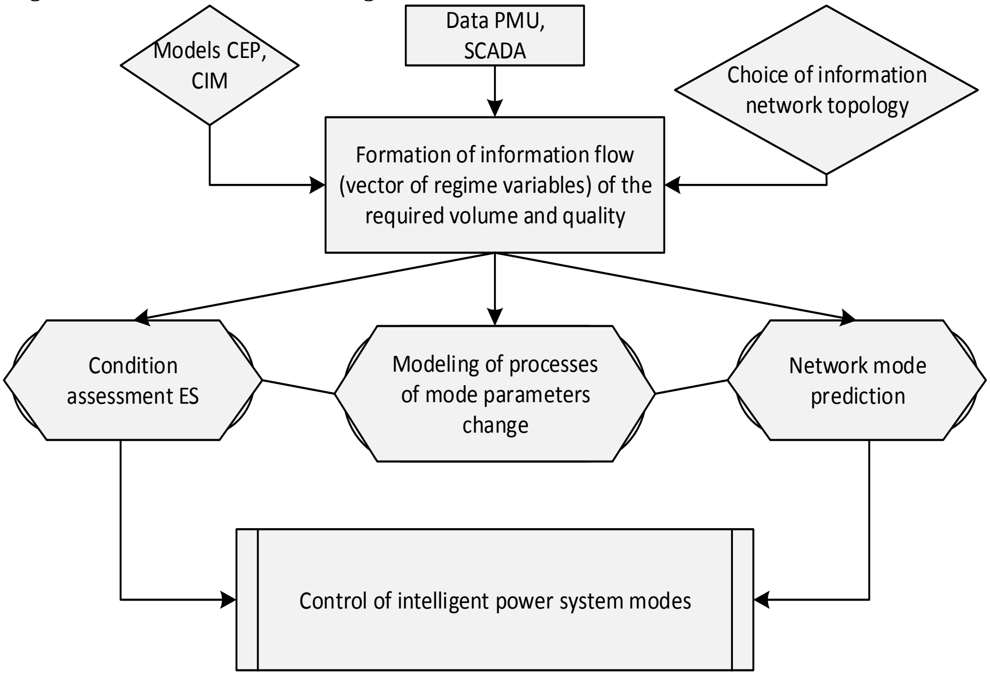

Fig. 1.General scheme of information flow processing in monitoring and control of IES modes

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Two-level technology to support decision-making in the management of regimes in IES

Figure 2 shows the two-level information technology, according to which:

-at the upper (first) level a qualitative analysis of the situation (which arose in the IES) will be performed using intelligent technologies;

-at the lower (second) level with the use of adaptive software packages are performed numerical calculations for situations that occur after the results of qualitative analysis.

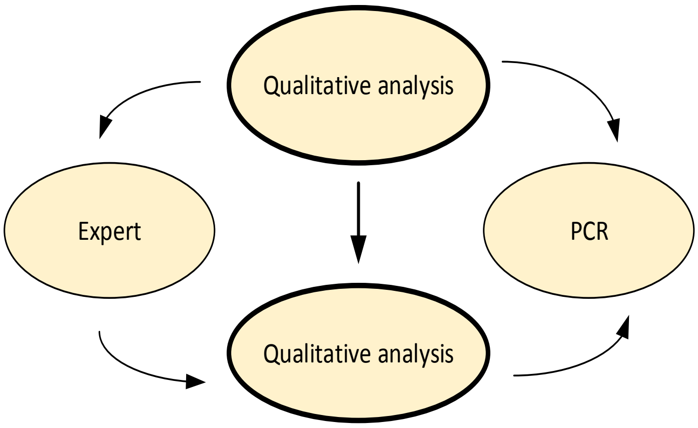

Fig. 2.Two-level information technology for decision support in regime management in IES

As technologies of intellectual support of decision-making at the stage of qualitative analysis the use of technologies of ontological, cognitive and step-by-step modeling is offered first of all. In the future, intelligent technologies can be supplemented with technologies of artificial neural networks, fuzzy sets, wavelet analysis, genetic algorithms, depending on the properties of information flows.

Varieties of information, its classification and mathematical models for its description

The information at the mode parameters is divided into [1] into four groups: *determined*, *probable*, *fuzzy* and *interval* – for various use of mathematical models in the conditions of active-adaptive control of EPS (Fig.3).

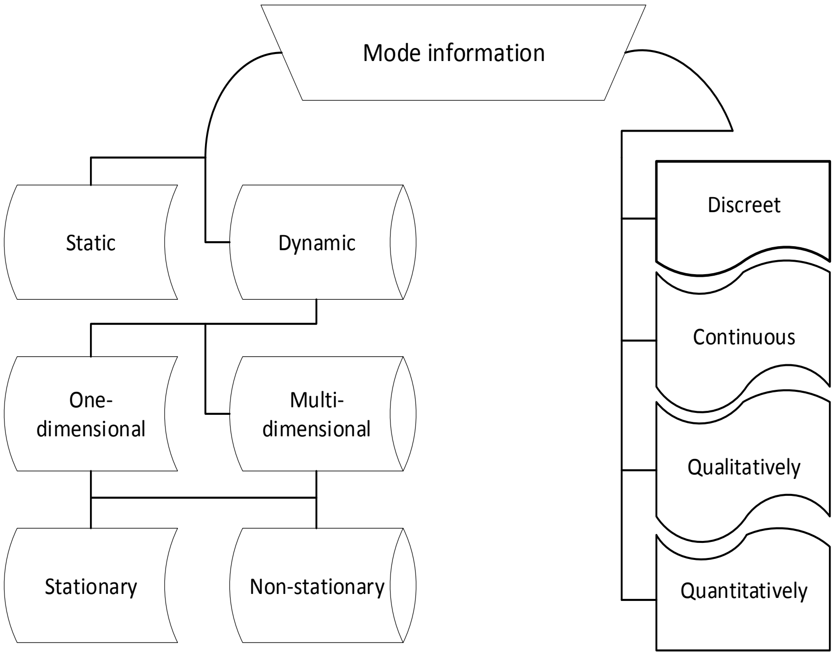

Fig. 3.Classification of mechanical models

Determined information is based on natural causal relationships and is due to the numerically unambiguous task of the types of equipment, its composition and nominal parameters. *Probable* information describes the stochastic nature of changes in the parameters of the mode, a set of network elements that correspond to this mode. *Fuzzy* information is when the values of the mode parameters are described by the functions of belonging to a fuzzy subset of their change. *Interval* information is typical for cases when only the probable range of changes of mode parameters is known, which is created by their minimum or maximum possible values

As an example, the technology of improving the quality of information flows, which is based on the theory of fuzzy sets (Fig.4).

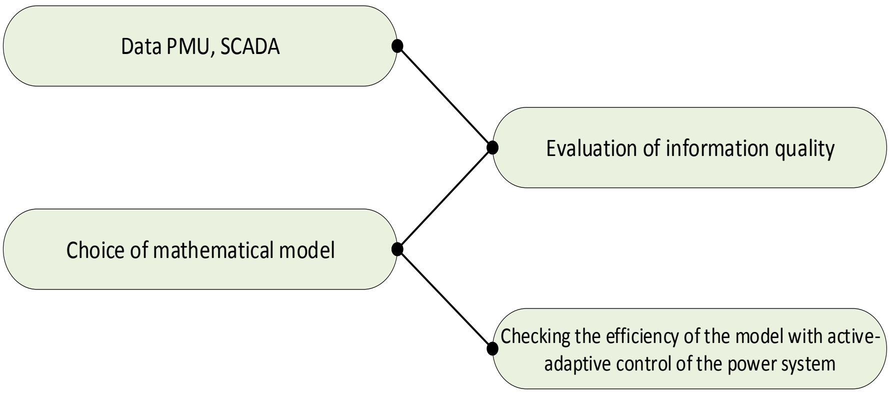

Fig. 4.Technology to improve the quality of information flows

The quality of the measured information is determined by the quality criterion. For this purpose all information base is presented in the form of four sets:

A_I – set of valid values;

A_{II} – set that corresponds to the full amount of information;

AIII – set that corresponds to an incomplete amount of information;

A_{IV} – set of inaccurate values.

To determine the completeness and reliability of information that provides the required accuracy of solving control problems, introduced a threshold level α for fuzzy areas, the quantitative value of which corresponds to the optimal parameters of information quality:

$$\alpha = \frac{1}{\ln N \cdot \sum_{i=1}^{N} \mu_{\tilde{A}_i}(A_i)} \left[\sum_{i=1}^{N} \mu_{\tilde{A}_i}(A_i) \ln \sum_{i=1}^{N} \mu_{\tilde{A}_i}(A_i) - \sum_{i=1}^{N} \mu_{\tilde{A}_i}(A_i) \ln \mu_{\tilde{A}_i}(A_i) \right] \quad (1)$$

where $\mu_{\tilde{A}_i}(A_i)$ – membership function for *i*-th of the above sets. The set of α levels is described as

$$\tilde{A}_\alpha = \{\tilde{A}_i / \tilde{A}_i \in A, \mu_{\tilde{A}_i}(A_i) \geq \alpha\},$$

where

$$\tilde{A} \leq \dot{A}, A_i \in A, \ \forall \alpha \in [0,1].$$

The proposed quality criterion allows to classify information and apply those mathematical models that give the greatest accuracy of its description.

Conclusion

The paper considers the approach to the development of a new IT infrastructure of IES, which includes a single information space and, as a consequence, the creation of prerequisites for a multi-level management system of intelligent power systems. Possibility to expand the class of models used in solving power problems, due to the CEP and CIM models. The two-level information technology for decision support in IES mode management is analyzed, which integrates intelligent technologies and software complexes for modeling and mode control. The classification of types of information about the parameters of the modes is indicated and the expediency of using various mathematical models depending on the quality of the mode information is revealed.

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ДОСЛІДЖЕННЯ ІНФОРМАЦІЙНИХ ПОТОКІВ В УПРАВЛІННІ РЕЖИМАМИ ІНТЕЛЕКТУАЛЬНИХ ЕНЕРГОСИСТЕМ.

Метою даної роботи є вирішення проблеми оптимізації керування техобслуговуванням і ремонтним обладнанням на великих підприємствах. Проведено дослідження загальних проблем створення інтелектуальних енергетичних систем з точки зору інформаційно-телекомунікаційних технологій. Розглянуто підхід до розробки нової інформаційно-технологічної інфраструктури інтелектуальних енергетичних систем. Після проведення аналізу оптимальною системою вбачається саме багаторівнева система керування інтелектуальними електроенергетичними системами. Технологія об'єднує інтелектуальні інструменти для аналізу ситуації та програмні системи для моделювання та контролю режимів. Використання IT-інфраструктури дозволяє створити єдиний інформаційний простір, що включає дані та знання, а також набір математичних моделей і методів для вирішення задач електроенергетики в умовах активного адаптивного управління. У висновках наводиться розписана класифікація типів інформації про параметри режимів та обумовлюється взаємозв' язок між якістю режимної інформації та застосування різноманітних математичних моделей.

Ключові слова: *інформаційні потоки, інтелектуальні електроенергетичні системи (IEC), Smart Grid, керування, інформаційно-технологічна інфраструктура.*

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