Intellectual processing of information of multi-level monitoring and diagnostics systems of complex technical objects

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Abstract
The article considers intellectual information multi-level systems for monitoring and diagnosing complex technical objects, taking into account modern information technologies. Ways of computer intellectualization of the functioning modes of such complex technical objects are shown. The analysis carried out in the work showed that one of the key tasks in the field of industrial energy at the moment is the development of methods and intellectual means of condition monitoring and technical diagnostics, which should carry out advanced diagnostics of the condition of individual nodes of complex technical objects on a real-time scale, which would provide generalization of such diagnostic information, selected from a large array of data that information that is critical for the object and transferred it to a higher level of the hierarchy. The peculiarity of the work is that it is necessary to solve the complex task of building systems of multi-level monitoring and diagnosing complex technical objects as integrated systems based on the intellectual principles of self-organization of complex systems. The work analyzes the subject area of building models of observed objects based on the data of multi-level monitoring and diagnostics of their states; the formulation of the scientific problem was carried out, the requirements for multilevel models and methods of their synthesis were determined. The expediency of using intellectual methods of information processing in multi-level monitoring and diagnostics systems is substantiated, models of decision-making and knowledge presentation are developed, hardware tools for the implementation of intellectual systems are proposed; developed algorithms for the optimization of the multilevel signal conversion function, which, due to their versatility, can be used in related fields of science and technology.

Keywords 1 Automated control systems, multi-level monitoring and diagnostics systems, adaptive multi-level monitoring and diagnostics systems, assessment of effectiveness, multi-level mass service models.

Introduction

The current stage of development of technologies used in nuclear, thermal, chemical and energy production is characterized by a significant increase in information exchange between all elements of complex technical objects (CTO) at all hierarchical levels. There is a need to form a single intellectual multi-level control system that provides a high level of automation and reliability of the entire system, covers manufacturers, transmission and distribution networks, and consumers [1]. At the same time, obtaining up-to-date information about the actual state of each network element and sharing this information between many participants is important, which collectively ensures an increase in the reliability of the system as a whole.

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Thus, one of the main tasks in the field of industrial energy at the moment is the development of methods and technical means of condition monitoring and technical diagnostics, which should carry out extended diagnostics of the condition of individual CTO on a real-time scale, would ensure the generalization of such diagnostic information, be isolated from a large array data of the information that is critical for the object and transferred it to a higher level of the hierarchy [3].

Systems of multi-level monitoring and diagnostics (SMMD) are partially devoid of a number of disadvantages. Compared to classical information and measurement systems, SBMD have increased resistance to external factors, increased security and ensure the security of data transmission [1, 2]. The application of this concept assumes that maintenance and repair of CTO should be carried out according to the actual condition [4, 5]. For this, a much larger part of the object must be covered by reliability assurance systems, which must carry out constant or periodic testing of its actual technical condition.

Sometimes in literary sources, the tasks listed above are combined under the general name "Asset Management" [6]. Currently, both practical and scientific work in this direction is actively being conducted, leading manufacturers of electrical equipment already offer a number of software products designed to collect and summarize statistical information about operating conditions and the actual condition of CTO.

Among the wide variety of publications aimed at solving the above-mentioned problems, one can note, for example, works [7, 8, 9], each of which considers certain issues related to the application of intellectual information processing of multi-level monitoring and diagnostic of complex technical objects.

Thus, the work [7] is devoted to the issues of preliminary preparation of experimental data before their further processing by computing means, in particular, with the help of information and measurement systems for monitoring and diagnostics. In turn, data preparation performed according to certain algorithms considered in this work provides an opportunity to reduce their volume for further processing. The work [8] is devoted to the issues of ensuring two-way exchange of information between different levels of CTO. The paper presents the results of a complex experimental study with the determination of the statistical characteristics of a wireless channel of information exchange between objects at a power substation with a voltage of 500 kV. In work [9], the issue of the application of methods of monitoring the condition of individual power transformer nodes based on the use of informational diagnostic signals is considered.

In recent years, the main directions of scientific research of the SMMD are methods of receiving, transmitting, storing, monitoring and intellectual processing of information, improving methods of processing received data. The starting points for building models of objects are the results of measurements of their parameters, as well as data about the environment [10, 11]. Objects have a multi-level structure that changes over time. Their state and behavior are typically described in discrete time and discrete state space.

Therefore, the main drawback of the existing multi-level monitoring systems is the difficulty of realizing their technical advantages in combination with acceptable cost and flexibility of application [1, 12].

The purpose of the work is the research and intellectual processing of information of SMMD, which ensures high-quality monitoring of CTO parameters on a real-time scale, selects the model of the research object, measurement and testing methods, and evaluates the effectiveness of the system.

To achieve the goal, the following scientific tasks were solved:

- to analyze the subject area of building models of observed objects based on the data of multi-level monitoring and diagnostics of their conditions;

- formulate a scientific problem, determine requirements for multilevel models and methods of their synthesis;

- justify the expediency of using intellectual information processing methods in SMMD, develop decision-making models and knowledge presentation, offer hardware and software tools for the implementation of intellectual systems; analyze the method of choosing the number of channels, develop algorithms for optimizing the multilevel signal conversion function, which, due to their versatility, can be used in related fields of science and technology.

2. Development of mathematical models for intellectual research of multi-level monitoring and diagnostics systems

In the process of analysis, it was found that complex technical objects have a number of features: multifacetedness and uncertainty of behavior, hierarchical structure, excess and variety of constituent objects of elements and subsystems, ambiguity of connections between them, multivariate implementation of management functions, territorial distribution. Therefore, in modern conditions, the development of methods, algorithms and technical means of constant monitoring of the state of a complex object, analysis of the processes taking place in it diagnosis and prediction of the object's behavior in the future is becoming very relevant. The most effective tool for intellectual research of multi-level monitoring and diagnosis systems is information and measurement systems, mathematical models, the theory of choice and decision-making [4, 5].

2.1. Decision-making model for intelligent multi-level monitoring system

The issue of the industrial use of intellectual SMMD has not been sufficiently worked out in both the scientific and technical aspects. The disadvantage of existing monitoring and diagnostic systems is the complexity of the components included in their composition, low manufacturability, and, as a result, high cost. For example, as a rule, expensive analog primary information converters are used, even in cases where it is enough to determine the value of the parameter at several testing points for adequate system operation. Also, certain difficulties arise when it is necessary to rebuild the structure of the monitoring system, change the algorithm of its operation, solve scaling problems, and process large data flows.

Therefore, the main drawback of the existing intellectual SMMD is the difficulty of realizing their undoubted technical advantages in combination with an acceptable cost [12]. This shortcoming does not allow SMMD to compete with classical systems in conditions of forced economy of material resources.

Therefore, the development and research of intellectual SMMD, which combine the ability to work reliably in harsh operating conditions with manufacturability, flexibility of application and competitive cost, is a serious scientific problem, the solution of which is of great importance for science and technology.

The main problems in the intellectualization of SMMD are the formation and selection of the model of the researched object; selection of measurement and control methods; selection of measurement parameters, assessment of system efficiency. As a decision-making strategy, the selection of existing methods, the method of logical inference based on the application of the theory of fuzzy sets, as well as the solution of the optimization problem were considered [2]. Decision-making was assessed using the Dempster-Shafer criterion.

An important issue of intellectualization is the development of a decision-making model that takes into account the following factors [1]:

- structure, external parameters and algorithms of functioning of multi-level systems;
- availability of structural elements, their parameters and functioning algorithms;
- mechanism of interaction of elements and nodes of the structure among themselves and with the surrounding environment;
- methods of multi-level monitoring and assessment of the adequacy of the CTO from the point of view of the stated goal.

The decision-making model in intellectual SMMD is presented as follows:

$$M_r = \{R, Q, P, S, D, K\} \quad (1)$$

where $R = \{R_i, i = 1,2, \dots, r\}$ - decision-making methods, $Q = \{Q_i, i = 1,2, \dots, q\}$ - an algorithm for extracting from a large array of data the information that is critical for object, $W = \{W_i, i = 1,2, \dots, w\}$ - external parameters, $P = \{P_i, i = 1,2, \dots, p\}$ - internal parameters, $S = \{S_i, i = 1,2, \dots, s\}$ - optimization algorithm of multilevel signal conversion function, $D = \{D_i, i = 1,2, \dots, d\}$ - destabilizing factors, $K = \{K_i, i = 1,2, \dots, k\}$ - criterion for assessing the adequacy of system operation.

The value of the confidence hypothesis function is determined based on the data of two (or more) independent measurement sources using the formula:

$$F_n(z) = \sum_{x \cap y = z} F_1(x) F_2(y) \Big/ \left[1 - \sum_{x \cap y = 0} F_1(x) F_2(y) \right] \tag{2}$$

where $F_1(x), F_2(x)$ – are measures of confidence in the measurement results, determined on the totality of the hypothesis space.

2.2. Decision-making scheme in the intellectual multi-level monitoring and diagnosis system

The decision-making scheme is presented in Figure 1. In the knowledge base, information is formed and stored about reference and actual values of measurement parameters, methods of metrological analysis, and the nature of destabilizing factors [1].

The speed of changes in the processes taking place in the CTO requires a high-speed performance of a multi-level intellectual system. This condition is satisfied by dynamic expert systems operating in real time.

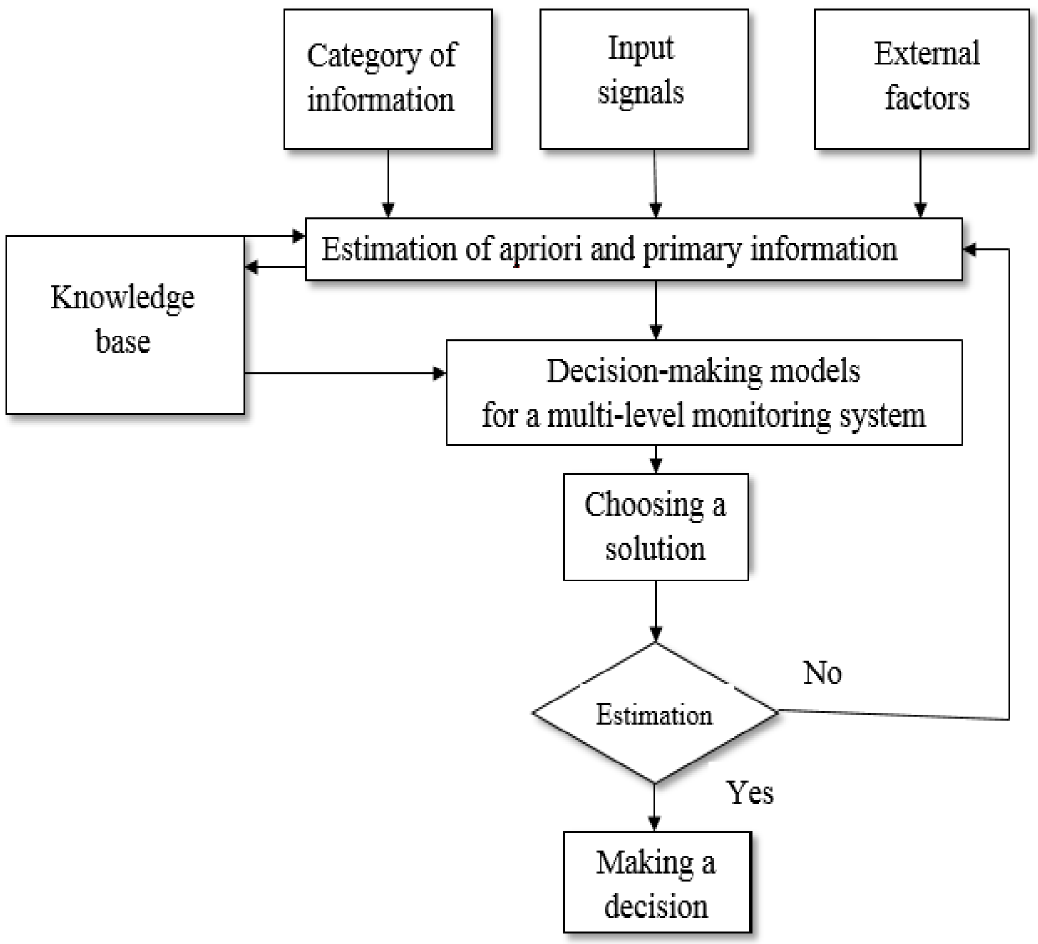

Figure 1: Scheme of decision-making in the intellectual multi-level monitoring and diagnosis system

The development of dynamic expert systems for the intellectualization of SMMD is connected with solutions to the following problems:

- determining the composition of the knowledge base and its formation;

- development of new and use of known theories and methods for describing information processes in intellectual multi-level systems;
- development of methods of presentation and organization of multi-level databases;
- search for appropriate computing environments for the implementation of multilevel computing algorithms.

So, the work defines a class of complex technical objects, the main feature of which is the complexity for multi-level monitoring and diagnostics, which is due to the stochasticity of the processes taking place, the complexity of the design, and the lack of information available for control. The need to measure and testing the parameters of complex technical objects and analyze the received data in real time is substantiated. The work also considered the issue of intellectual processing of information in SMMD. The use of intellectual multi-level information processing methods to take into account changes in the state of the CTO under the influence of external and internal factors is substantiated, a decision-making model and an information presentation model are proposed, and methods of further intellectualization of SMMD based on dynamic expert systems are proposed. The use of work results increases the safety of CTO operation, which is a significant contribution to the development of the country's economy.

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