Microprocessor Means for Technical Diagnostics of Complex Systems

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Abstract. The construction of algorithms for assessing the operability and the recognition of technical states of complex technical systems can be carried out by preliminary modeling of these problems on large computers. This work is considering the expediency of using multi-level modern microprocessor means technical diagnostics for these purposes.

Keywords: complex technical systems, technical diagnostics, technical states, algorithm, management of object maintenance.

1. Introduction

Providing high reliability of functioning of modern complex technical systems (CTS) includes a wide range of problems, the solution of which is aimed at the efforts of many specialists of different profiles in the design, manufacture, testing and operation of such systems. The issues of technical diagnostics with the subsequent organization of effective maintenance, the main task of which is to maintain the required level of reliability of complex systems during operation.

At the same time, it should be borne in mind that the characteristic features of modern CTS are the high degree of integration of the unit and the nodes, the developed logistics structure and high saturation of computer technology, the wide application of integrated circuit technology and multi-layer printed editing [1]. Therefore, maintenance of such systems is characterized by great laboriousness and a richness of control and diagnostic operations, an increase in the nomenclature of the measured CTS parameters, an increase in the requirements for accuracy, reliability and level of processing of control results [2]. Therefore, a special place in the complex of technological operations for CTS maintenance is concurrently granted to operational control. Qualitatively new approach in the development and use of operational and control-diagnostic devices leads to a change in the organizational and technological structure of operational control and maintenance systems. Application in the control and diagnostic systems of microprocessor means allows to solve a wide range of problems in the diagnosis of CTS [2-6].

Among these problems an important place is occupied by the issues of technical diagnostics.

The architecture of constructing modern microprocessor means (MPM) for the technical diagnosis of CTS is largely determined by the constructive and functional complexity of the monitored objects. If, for example, for CTS of ordinary complexity, the automation of workability control is reduced mainly to the allowable evaluation of individual controlled parameters or their disunited summation, then for complex CTS, which are characterized by a multitude of such parameters, a peculiar hierarchical structure and unequal connection of individual aggregates a specific complex approach to the solution of the task of assessing the level of operability of objects [3]. In this case, the problem arises of recognizing the classes of technical conditions of RES, which are formed on the basis of a generalized set of performance indicators and controlled parameters. This work is considering the expediency of using multi-level MPM technical diagnostics for these purposes.

It is known that the main task of autocontrol systems is to identify one of the conditions in the monitored objects - workable or inoperable (failure, halting or malfunction). The criterion of efficiency is usually reduced to the description of the external behavior of the CTS, which is characterized by changes in its characteristics, internal or external parameters. Taking into account the working conditions of objects, which are described by the relationships between the monitored parameters, it is possible to form classes of technical states defining the region of the workable and inoperative CTS states. Obviously, the corresponding values of the internal and external parameters of the CTS determine the boundary points of these states. The task of autocontrol systems is to determine the working conditions that are most relevant to the given criterion. Direct control of the indicators describing this criterion and the search for boundary points of workability is hampered by a number of difficulties associated with the diversity of these indicators, the complexity of the representation and interrelation of the technical implementation. The development of MPM technical diagnostics, performed in a hierarchical structure, avoids these difficulties.

2. Materials and methods of research.

During operation, modern CTS can be in the following states: normal working capacity (S1), described by a complex of nominal values of characteristics and parameters; anticipatory tolerances for controllable parameters (S2); operational nominal tolerances for controlled parameters, the excess of which is classified as a fault (S3) or failure (S4); reserve condition (S5).

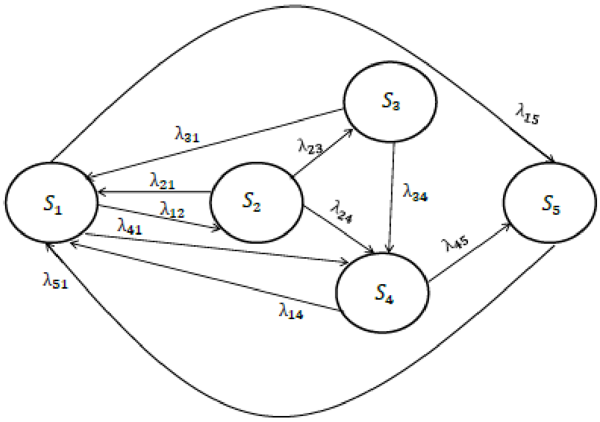

Fig. 1. The Markov model, of graph of discrete states of the object

To assess the possibility of monitoring these states, we will depict the maintenance process of CTS in the form of a Markov model, which is a graph of discrete states of the object (Fig. 1). The transition of CTS from one state to another occurs under the influence of certain events - failures, malfunctions, regulations, performance of regulated maintenance, etc. The arrows on the graph indicate possible transitions of the system from one state to another. For clarity of the presented model, we characterize the intensity of the transitions noted above the corresponding arrows of the graph: when performing scheduled maintenance in the standby state (λ_{15}); from standby to operable condition after elimination of failures or maintenance (λ_{51}); gradual failures, associated with the acquisition of controlled parameters of the values of anticipatory tolerances (λ_{12}); when conducting regulating and adjusting works (λ_{21}); sudden failures (λ_{14}); gradual failures associated with the obtainment of pre-emptive values of the monitored parameters of the states of malfunction (λ_{23}) or failure (λ_{24}); gradual failures associated with a succession of malfunctions and failures (λ_{34}).

Thus, from the state S1, the monitored CTS can be transferred to the state S5 when performing the scheduled maintenance (λ_{15}) or when gradual (λ_{12} - λ_{23}- λ_{34}) and sudden (λ_{14}) failures occur. When the REN have reached the S2 state, it is necessary to perform regulating and adjusting operations in order to transfer the object to the *Si* state. If this is not possible, the object goes into the conditions of malfunction (S_3) or failure (S_4). In the future, it is advisable to transfer this object to a standby state (λ_{45}) for restoration work.

3. The results of research

In accordance with the methodological recommendations given in [4, 5], we will compose a system of differential equations directly from the given graph (Fig. 1), describing the Markov model of discrete states of the object:

$$\begin{aligned}
\frac{dP_1}{dt} &= -P_1\left(\lambda_{12}-\lambda_{14}-\lambda_{15}\right)+P_2\lambda_{21}+P_3\lambda_{31}+P_4\lambda_{41}+P_5\lambda_{51}\,;\\
\frac{dP_2}{dt} &= -P_1\lambda_{12}+P_2\left(\lambda_{21}+\lambda_{23}+\lambda_{24}\right);\\
\frac{dP_3}{dt} &= -P_2\lambda_{23}+P_3\left(\lambda_{31}+\lambda_{34}\right);\\
\frac{dP_4}{dt} &= -P_1\lambda_{14}+P_2\lambda_{24}+P_3\lambda_{34}+P_4\left(\lambda_{41}+\lambda_{45}\right);\\
\frac{dP_5}{dt} &= -P_1\lambda_{15}+P_4\lambda_{45}+P_5\lambda_{51}\,.
\end{aligned} \tag{1}$$

Taking into account the use of the limiting probabilities of the investigated CTS states P_i (S_i), we transform a system of equations to an algebraic form (1), the left-hand side of which is equal to zero. Then $\sum_{i=1}^{5} P_1 = 1$. In the future, given the intensities of the transitions λ_{ij}, the numerical values of the CTS residence probabilities in S_i states are determined, which to a large extent predetermines the architecture of constructing the MPM of technical diagnostics.

It is most expedient to build the technical diagnostics MPM on a distributed architecture, based on the functional decentralization, i.e., the monitoring and diagnostic system must be performed in multi-level with a hierarchical structure. In this case, the control and diagnostic process is subdivided into sub-processes with well-defined interconnection methods for information transfer.

Figure 2 shows a two-level MPM of technical diagnostics, which consists of two lower-level subsystems and a coordinating microcomputer. Lower-level sybsystems A and B should conduct a diagnostic control of measuring parameters with different combinations of sensors and perform preliminary processing of the received information. In this case, the admission control of the incoming information determines the position of the controllable parameter in the field of system operability. Thus, with the help of lower-level subsystems, it is possible to fixate the moments of the CTS transition from the state of normal working capacity S_1 to the states $S_2 - S_5$ and to obtain quantitative information about these states. The tasks of recognition of technical states and control by measuring parameters are solved by the coordinating upper-level microcomputer. Taking into account the quantitative characteristics of the Markov model of CTS states, it is possible to preliminarily describe the problems solved by both computers and determine the architecture of their construction by defining the corresponding amount of memory, organizing the interaction of functional systems, etc. Thus, the RAM memory size of the coordinating microcomputer depends mainly on the mathematical model and the algorithm for recognizing the technical states of the Markov model.

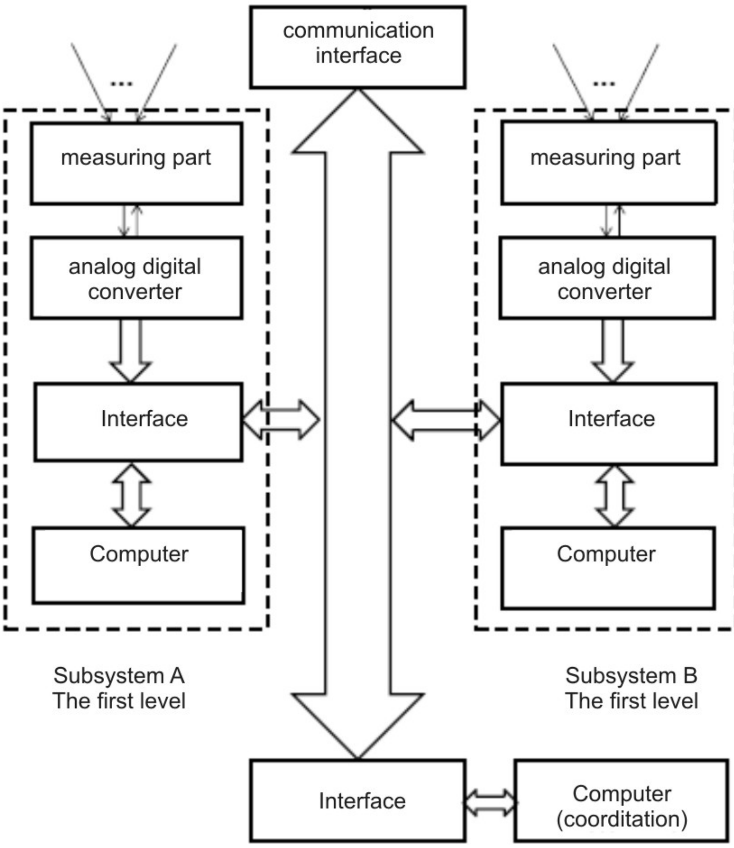

Fig. 2. The two-level MPM of technical diagnostics

The mathematical basis for the recognition of technical states of CTS can be laid by Bayesian criterion [6-8] or the maximum likelihood principle for equiprobable states P_i

$$\Lambda_k = \frac{\varphi\left(K_1/x_1, x_2, ..., x_n\right)}{\varphi\left(K_2/x_1, x_2, ..., x_n\right)} \geq 1, \tag{2}$$

Where Λ_k is the criterion for recognition (classification) of technical states of CTS; *K1*, *K2* - the investigated classes of technical states of CTS; $x_1, x_2, ..., x_n$ - indicators of technical condition or monitored parameters of the object.

For complex CTS, it is advisable to install the following classes of technical states [9-12]:

- class *K1* - a set of CTS status indicators requiring continuous monitoring, the deviation of which can cause a malfunction or complete failure of the object;

- class *K2* - a set of indicators of the state of CTS, requiring periodic monitoring, the deviation of which can cause partial failures or malfunctions of the object;
- class *K3* - a set of indicators of the state of CTS, which determine the conduction of regulated maintenance.

In the general case, the number of classes considered exceeds the number given in the Markov model (Fig. 1).

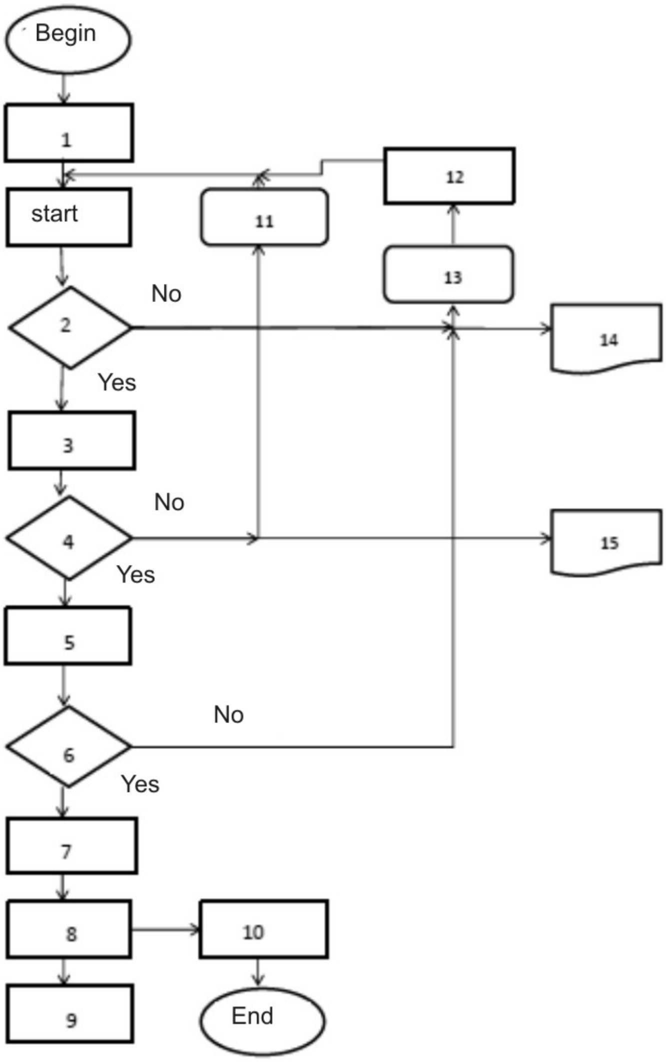

Fig. 3. The scheme of the algorithm of operation of the subsystem of the lower-level MPM

The scheme of the algorithm of operation of the subsystem of the lower-level MPM is shown in Fig. 3. The presented algorithm solves the problem of estimating the monitored parameter for finding it in the field of operability. The values of the monitored parameter are compared with the values of its admissible values, which are stored in the memory of the microcomputer (procedure 1). In addition, a ping sequence of sensors installed in the CTS and an algorithm for calculating the parameters determined by indirect methods are also stored in memory.

Procedure 2 is organizing a cycle of MPM selecting the technical diagnostics of the corresponding controlled parameter. If the MPM is not correctly connected, the system is dynamically stopped by the processor (procedure 13) and the command is repeated to connect the desired sensor to the monitoring system (procedure 12). Simultaneously, for a high-level microcomputer, a signal is generated about the absence of such a connection at a given time (procedure 14). When connecting the corresponding object sensor to the MPM in the microcomputer from the measuring part (Fig. 2), information is received on the value of the parameter controlled at a given time (procedure 3). Correspondence of the CTS parameters of the working capacity field can be carried out with the help of the admission control according to the precompiled algorithm stored in the micro-computer memory (procedure 4). When the monitored parameter exits the boundaries of the working capacity field, the lower-level system is dynamically stopped (procedure 11) and a message "out of tolerance" is generated for the upper-level computer (procedure 15). Then the upper-level computer is assuming direct control of the process of measuring and recognizing the technical state of the object. If the complex evaluation shows that the output of one parameter outside of the working capacity field does not affect the overall performance of the CTS, then the control of the process of measuring parameters and analyzing the state of the object is transferred again to the lower-level computer. The values of the CTS parameters that have passed the admission control are entered in the RAM of the lower-level micro-computer (procedure 5). Further, it is checked whether all the parameters are monitored (procedure 6). If the answer is negative, the system stops dynamically (procedure 13) and procedures 2-6, 12 are repeated. With full control of CTS, a conclusion is made about the state of the object (procedure 7). The result of this evaluation is stored in the computer's RAM instead of the information recorded during the procedure 5 (procedure 8). In the future, this information can be used for digital indication (procedure 9) or registration on a digital printer and output to a upper-level computer (procedure 10).

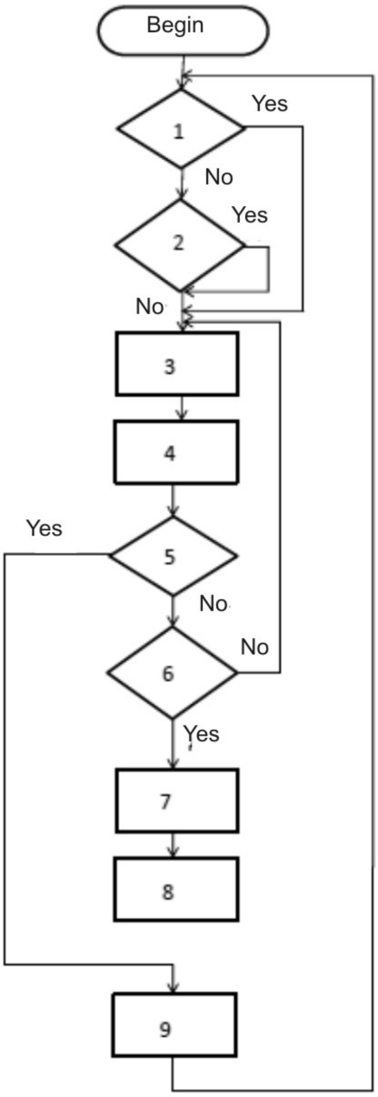

Fig. 4. The algorithm of operation of the lower-level subsystem, the upper-level computer interacts directly with the subsystem

As can be seen from the algorithm of operation of the lower-level subsystem, the upper-level computer interacts directly with the subsystem. This interaction clearly illustrates the algorithm of the coordinating microcomputer (Fig. 4). The described algorithm, in addition to the described functions for coordinating the operation of the entire technical diagnostic system, determines the collection of information from lower-level subsystems (A and B), by processing which the CTS technical condition is recognized.

The coordinating microcomputer performs a sequential ping of lower-level subsystems A (procedure 1) and B (procedure 2) for the presence of requests (procedure 15 in Fig. 3). If there are no requests, the computer reads the CTS status information (procedure 3) and processes it (procedure 4). If there is such a request, the computer switches to procedure 3 (reading data from the information buses of lower-level subsystems A and B) and the technical condition of CTS is recognized by formula (2) (procedure 4). On the basis of the received data, a decision is taken on whether the object is in operable or faulty state (procedure 5). If the technical condition of the CTS does not meet the specified requirements or the controlled parameters approach the permissible values, procedures 3-6 are repeated. If the technical condition of the object is classified as inoperative (procedure 6), the coordinating computer goes to the malfunction search routine (procedure 7), after which the faulty CTS unit is indicated (procedure 8). If the departure of parameters beyond the tolerance limits does not affect the overall operability of the object or all of its parameters are normal, the information on the current state of the REN is updated on the indicator board (procedure 9) and MPM proceeds to re-execute all the I procedures.

Conclusions

The construction of algorithms for assessing the operability and the recognition of technical states of CTS can be carried out by preliminary modeling of these problems on large computers.

Functional versatility, programmability, a large degree of integration, high reliability, uncomplicated modification of the performed functions and the low cost of microprocessor means determine the possibility of their wide application in the systems of technical diagnostics and management of object maintenance.

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