Adaptive accumulation and diagnostic information systems of enterprises in energy and industry sectors

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Abstract. Our paper describes the methodology of an effective system construction based on information systems self-diagnosis using the case of Ukrainian enterprises in metallurgy, energy, and chemical industry. It describes the method of organization and implementation of self-diagnosis, mechanisms of detection, as well as the identification and localization of failed modules. The results formulate the criteria of sufficiency of efficiency of diagnostic information in the absence of restrictions on performance of elementary checks. Moreover, it yields the criterion of sufficiency of diagnostic information in the presence of restrictions on performance of elementary checks.

1 Introduction

The rapid development of modern high-tech society requires the intensive development of information technology distinguished by a high degree of autonomy [1]. This problem is especially acute for manufacturing companies that operate under the influence of extreme factors. Among such companies are enterprises of metallurgy, energy [2], chemical industry, etc. The functioning of production units of such enterprises is provided by various types information systems. These systems are used to plan and control all processes [3]. These information systems work autonomously under the influence of external and internal destabilizing factors [4]. With the help of information systems, it is possible to increase labor productivity of all production centers while reducing the number of people employed in production and significantly reducing the share of manual labor [5]. The systems are constantly being modernized due to the intensification of capital investments in the production process.

This paper emphasizes that the information systems of enterprises operate under the influence of external and internal destabilizing factors. Under negative influence, the system modules may fail. However, the systems must operate offline for a specified time. This operating condition can be fulfilled by providing the properties of functional stability [6].

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Functional stability is a guarantee of the functioning of the information system, possibly with a decrease in quality, during the specified time under the influence of external and internal destabilizing factors [7]. External and internal destabilizing factors are failures, failures of system modules, mechanical damage, thermal effects, errors of service personnel. The main stages of ensuring functional stability are the detection of the module that failed in the control, diagnosing the module that failed and the restoration of the information system of the enterprise.

Therefore, one of the most important prerequisites for ensuring functional stability is to build an effective system for diagnosing key units at each production centre of the production enterprise.

This paper is structured as follow: Section 2 describes materials and methods used in this research. Section 3 shows the results formulate the criteria of diagnostic information sufficiency in the absence of restrictions on elementary checks performance and the criterion of diagnostic information sufficiency in the presence of restrictions on elementary checks performance. Finally, Section 4 provides final conclusions, draws policy implications and presents the pathways for further research.

2 Materials and methods

In this paper, we propose a new approach to diagnosing complex technical systems. The diagnostic procedure is performed for the information system of the metallurgical enterprise. The essence of this approach is as follows:

 - the diagnostic procedure can be completed at any time;

 - the choice of the module which makes the decision on a condition of information system of the enterprise is free.

When the system works as intended, checks occur randomly. Randomness concerns the choice of a pair of modules that test each other and the test time between them. Therefore, after some time in the information system can be carried out any number of basic checks [8]. Assessment of the state of the information system [9] of the enterprise on the basis of elementary checks can be presented in the form of two methods: the method of self-control and the method of adaptive self-diagnosis.

The method of adaptive self-diagnosis is to adapt to a negative situation in the information system. Diagnostic information about the state of the modules accumulates in a chaotic manner and depends on the negative situation. After analyzing the obtained data on the state of the system, we find a fault with a probability not lower than the specified. Depending on what time is taken to start the adaptive self-diagnosis procedure, two adaptive self-diagnosis strategies are possible.

The first strategy. The method of adaptive self-diagnosis begins at the beginning of the last cycle of self-monitoring t_k. According to this scheme, elementary checks are taken into account, which are performed for some time τ and show the presence of a fault in the information system of the enterprise. Preliminary results are not analyzed and a priori probabilities of serviceable condition of system modules at time t_0 are not determined. Deciphering the syndrome is carried out after the end of the method of adaptive self-diagnosis.

The second strategy. The method of adaptive self-diagnosis begins at time t_0. Based on the results of elementary checks, which are performed during time τ, the a priori probabilities of serviceability of the enterprise information system modules are determined. Then the result of adaptive self-diagnosis is formed and its reliability is determined.

After receiving the diagnostic information, each module of the information system of the enterprise evaluates its readiness to issue the results of self-control of the system with a given reliability.

3 Practical results

The information system of the enterprise is organized in such a way that the working information is transmitted to the module of the system after receiving a signal about its readiness or serviceability. Therefore, it is necessary to provide the minimum time from the moment of the beginning of work of a method of self-control to the moment of issue of the information on serviceability of all modules of information system of the enterprise. Each time of the self-control procedure corresponds to a certain value of the probability [10] that all modules of the information system of the enterprise are controlled or *the probability of issuing information P_{II}* about the serviceability of the modules is determined.

Statement 1. *The dependence of the probability of deleting the P_{II} during the execution of a set of elementary checks. Then it is enough to perform checks of the checked data for any time that have the value of the probability P_{II} is provided. Moreover, there is no need to track the current structures of verification links in the information system of the enterprise.*

After reaching the set value of the probability P_{II}, the procedure for performing basic checks is completed. There are two options for analyzing the structure of test relationships:

1. the analysis is performed in order to learn about the verification of modules. If all modules are checked, the information on serviceability of modules of information system of the enterprise is issued. If not, all modules are checked, the procedure of elementary checks is repeated;

2. the analysis of the structure of verification connections is not carried out, and information on the serviceability of the modules of the information system of the enterprise is issued immediately.

As a special case it is possible to consider self-control with restriction on performance of elementary checks before receiving the full diagnostic graph. In this case, as a limitation, we use the condition of the absence of multiple edges in the diagnostic graph. The method of self-diagnosis of the information system of the enterprise at casual performance of elementary checks can be presented in the form shown in fig. 1.

As a criterion for the adequacy of diagnostic information, consider the probability of information. At self-control of information system of the enterprise elementary checks occur at arbitrary moments of time of functioning of modules on purpose.

Denote by α_i, α_j and β_i, β_j, $i \neq j$, $i, j = 1,2, \dots, N$ the value of time of employment and freedom of the module during the performance of basic functions in the information system of the enterprise. By M_i, $i = 1,2, \dots, N$ and M_j, $j = 1,2, \dots, N$ denote i-й and j-й modules of the enterprise information system.

The time of operation of the information system of the enterprise is broken down into intervals τ_η, $\eta = 1,2, \dots, s$. The interval τ_η satisfies the condition $t_{ec} < \tau_\eta < \alpha_i$, where t_{ec} − time of execution of elementary check. It will be executed at s intervals rs basic inspections. At $rs < N$ the probability that all modules are tested is equal to 0. At $rs > N$ the probability that all modules tested is based on the retest test theorem for the case where each experiment can have N mutually exclusive consequences with equal probabilities $P = 1/N$.
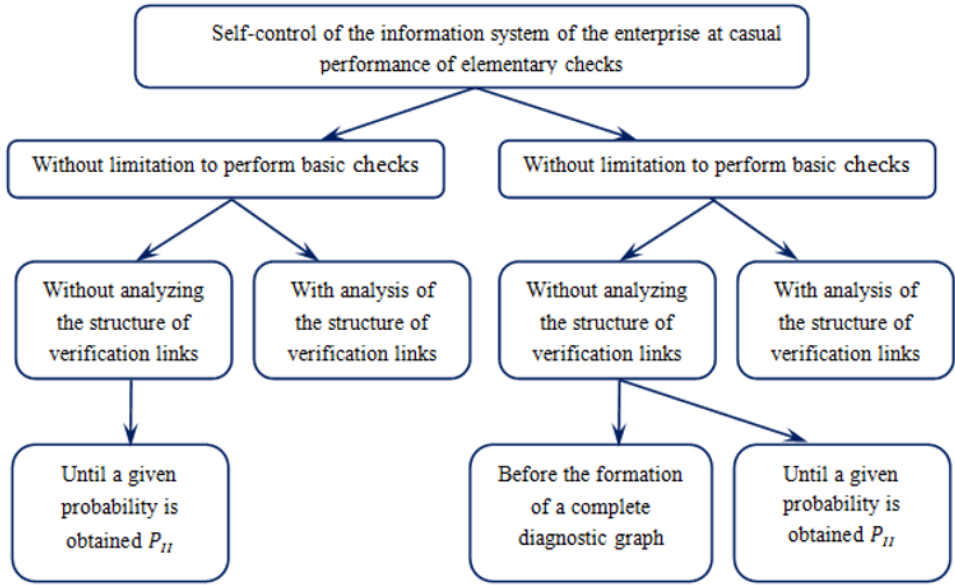
Fig. 1. The method of self-diagnosis of the information system of the enterprise at random performance of elementary checks

Statement 2. (criterion of sufficiency of diagnostic information in the absence of restrictions on performance of elementary checks) *In the information system of the enterprise of self-control organized by means of elementary checks occur at arbitrary moments of time of functioning of modules on purpose*

$$P_{II} = \left(1 + \frac{\Sigma_{i=1}^{\xi} \frac{1}{Y_j}}{\Sigma_{j=1}^{\eta} \frac{1}{X_j}}\right)^{-1}, \tag{1}$$

where $X_1, X_2, \ldots, X_\eta$ relevant members $m_1!, m_2!, \ldots, m_N!$ from the formula

$$P_{m_1, m_2, \ldots, m_N, sr} = \frac{(sr)!}{m_1! \, m_2! \ldots m_N!} \cdot \frac{1}{N^{sr}}, \tag{2}$$

and $Y_1, Y_2, \ldots, Y_\xi$ such members $m_1!, m_2!, \ldots, m_N!$ for which

$$\prod_{i=1}^{N} m_i = 0. \tag{3}$$

We show the dependence X_j, Y_j of rs. Since such values are difficult to find, we find their average values $X_{av}(rs_k)$, $Y_{av}(rs_k)$, where through s_k the number of the last interval of division of time of functioning of information system of the enterprise is marked. Next to find the average values X_{av}, Y_{av} you need to define a function $\tilde{P}_{II}(rs_k)$. This function will be considered the main one for finding the probability values P_{II}. Correspondence between functions $P_{II}(rs_k)$ and $\tilde{P}_{II}(rs_k)$ is set based on the processing of a certain amount of computational values $P_{II}(rs_k)$ i $\tilde{P}_{II}(rs_k)$. Average values $X_{av}(rs_k)$, $Y_{av}(rs_k)$ are from the ratios

$$X_{av}(rs_k) = \frac{1}{2}\left(X_{max}(rs_k) + X_{min}(rs_k)\right),$$
$$Y_{av}(rs_k) = \frac{1}{2}\left(Y_{max}(rs_k) + Y_{min}(rs_k)\right). \tag{4}$$

Number of terms $|X_i|$ and $|Y_j|$ is found as the number of different placements with k checks on N different modules ie

$$K_x = |X_i| = \binom{k-1}{N-1};$$

$$K_y = |Y_j| = \binom{N+k-1}{N-1} - \binom{k-1}{N-1}. \tag{5}$$

Statement 3. *In the information system of the enterprise self-controls organized by means of elementary checks occur at arbitrary moments of time of functioning of modules on purpose. The probability of issuing information that is due to the comparison of deviations from the mean values is determined by the ratio*

$$\tilde{P}_{II}(k) = \left(1 + \frac{K_y \cdot X_{cp}(k)}{K_x \cdot Y_{cp}(k)}\right)^{-1}, \tag{6}$$

where

$$X_{av}(k) = \frac{1}{2}\left([k-(N-1)]! + \left[\frac{k}{N}\right] \cdot \left[\frac{k-1}{N}\right] \cdot \dots \cdot \left[\frac{k-(k-N)}{N}\right]\right),$$

$$Y_{av}(k) = \frac{1}{2}\left(k! + \left[\frac{k}{N-1}\right] \cdot \left[\frac{k-1}{N-1}\right] \cdot \dots \cdot \left[\frac{k-(k-N+1)}{N-1}\right]\right). \tag{7}$$

We will introduce restrictions on the implementation of basic inspections. Let this limitation be the absence of multiple edges in the diagnostic graph of the enterprise information system. Therefore, the maximum number of checks in the system, and hence the maximum number of edges of the diagnostic graph will be equal to $N(N-1)$, where N is the number of modules in the enterprise information system (vertices of the diagnostic graph). In this case, each vertex may have an $N-1$ edge included.

Statement 4. (criterion of sufficiency of diagnostic information in the presence of restrictions on performance of elementary checks)

The number of terms K_x is defined as number of various placements from k checks on N various modules so that each module was checked at least once and there would be no module in which number checks more than $N-1$.

The number of terms K_y is defined as the number of different locations from k checks on N different modules so that at least one module was not checked and there would be no module in which the number of checks is greater than $N-1$.

In this way, as a result of performing a number of elementary checks, a certain structure of verification links is obtained. After the analysis of the received structure it is possible to draw a conclusion about result of control of information system of the enterprise which with a certain accuracy reflects a real condition of system and is characterized by a certain reliability of control.

4 Conclusions

All in all, one can see that the Ukraine's energy sector is undergoing an active transformation from an outdated model dominated by large producers, fossil fuels, an inefficient management system to a new model with a competitive environment and innovative approaches to development. The country has significant potential for the use of alternative and non-traditional energy sources, including wind, solar and thermal energy. At the same time, the rapid development of modern high-tech society requires the intensive development of information technology with a high degree of autonomy for energy companies.

It should be noted that Ukraine's energy strategy is aimed at improving energy efficiency, using renewable sources, and increasing security. The development of modern energy is inextricably linked with the construction of functionally stable information systems with a high degree of autonomy of self-diagnosis (information system is able for some time

autonomously, without any human involvement to diagnose the state of sensors, sensors and other telemetry infrastructure). and betray their function as serviceable equipment).

The built system of adaptive diagnostics is effective and provides functional stability of the information system of Ukrainian enterprises in the metallurgical, energy and chemical industries. Assessment of the state of the information system of the enterprise is carried out by the method of adaptive self-diagnosis. It allows you to detect faults that occur in the modules of the information system in a minimum of time.

In the process of scientific research, the dependence of the probability of information issuance on the time of performing a set of elementary checks was revealed and the correlation for the probability of information issuance was found. It is also investigated that in the information system of the enterprise self-controls are organized by means of elementary checks and occur at arbitrary moments of time of functioning of modules on purpose. Criteria of sufficiency of diagnostic information in the absence of restrictions on performance of elementary checks and in the presence of restrictions on performance of elementary checks are received.

The research results are essential for the design, modernization and integration of existing enterprise information systems into one generalized enterprise information system in order to ensure their high efficiency in the intended operation. The lack of similar solutions in our country and abroad makes research results a priority.

We see prospects for further research in the design of new and improvement of existing models and methods of diagnosing the information system of the enterprise, which is guaranteed to ensure the efficiency of the information infrastructure for some time. At the same time, we will take into account the needs of enterprises operating in the energy sector and actively use information systems that collect, systematize and process large arrays of telemetry data on various aspects of the system 24/7.

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