Integrated information and analytical systems for monitoring technical condition of electromechanical equipment

D A Malov

SPIIRAS, 39, 14 Line of Vasilyevsky Island, St. Petersburg, Russian Federation

E-mail: dmalov@iias.spb.su

Abstract. The presented article shows one of the approaches to the development of the module for monitoring a technical state, diagnostics and an estimation of the residual life of electromechanical equipment. The main tasks and directions of the development of a modern industrial enterprise are integrated information and analytical systems. The developed module is necessary for the formation of maintenance plans for process equipment based on its actual state. The analytical task of the proposed module is the prediction of equipment defects with different delta of a time delay. The block diagram of the equipment diagnostics module allows dynamically changing the depth of the forecast.

1. Introduction

Today the creating an integrated information and analytical system and the infusion of energy-saving technologies are the main tasks and directions for the development of a modern industrial enterprise [1-4].

Today, there is no need to prove the effectiveness of the use of complex integrated automation systems. Many of enterprises are at the stage of development and implementation of such systems, and some of them are already actively using their functionality. The best approach of implementing these systems is a modular approach. Since the process of developing such systems is quite lengthy and implies increasing functionality as their life cycle proceeds. A modular approach implies functionality and new modules added “on the go” to the formed structural basis, expanding the range of tasks solved by this system.

At the enterprises of the mining industry in recent years there has been a trend of a sharp increase in the energy intensity of the final product [5, 6, 10]. Some of the research has shown that this is mainly due to a sharp increase in the number of equipment failures. Moreover, among these failures, more than three quarters of equipment failures are failures of the machine [7-9]. Accordingly, the level of reliability and safety of technological processes is largely determined by their technical condition [11, 14]. In this regard, the actual task of developing the mining enterprise is the creation, development and implementation of special automated equipment diagnostics complexes [13, 15,16]. These complexes allow detecting defect and predicting the duration of the working condition without any equipment maintenance. Moreover these complexes allow making the transition from maintenance according to a schedule to maintenance according to the actual state of electromechanical equipment [8, 12]. In this regard, the development of a module for monitoring a technical state, diagnostics and an estimation of the residual life of electromechanical equipment is one of the urgent tasks being solved in a modern mining enterprise.
The article shows one of the approaches to the development of a module for monitoring a technical state, diagnostics and an estimation of the residual life of electromechanical equipment for an integrated information and analytical system. A description of each stage with an indication of organizational measures and the planned costs of their implementation are shown.

2. Development of a diagnostic module

The purpose of development of the information and analytical system module is formulation of plans for servicing technological equipment according to its real state. The special analytical task is prediction of equipment defects with a different delta of a time delay. This delta can be statically installed or dynamically changed as necessary or according to desired by the enterprise using this equipment.

The scheme of the development and implementation of the diagnostic module should be carried out in several stages, which are shown in Figure 1.

![Diagram of the development and implementation of the diagnostic module](image)

**Figure 1.** The scheme of the development and implementation of the diagnostic module.

Next, we will consider in more detail each of the stages.

3. Formation of the information space for the operation of the system module

The formation and organization of the information space are the first and most important stage of a creation of a diagnostic module.

At this stage, the information field is formed. It includes decisions what kind of information is needed for the system operation, what is its volume, frequency of receipt, how its collection and aggregation is organized, where it is stored and how information is exchanged between different parts of the system [17, 19]. In addition, at this stage, a decision is made on the size and composition of the information array on which the development of analytical modules of the system will be carried out [18, 20].
It is necessary to assess the fullness or sufficiency of the information field of the system. In case the information field is insufficient, it is necessary to take measures to develop special methods for increasing the information field of the system to the required size. For this purpose, special indirect calculations are used, in addition, so-called “Intelligent Sensors” can be used - special modules that allow predicting the values of parameters and solving the problems of reducing of insufficient of information [23, 24, 30].

For the initial development of the structure of the system, an information field should be formed. The information for the system should be listed and divided into classes. The results of this division are presented in table 1.

**Table 1.** The list and classification of information parameters necessary for the operation of the equipment diagnostics module

| №  | Name of the parameter group                                      | Example of the name of the parameters included in this group                                                                 |
|----|-----------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------|
| 1  | Technical characteristics of the machine and equipment          | Activity time, maintenance and services data, machine operation parameters                                                 |
| 2  | Intelligent computing                                          | The relative age of the machine (determining of the percent of the life cycle)                                             |
| 3  | Data on known defects                                           | Defect 1 ... n (a defect is or not, the real value of defects, the value of defects, predicted by the system)              |
| 4  | Technological process data                                      | Speed, loading and other parameters of technological processes                                                              |
| 5  | Direct diagnostic parameters                                    | Current values of current and voltage, instantaneous values of power, leakage currents, etc.                                |
| 6  | Indirect diagnostic parameters                                  | Interturn closures, defective contact joints, interfacial insulation damage, etc.                                           |
| 7  | Calculated parameters of the analytical module                 | The probability of a defect after 5, 15 minutes, 12, 24 hours, 1, 3 months, 1 year                                           |
| 8  | Tuning Parameters and weight coefficients for the implementation of analytical calculations | Weighting factors for the operation of the module subsystems, expert assessments as variables (for the initial system settings), etc. |
| 9  | Parameters of operator's actions (including operatively - technological and service personnel) | Start / Stop equipment, checkback of accidents, defects and other actions                                                   |
| 10 | Additional information for system operation                    | Variables whose value is used to organize information exchange, synchronization of the module and its subsystems, and other parameters |

The formed information field in the conditions of a fully functional system will contain two types of data - historical data and real-time data. In the process of developing testing algorithms, only historical data will be used. In addition, for the formation of algorithms a clustering process should be run that carries out the correlation of parameters to one of the generated classes.

To assess the reliability and timeliness of information, it is necessary to conduct a series of experiments in real-production conditions in real time. Moreover, before carrying out this assessment, it is necessary to organize the process of collecting and storing the information used by the diagnostic module, as well as to properly configure the information exchange with linked systems [25, 29].
4. Development of the structure and algorithms of the system module

At first additional subsystems that allow solving the problems of information insufficiency should be singled out during developing the structure and algorithms of a system module. For the task in question, it is advisable to develop the following subsystems:

- The subsystem estimation of the life cycle of the equipment.
- The subsystem for predicting the development of a defect.
- The subsystem of the intellectual determination of the parameters of the equipment in the period between diagnostics (the subsystem that solves the problem of information insufficient).
- The subsystem of partly forming of the information field of the system from the information database of an enterprise.

For solving analytical tasks by the diagnostic module and taking into account the selected subsystems, a system can be used. The block diagram of this system is shown in figure 2. In addition, there is reason to believe that the graph of power consumption will take the following form:

![Figure 2. Block diagram of the equipment state diagnostics module.](image)

For the operation and development of analytical modules of the system we used various principles among which, according to the authors, it is advisable to use neuro-fuzzy algorithms, algorithms of neural networks and genetic algorithms. The efficiency of these algorithms largely depends on the quality of the information that was the basis for their development. Therefore, when obtaining unsatisfactory results in the process of testing the data of the algorithms for working capacity, it is necessary to make adjustments to the data information space created to ensure the operation of the system.

5. Conclusions

To date, a significant number of methods and methodologies have been developed for monitoring, detecting and diagnosing defects of asynchronous motors. Research in this area must be deepened. It will help to create systems capable of diagnosing each of the defects individually or a combination of several of them when they occur simultaneously. To integrate new diagnostic methods and parameters, it is necessary to create flexible integrated systems. The transition to monitoring the real current technical condition of electromechanical equipment will reduce financial and labor costs in operation, get rid of sudden production stops and rationally plan the timing and content of maintenance and repair. Today, no one doubts the need to equip electromechanical equipment with monitoring and diagnostic
systems, since the probability of detecting developing damages in equipment that is equipped with a diagnostic system is much higher than with traditional types of diagnostics on operating equipment. The integrated information and analytical system for diagnostic and maintenance is a part of the infrastructure in addition to the automated process control system, relay protection, etc. This system necessary to detect technological violations and prevent equipment damage due to the manifestation of defects developing in their nodes and systems.

References
[1] Zhukovskiy Y L, Starshaia V V, Batueva D E, Buldysko A D 2019 Analysis of technological changes in integrated intelligent power supply systems. Innovation-Based Development of the Mineral Resources Sector: Challenges and Prospects 11th Conference of the Russian-German Raw Materials 249-258
[2] Abramovich B, Sychev Y 2016 Problems of ensuring energy security for enterprises from the mineral resources sector. Zapiski Gornogo Instituta - Journal of Mining Institute, 217(1) 132-139
[3] Abramovich B N and Sychev Y A 2016 Energy Safety of Technological Processes of Oil Extraction Neftyanoe Khozyaystvo - Oil Industry 9 120-123
[4] Malarev V I, Kopteva A V, Nogtev R A 2018 Electric Drive Simulation for Drilling Machine Spinner. IOP Conference Series: Earth and Environmental Science 194(5) 052012
[5] Malarev V I, Kopteva A V, Nogtev R A 2018 Electric Drive Simulation for Drilling Machine Spinner. IOP Conference Series: Earth and Environmental Science 194(5) 052012
[6] Zhukovskiy Y, Malov D 2018 Concept of Smart Cyberspace for Smart Grid Implementation IOP Conf. Series: Journal of Physics 1015(4) 042067
[7] Vasilev B U, Grigorev P S, Shulgenko V M 2018 Configuration and energy supply of promising types of underwater pumping complexes for transportation of hydrocarbons from the shelf. Neftyanoe Khozyaystvo - Oil Industry 3 77-81
[8] Vasilev B U 2017 Factors of environmental safety and environmentally efficient technologies transportation facilities gas transportation industry. IOP Conference Series: Earth and Environmental Science 50(1) 012003
[9] Leonidovich Z Y, Uriievich V B. 2015 The development and use of diagnostic systems and estimation of residual life in industrial electrical equipment. International Journal of Applied Engineering Research 10(20) 41150-41155
[10] Saveliev A, Malov D, Tamashakin M, & Budkov V. 2017 Service and multimedia data transmission in IoT networks using hybrid communication devices MATEC Web of Conferences. – EDP Sciences 113 02010
[11] Kazanin O I, Sidorenko A A, Sementsov V V 2014 Determination of technology parameters of the thick steep gassy seams mining with sublevel caving and coal discharge mining system. Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu 6 52-58
[12] Kazanin O I, Sidorenko A A, Vinogradov E A 2017 Substantiation of the technological schemes of intensive development of gas-bearing coal beds ARPN Journal of Engineering and Applied Sciences 12 (7) 2259-2264
[13] Novoseltseva M V, Masson M V, Pashkov E N, 2016 Investigation of Input Signal Curve Effect on Formed Pulse of Hydraulic-Powered Pulse Machine Novoseltseva IOP Conference Series: Materials Science and Engineering 127(1) 012007
[14] Vasilev B Y, Van Tung L, Ikukena D 2018 Research on the Switching Algorithm of Voltage Vectors in the Direct Torque Control System. International Russian Automation Conference (RusAutoCon) Sochi 1-7
[15] Zhukovskiy Y, Korolev N, Koteleva N 2018 About increasing informativity of diagnostic system of asynchronous electric motor by extracting additional information from values of consumed current parameter Journal of Physics: Conference Series 1015(3) 032158
[16] Boikov A V, Saveliev R V and Payor V A 2018 DEM Calibration Approach: design of experiment
[17] Kosarev O V, Tsvetkov P S, Makhovikov A B, Vodkaylo E G, Zulin V A, Bykasov D A 2019 Modeling of Industrial IoT complex for underground space scanning on the base of Arduino platform. Topical issues of rational use of natural resources 407-412

[18] Vasileyeva NV, Fedorova E R, Koteleva N I 2018 Real-time control data wrangling for development of mathematical control models of technological processes. Journal of Physics: Conference Series 1015(3) 32067

[19] Vasilyeva N V, Fedorova E R 2018 Statistical methods of evaluating quality of technological process control of trends of main parameters dependence. Journal of Physics: Conference Series 1118(1) 012046

[20] Palyanova N V, Zadkov D A, Chubukova S G 2017 Legal framework for the sustainable economic and ecological development in the coal industry in Russia. Eurasian mining 1 3-5

[21] Gabov V V, Zadkov D A 2017 Peculiarities of stress field formation during cutting isotropic material by mining machine cutters. IOP Conf. Series: Earth and Environmental Science 87(2) 22007

[22] Vasilyeva, N., Koteleva, N. and Ivanov P 2018 Quality analysis of technological process control. International Journal for Quality Research 12(1) 111-128.

[23] Boikov A V, Savelev R V, Payor V A 2018 DEM Calibration Approach: Random Forest, Journal of Physics Conference Series. 1118 012009

[24] Zhukovskiy Y, Koteleva N 2017 Method of data storing, collection and aggregation for definition of life-cycle resources of electromechanical equipment. IOP Conference Series: Earth and Environmental Science 87(3) 032057

[25] Siziakova E V, Ivanov P V, Boikov A V 2019 Application of calcium hydrocarboaluminate for the production of coarse-graded alumina, Journal of Chemical Technology and Metallurgy. 54 1 200-203

[26] Siziakova E V, Ivanov P V, Boikov A V 2018 Hydrocarboaliminate calcium application in aluminum processing for production of special cement brands, Journal of Physics Conference Series. 1118 012018

[27] Safina, E., Khokhlov, S. Paradox of alternative energy consumption: lean or profligacy? 2017 International Journal for Quality Research 11 (4) 903-91

[28] Khokhlov, S., Safina, E., Vasilyev, V2018 Risk-oriented approach implementation in departments ranking and teaching staff motivation International Journal for Quality Research, 8 (8) 39-47

[29] Heilig A, Mamaev I, Hein B and Malov D 2018 Adaptive particle filter for localization problem in service robotics. 13th International Scientific-Technical Conference on Electromechanics and Robotics "Zavalishin's Readings" MATEC Web of Conferences 161 01004