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VBA BASIC-BASED PREDICTIVE MAINTENANCE SYSTEM (PdM): A NEW APPROACH TO MONITORING ELECTRIC MOTORS IN COMMERCIAL FACILITIES IN UKRAINE

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Abstract. *The rapid development of modern technologies is primarily aimed at ensuring the uninterrupted and reliable operation of strategically important equipment for the production and maintenance of critical infrastructure productivity against the backdrop of today's crisis challenges. Predictive maintenance, which aims to preventively protect mechanisms and machines, is positioned as key to maintaining equipment performance, reducing potential downtime, and increasing overall equipment reliability. The purpose of the study is to conduct a comprehensive analysis of the key concepts of the predictive maintenance (PdM) system for electric motors. The article focuses on the potential of PdM in the process of monitoring the operation of electric motors in commercial facilities in Ukraine. The basic approaches, challenges, and advantages of predictive maintenance systems are considered. Individual practical cases of their application are analyzed. It is substantiated that PdM, as a way of qualitatively applying information obtained from machine learning algorithms, sensors, and monitoring systems, allows for the preventive prediction of the moment when equipment maintenance becomes necessary, which contributes to the timely prevention of critical breakdowns, minimization of downtime, and repair costs. The feasibility of using PdM systems in the energy sector of Ukraine to monitor the technical condition of generators, turbines, and electric motors (in particular, by analyzing temperature and vibration) to identify anomalies in operation and prevent potential emergencies, thereby increasing the reliability of power supply systems, has been proven. Based on a review of modern predictive methods based on the processing of information from measuring transducers (temperature sensors, vibration and acoustic sensors, voltage indicators, electromagnetic transducers) using machine learning methods, the necessity of applying predictive control methods for electric motors in real commercial facilities in the realities of the Ukrainian power system has been proven.*

Keywords: *predictive maintenance (PdM) systems, power system, preventive protection, risks, monitoring, technical condition, electric motors.*

Introduction

During the operation of electromechanical units, their technical characteristics may change, which can lead to equipment failure. Like all electromechanical equipment, electric motors are subject to a variety of adverse influences, such as mechanical damage, thermal and environmental loads, which require maximum attention, as any unplanned downtime of machines or systems can disrupt or interrupt the core activities of a manufacturing company, potentially leading to significant fines or loss of reputation.

Existing traditional approaches to maintenance, in particular, planned maintenance or reactive maintenance, suffer from certain assumptions and limitations, such as high costs of failure prevention or repair, inadequate or inaccurate calculations of the degradation process, and others. In connection with the popularization of the trend towards the development of intelligent manufacturing, machine data analysis, and the integration of artificial intelligence into all spheres of life and production, predictive technical control should be considered as a fundamentally new type of electrical equipment maintenance, including monitoring functions, technical condition assessment, and decision support systems based on machine learning. In the context of the crisis situation in Ukraine's energy system during wartime, the possibilities for large-scale use of predictive maintenance systems require further research.

Literature Review

The subject of the study is a topical issue in contemporary scientific discourse. In particular, publications by S. Moosavi et al. [1], L. de Oliveira et al. [2], L. Wang et al. [3], and O. Lyashenko et al. [4] are devoted to the basic issues of diagnostic system design, specific methods of fault diagnosis, and prediction of failure times of electromechanical units based on the processing of information from measuring transducers using machine learning methods. The combination of these methods is called predictive maintenance, which includes collecting data for analysis and allows repairs to be carried out when necessary.

Analyzing primary information diagnostic systems, authors L. Ehrig et al. [5], J. Campos et al. [6], and A. Bousdeki et al. [7] emphasize that the data arrays obtained from the sensors are pre-processed, after which the functions of recognition, cleaning and restoration of data, and classification of defects in real time are performed. As a rule, comprehensive fault diagnostics are implemented in two directions: detection of mechanical and electromagnetic defects in the unit.

Scientists O. Zhurylo et al. [8], S. Krawczyk, M. Szuba [9], P. Muneeshwari et al. [10] argue that modern predictive maintenance systems make it possible, on the one hand, to minimize resource costs for scheduled equipment maintenance and, on the other hand, to reduce the risks of unscheduled downtime of electromechanical

equipment, which could potentially be caused by unexpected breakdowns. However, despite the considerable attention paid by scientists to modern PdM systems, a number of issues remain unresolved.

The purpose of the study is to provide a general overview of existing approaches to the diagnosis and prediction of faults in predictive technical control systems for monitoring electric motors in commercial facilities in Ukraine.

Research Results

Modern predictive maintenance systems use a number of methods, including analysis of vibration signals from electrical equipment, which can indicate the onset of wear or impending failure; acoustic analysis of sound signals; thermal imaging identification of anomalies in temperature characteristics; and analysis of the composition of lubricants, which indicates the presence of contamination or worn parts, etc. [11]. Machine learning algorithms play a key role in PdM, as they enable the creation of models that accurately predict when maintenance will be required for equipment. The key algorithms currently in active use are time series analysis and regression analysis.

The entire predictive maintenance system is aimed at implementing certain functions, including reducing equipment downtime, increasing equipment reliability by eliminating breakdowns before they become critical, reducing overall equipment repair and maintenance costs, and optimizing the use of resource potential [12].

However, the use of PdM comes with a number of challenges and limitations. In particular, these include the need to collect and analyze large amounts of data in real time from monitoring systems and sensors. This situation necessitates the use of specialized algorithms and powerful computing resources. Another challenge is the reliability of machine learning models to ensure high prediction accuracy, as even minimal errors can lead to unreliable predictions. Integrating PdM with existing production systems can also be a difficult task.

It is worth noting the high cost of implementing reliable PdM systems, which may require significant investment. At the same time, the cost of high-quality equipment for information accumulation, monitoring systems, and the development of machine

learning algorithms can be justified by convincing long-term benefits [13].

A modern solution in the field of predictive maintenance of electric motors is the use of PdM based on VBA BASIC. In particular, with the help of VBA BASIC, it is possible to successfully integrate predictive maintenance measures directly into a specific machine or system. In particular, MES functional blocks encapsulate functions that continuously monitor the status and number of status changes of individual units and entire installations. The time until the next maintenance is also calculated on an ongoing basis based on specified parameters. In addition to this basic functionality, additional individual parameters can be included: for example, the power factor can be taken into account for machines that do not always operate at the same power [14]. Thanks to the consistent and comprehensive combination of all data from predictive maintenance and condition monitoring, it is possible to achieve an innovative intelligent maintenance system.

In addition to predictive maintenance information, VBA BASIC can integrate and display more key values in parallel with maintenance data. For example, constant overall productivity or information about smart meters to optimize the use of energy and other resources. Each VBA BASIC system typically has an integrated web interface, so all machine, production, and maintenance data can be easily displayed on any mobile device and accessed in real time [15]. Many functions are available in VBA BASIC as functional blocks that can be quickly and easily integrated and parameterized. In addition to mobile access, notifications can also be set up to inform the responsible employee or department by email or text message when predefined threshold values are reached [16].

It can be argued that the monitoring of electric motors in modern commercial facilities can be effectively modernized with the help of this system. The prospects for digital optimization of such a predictive maintenance system are seen primarily in:

- the development of the Internet of Things (IoT), which makes it possible to increase the number of connected devices that function and transmit information in real time, ensuring greater accuracy of information and forecasting;

- the integration of artificial intelligence and augmented reality tools to create more complex models for multi-factor data analysis and forecasting;
- the use of cloud technologies to process large amounts of information, which potentially reduces costs and facilitates access to data;
- Development of cyber-physical systems (CPS) that combine physical and cybernetic components for integrated monitoring and control of production processes;
- Creation of digital twins – accurate virtual models of physical objects or systems that allow potential problems to be identified and their development to be predicted;
- integration with enterprise resource planning (ERP) systems for uninterrupted production;
- use of blockchain technologies to ensure data transparency and security in PdM.

The process of implementing a new approach to monitoring electric motors in commercial facilities in Ukraine must take into account a number of specific features and a certain phased approach. In particular, the following aspects are essential:

1) preliminary assessment of the readiness of the production facility, the level of digitalization, and the readiness of personnel; the development of a long-term strategy for the implementation of PdM should include planning the stages of implementation, defining key objectives and performance metrics, and developing action plans to achieve the set goals for greater consistency and continuity of the PdM implementation process;

2) selecting the appropriate equipment for collecting the necessary data, compatible with existing systems at the facility;

3) Development of machine learning models, including the selection of algorithms and model tuning for maximum analysis and forecasting accuracy.

4) Integration of PdM with the production and information systems operating at the facility to establish effective information exchange, training of personnel to work with new equipment and software.

5) Regular monitoring and evaluation of the effectiveness and accuracy of analysis and forecasting processes, identification of potential problems for making adjustments to processes for greater reliability of forecasting; performance measurement should include analysis of key performance indicators – reduction of repair costs, reduction of unplanned downtime, increased productivity, etc.

6) ensuring the security and protection of confidential data using modern methods of multi-factor authentication, blockchain, encryption, and security audits;

7) standardization of data collection and analysis procedures to achieve high consistency and quality of work, integration of new technologies and solutions, including the use of international standards of ISO, IEC, and other international organizations [17] that regulate the requirements for data collection, analysis, and storage;

8) increasing the social responsibility of commercial facilities by supporting sustainable development and minimizing negative environmental impact;

9) compliance with regulatory requirements and adaptation to industry requirements for equipment maintenance and monitoring.

One of the key advantages of PdM is its adaptability and flexibility. It is evident that the operating parameters of commercial facilities are subject to change under the influence of various factors, so it is important to ensure that the predictive maintenance system can take these changes into account. This requires regular upgrades of machine learning models, integration of new technologies, and sensor configuration.

Global trends in the automation of production processes, total digitalization, and the development of artificial intelligence are contributing to the introduction of PdM in the energy sector. In addition, PdM contributes to the environmental sustainability of enterprises and optimizes supply chains: minimizing the number of unplanned breakdowns and downtime contributes to the stability of production processes, strengthening relationships with suppliers, and faster technology development.

Innovation and experience sharing are key factors in the successful implementation of predictive maintenance systems. An innovative approach allows for the improvement of machine learning models, the implementation of advanced

monitoring technologies, and increased competitiveness. At the same time, forming collaborations with other companies that successfully integrate PdM allows for the assimilation of resource potential and knowledge to achieve maximum results.

Conclusions and Prospects for Further Research

Currently, there is a shift from traditional approaches to the maintenance of electromechanical systems in the form of breakdown or scheduled maintenance to predictive maintenance. An overview of various aspects of the implementation and operation of modern predictive maintenance systems allows us to insist on the enormous potential of PdM to reduce downtime and increase equipment reliability, minimize repair and maintenance costs, and improve the overall efficiency of production processes. At the same time, the implementation of PdM requires significant investment and careful preparation, as well as the integration of new digital tools into existing processes.

With the development of artificial intelligence, the Internet of Things, and cloud solutions, the capabilities of PdM will only multiply, ensuring stable and reliable equipment operation, increasing the accuracy of forecasting and the effectiveness of preventive protection. It can be argued that maintenance forecasting systems in the modern context should be viewed not only as technologies, but as a strategic approach that enables commercial entities to successfully adapt to the dynamics of market conditions, maintaining competitive advantages and achieving new opportunities in the reliability and efficiency of production processes in complex crisis conditions.

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