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DESIGN PECULIARITIES OF MULTI-LEVEL SYSTEMS FOR TECHNICAL DIAGNOSTICS OF ELECTRICAL MACHINES

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Abstract: The main goal of the paper is the development of structure of intelligent distributed multi-level system for technical diagnostics of electrical machines. The system implements the following principles: distribution of computational resources among different levels of the system to provide required periodicity of measurements and signal processing; structuring of the diagnostic information on hierarchical principle; classification of the diagnostic information in accordance with its importance for the optimization of information exchange.

Key words: electrical machine, multi-level system for technical diagnostics.

1. Introduction

Different types of electrical machines are the most common type of electric power equipment used in almost all sectors of the economy. Today the vast majority of powerful electrical machines in operation in Ukraine have been worn out. Nevertheless, taking into account the financial capabilities of the state, most of the obsolete equipment is still in use. This leads to a need for the development of special means that would give an opportunity to assess and maintain the proper level of reliability of the electrical equipment in use. One of the possible ways to solve this important problem is creation and implementation of the systems for technical diagnostics of electrical equipment.

Research towards the creation of methods and systems for technical diagnostics of electric power equipment has been conducted at the Institute of Electrodynamics since the late 70s – early 80s of the XX century. They were started under the leadership of DSc B.H.Marchenko following the idea of Academician of NAS of Ukraine H.H.Schastlivyi.

The task of improving the reliability of various energy facilities, electrical machines in particular, was (and still remains at the present time) extremely important because a large number of machines that were in operation, were approaching exhaustion of their service life. The use of the traditional reliability theory approach, the main characteristic of which is to experimentally evaluate the probability of faultless operation grounding on the operating experience of a large number of similar objects turned out to be almost impossible. This is because it is quite difficult to gain statistics on failures for high power equipment (compared to, for example, mass electronic equipment), as powerful electrical facilities are mostly unique. Therefore, it was necessary to find completely new ways to solve the problems of software reliability.

That time, a set of objectives have been formulated, that had determined the research direction for several generations of the Institute scientists: acquisition, transfer and further processing of the information carried by the physical processes that accompany work of the equipment and reflect its actual technical state.

The progress of the research in this direction took place in several stages – from the development of the analogue electronic devices in the 1980s able to process only relatively slow processes (temperatures and vibrations of static parts of the electrical machines) to the digital systems built on modern computing components able to work with a wide range of diagnostic signals, to receive data from the moving parts of the equipment, and to implement complex algorithms for signal processing.

Modern electric power industry, taking into account the transition to smart grids, requires the development of integrated multi-level control systems, which ensure a high level of automation and reliability of the whole power system, including power producers, transmission and distribution networks, consumers etc. [1]. On this account, obtaining up-to-date information on the actual state of each energy facility and exchanging this information with all participants of the electricity market takes an important place. All this taken together enhances the reliability of the whole power system [2].

Thus, one of the key tasks set before the power industry today is the development of methods and means of technical diagnostics [3, 4] capable of performing a deep on-line diagnosis of electric power devices, and providing generalization of such diagnostic information, extraction of the information which is critical for the system as a whole, and its further transfer to a higher level of hierarchy.

This task can be fulfilled by the creation of an intelligent distributed multi-level system for technical diagnostics of the electric power equipment the basis principles of which are:

– decentralization of computing resources to provide a required frequency of acquisition and processing of the diagnostic signals;

– gathering of diagnostic information according to the hierarchical principle;

– classification of diagnostic information according to the degree of criticality to optimize the dataflows between hierarchical levels of the system.

Implementation of such a system into a power utility will provide accurate and timely detection of failures of all its critical devices due to the continuous deep diagnostics of their actual state. Besides it will allow the service personnel to be timely informed on the location and type of the defects detected, and the summarized information concerning the actual state of the equipment to be transferred to the higher level of hierarchy for quick response [4]. Finally, the system will enable to increase the reliability of the power system as a whole, to provide electricity of high quality that is an important prerequisite for the integration of the Ukrainian power system into the unified European system.

In terms of the above-stated, the purpose of this paper is to develop a structure of the intelligent distributed multi-level system of technical diagnostics of electrical machines, which complies with the concept of Smart Grid and provides for the integration into the intelligent networks.

2. Requirements to modern systems of technical diagnostics of electrical machines

The concept of Smart Grid involves the active engagement of consumers and suppliers, as well as the decentralization of system management to ensure the highest quality of electricity supplied to the consumers [3]. The key factor to achieve this aim is the increase in the reliability and controllability of all elements of the power grid. This changes accents in the approach to the maintenance of electrical equipment [1, 4].

In particular, the traditional approach to the equipment maintenance is based on the so-called “preventive maintenance”, and the technical diagnostic tools are used mainly for finding defects immediately after outage of the equipment. The highly important facilities are equipped with their own monitoring systems, which provide alarming in case of emergency, but do not have sufficient means to detect, classify and localize defects.

The Smart Grid concept assumes that maintenance and repairs should be carried out based on actual state of the equipment. To implement this, a much larger part of the equipment must be provided with special systems for continuous or periodic monitoring of the actual technical state [1]. In addition, those systems themselves should provide more functions: bidirectional exchange of information at all levels, remote monitoring, failures forecasting, planning of need for spare parts, evaluation of the residual life of equipment, etc. Distribution of computing among different levels plays an important role in the implementation of those functions [5].

It is known that any complex technical object can be considered as a certain hierarchical structure [6, 7]. For example, let us consider a conventional fragmentation into several hierarchical levels while diagnosing particular construction parts of an electrical machine (Fig. 1).

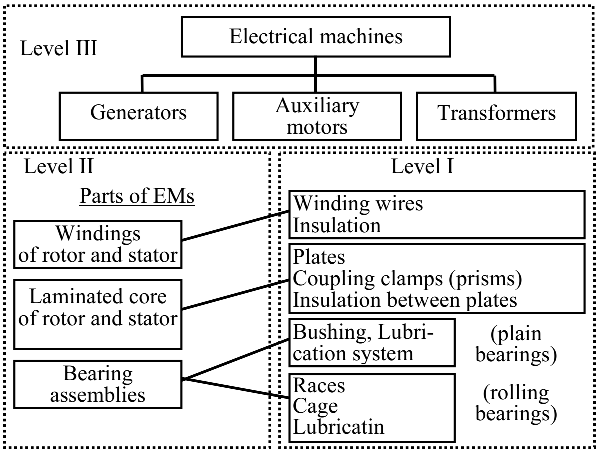

Fig. 1. Hierarchy of construction parts of electrical machines.

The first level is formed by the construction parts of the electrical machines. This level determines a set of possible defects in the equipment. Deep studies of the elements located on the first level of the hierarchy provide all the necessary information about types, reasons, and symptoms of the defects. As a result of that analysis, the diagnostic models are built and the diagnostic signals and parameters are chosen [7].

The second level represents components that are structurally a unit. These include, for example, stator and rotor windings of rotating machines, magnetic cores, bearing assemblies, a frame, a cooling system etc.

The third level is the electrical machine as a whole: generators, auxiliary motors, transformers, pumps etc.

The development of the diagnostical system for electrical machines capable to detect all possible defects and their combinations is an extremely difficult technical challenge. The cost of such a diagnostical system can exceed the cost of the main equipment. Thus, it can even lose a sense from an economic point of view. This raises important questions to be disposed when developing the diagnostical system: which elements of the object under diagnosing are critical for proper operation of the equipment, and which are not. So, at the stage of the system's structure design, the constructor should clearly define the list of defects which must be detected by the system and identify the units of the equipment, in which those defects may emerge.

Obviously, any diagnostical system is sure to detect catastrophic defects as they have a distructive influence on the operation of the equipment. However, some non-catastrophic or partial defects can be left out of the system's sight. This approach to the development of the system makes it possible to simplify its structure and reduce the amount of information which is processed in the system and transferred between its hierarchical levels. In this way, the overall system's price can be reduced, and available computing resources can be reallocated to perform more critical functions.

3. Structure of an intelligent multi-level distributed system of technical diagnostics of electrical machines

Let us discuss the main components of the diagnostic system and their functions.

First of all, the system should include sensors of the physical quantities under measurement. Depending on the object to be diagnosed, these can be thermocouples or thermistors – to measure temperature; accelerometers – to measure vibrations; measuring microphones – to determine the level of acoustic noise; various sensors of electrical parameters (instrument transformers, shunt meters) – to determine the electrical parameters and accounting of power.

Modern diagnostical systems are based on digital computing means (microcontrollers, personal computers, industrial workstations). For the diagnostic system, which must comply with the basic principles of the Smart Grid concept, this requirement is mandatory because digital information exchange is performed. Thus, the measured signals must be converted into digital form for further processing by computing facilities. To do this, the signals from sensors must pass a pre-processing: conversion to some uniform voltage range and selected frequency band.

In some cases (mainly for compatibility with pre-installed diagnostical systems), it can make sense to separate functions between different devices: the measuring and pre-processing of data can be made directly on the metering points, and converting into digital form – in a single unit allowing switching of a number of analog channels.

However, in most cases, when developing the diagnostic systems based on modern components, it is reasonable that all the above features be combined in a single functionally completed device that has a digital interface for two-way exchange of information. As an input, it has to accept control commands, as an output – to provide samples of the measured diagnostic signal in some standardized form. This interface can be either wired (based on RS232, Ethernet, USB standards) or wireless (based on Bluetooth, Wi-Fi, ZigBee standards).

For a further data analysis and making diagnostic decisions, the measured and converted to digital form signals are transmitted to the computational kernel, which, depending on the particular needs, can be either a microcontroller or a modern high-speed computer.

To display the results of diagnosing, the structure of the system must include appropriate tools that, in particular, should provide authentication of the system's users, control of access rights, data protection.

Diagnostical systems for complex objects can measure a large number of diagnostic signals, leading to the exchange of a huge amount of information between the system components. To reduce the load on the communication channels (especially when using wireless data links), decentralization of computing resources may be useful that is one of the principles of the Smart Grid concept. This is fulfilled as follows: the measured samples of a diagnostic signal are not directly transmitted to the computational kernel but are processed in a simplified way in the module responsible for their measuring. Further, depending on the results of the preliminary analysis, this module decides what information can be provided to the computing core. The following cases can be considered:

– do not send any information – if no deviation from the normal state was detected;

– give a warning signal – if non-significant deviation was found;

– provide a measured implementation to the computational kernel for a full analysis – if the deviation detected can be considered significant;

– set an alarm for immediate response – if critical deviation is found.

To be able to perform all the above functions, the module for measuring and processing of diagnostic signals must have its own computing core and software.

It should be noted that taking into account the severity of defects at the design stage of the system makes it possible to simplify its structure and reduce the amount of information processed in the system and transferred between the hierarchical levels, which can ultimately reduce the system's cost while maintaining its functionality at a required level.

The distribution of functions between the hierarchical levels can be implemented as follows:

Level I – pre-selection and preparation of diagnostic signals (measuring of diagnostic signals, their amplification, filtering, and conversion to digital form);

Level II – preliminary signal processing and making intermediate diagnostic decisions (simple algorithms the implementation of which does not require significant computational resources, the classification of information according to the criticality of defects); signaling a higher level in case of defects; accumulation of small amounts of measurement data and transfer it to a higher level (by request);

Level III – storing, processing and full-depth data analysis, rapid response to alarms of lower-level components, making diagnostic decisions on the state of the facility in general, statistical data archiving, reliability prediction and assessment of the residual life of equipment, planning of repair works; presentation of data to users.

Taking into account all the above considerations, the structure of the diagnostic system is shown in Fig. 2.

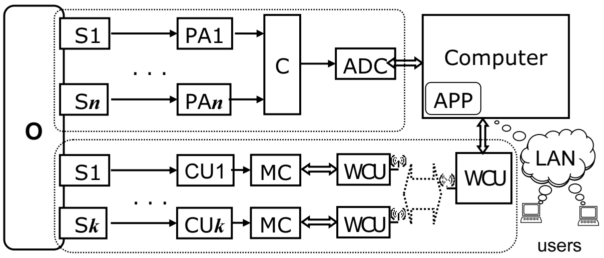

Fig. 2. Structure of an intelligent distributed multi-level system for technical diagnostics of electrical machines: O – the equipment to be diagnosed; S – the sensor; PA – the preamplifier; C – the commutation devise; ADC – the analog-to-digital converter; CU – the conversion unit; MC – the microcontroller; WCU – the wireless communication unit; APP – the application package for data analysis, diagnostic decision making, assessment of residual life; LAN – the local area network.

6. Conclusion

Systems for technical diagnostics and condition monitoring help to increase reliability and controllability of power grid components which are the determining factors to ensure high quality of power supply. In order to achieve this goal, the structure of the diagnostic systems must be built on hierarchical principle and consist of at least 4 levels, which perform the functions described in this paper.

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ОСОБЛИВОСТІ ПОБУДОВИ БАГАТОРІВНЕВИХ СИСТЕМ ТЕХНІЧНОЇ ДІАГНОСТИКИ ЕЛЕКТРИЧНИХ МАШИН

Михайло Мислович, Роман Сисак

Розроблено структуру інтелектуальної розподіленої багаторівневої системи технічної діагностики електротехнічного обладнання, яка реалізує такі принципи: розподіл обчислювальних ресурсів між різними рівнями для забезпечення необхідної періодичності вимірювань та обробки сигналів, групування діагностичної інформації по ієрархічному принципу, класифікація інформації за критичністю для оптимізації інформаційного обміну.

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