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BLACK BOX FOR ELECTRICAL MACHINES

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SUMMARY

This article describes a specific monitoring system for electrical machines, called black box for electrical machines (Electrical Machines Black Box, EMBB).

Detailed analysis about problems of harmful working conditions that can occur on all electrical machines has been made. Based on these data and on measurement and control of various parameters such as voltage, current, temperature, vibration, black box detects and records the following harmful working conditions: asynchronous operation, incorrect synchronisation, significant asymmetry, two-phase operation, run-out (over-sped), overloading, excessive heating of stator iron and/or stator winding, excessive vibrations of the generator housing. In addition to these harmful working conditions, EMBB system records the number of machine starts, which also represents vital information that significantly affects the machine lifetime.

EMBB system is realised as a combination of measurement sensors, programmable processing unit associated with measuring modules and application program that manages the process unit. EMBB modular type design enables additional system extensions.

KEYWORDS

monitoring, electrical machine, synchronous generator, black box

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1. INTRODUCTION

Production of electrical energy according to the requirements of the power system is the basic task of each power plant and permanently making a profit is the main goal of their respective owners. Electrical power system is the backbone of modern technical civilization and today's economy. One cannot imagine functioning without stable, uninterruptable supply of electric energy that is needed both in industry and in most areas of our private lives. The users of electric energy treat it sometimes as granted, considering it as a primary good and even as one of the human rights [2]. According to its importance this system has to be maintained, controlled and protected against possible faults and other abnormal phenomena.

A key issue in the operation of all machines is the proper and reliable work, which in economic terms is a maximum financial benefit and staying within technical constraints. Moreover, the capital investment required for equipment often necessitates high levels of availability to ensure a reasonable rate of return [2]. Thus, the minimization of operational costs resulting from unplanned downtimes, unnecessary maintenance and a reduction of the system capabilities has become a core objective of industry.

In order to enable better asset management and also to protect capital investments, monitoring system called “Electrical Machines Black Box” (EMBB) has been developed. Name Black Box was chosen because of similarity in purpose of this system with an airplane black box, which helps investigators uncover the causes of aircraft accidents. Therefore, the device was named Black Box in order to be recognizable to the users. In the case of fault, failure or operation under harmful working condition, recorded informations can be used to determine the causes.

The aim of this paper is to show how data measured, calculated and stored by Black Box can extend the life-time of the machine and give manufacturers and users of the machine insight in useful information during machine work period that can help in better asset management.

2. BACKGROUND AND MOTIVATION

The detection of machine fault conditions is of great significance. With the appropriate machine monitoring and fault detection system early warning signs can be obtained for preventive maintenance, improved safety, and improved reliability of electrical machines. Faults can produce machine shutdown, economic and time losses, and even human casualties. Early, fast and accurate detection and diagnosis of fault conditions is critical in preventing major damage.

Based on many years of experience in the analysis of failures and continuous monitoring systems for electrical machines, and constant cooperation with manufacturers and users of power equipment, a development of specific monitoring system was initiated.

Today, the power systems are equipped with various monitoring systems used for condition monitoring of the most important equipment. Different parameters are measured and presented to the users as current values, or used for numerous calculations and database storage. For the data collected in this way an expert analysis is necessary in order to obtain informations useful to the end user. EMBB system uses a different approach in which only the most relevant informations are displayed to the users.

In cooperation with the manufacturers of power equipment, and by numerous analyses and experiences, the most important parameters that need to be measured are chosen to be able to make conclusions about the operation of the machine and various harmful conditions through which the machine goes during its use as part of a complex power system.

The purpose of the EMBB system is dual:

1) After the occurrence of a malfunction or possible damage, EMBB system is used to determine whether and to what extent the machine was operating under harmful working conditions, which could lead to failure. For electric machine manufacturers this is crucial, especially within the warranty period of machine usage. In the case of reclamation, with EMBB system it can be easily determined whether the machine was operating outside of the parameters determined by contract. In such cases the manufacturer could refuse the request for the reclamation.

2) Another important purpose of EMBB system is to enable users of electrical machines insights into all harmful and fault conditions during machine operation, recorded by EMBB system. By reviewing all recorded data the machine users can conclude that some operating procedures are wrong or that certain part of the system are failing during operation. Based on those findings machine users could made corrective measures which would greatly contribute to the reliability and availability of the entire system.

3. HARMFUL WORKING CONDITIONS EMBB SYSTEM DETECTS

EMBB system was originally designed for synchronous machines, but similar system can be applied to other machine types as well. With EMBB system the following harmful working conditions can be detected: asynchronous operation, incorrect synchronization, significant asymmetry, two-phase operation, run-out (over-speed), overloading, and excessive heating of stator iron or stator winding and excessive vibration of the generator housing (fig. 1). These non-standard conditions represent a significant electromagnetic and thermal stress for the machine, which greatly reduces its lifetime.

In addition to these harmful working conditions, EMBB system records the number of machine starts, which also represents vital information that significantly affects the machine lifetime.

Short description of harmful working conditions which EMBB system detects:

1. **Asynchronous operation** is a machine's condition, which can occur if excitation current is for some reason terminated, in the machine that is loaded and connected to the power grid. In that case the rotating magnetic field changes direction, the machine shifts from generator to motor operation causing extremely high currents in the stator winding. The amplitudes of these currents may be similar to those in short circuit, which represent risks to machine lifetime.

2. **Incorrect synchronization** is a machine's condition, which can occur during machine and power grid merger. This condition is a result of failure to fulfil all the rules of synchronization.

3. **Significant asymmetry** implies difference between phase currents which are larger than those specified by machine characteristics or by the contract.

4. **Two-phase operation** represents a machine's condition in which two phases of stator winding are loaded while the remaining third phase is unloaded. This condition represents significant asymmetry and significantly influences machine lifetime.

5. **Run-out** implies that the machine speed exceeded the rated speed of rotation, which in most cases is defined as the speed 20% higher than the rated speed [3]. This parameter is defined separately for each machine, depending on the type of turbine, regulation protection, and implementation project. Number of run-outs significantly affects machine lifetime.

6. **Overloading** represents a machine's condition where the stator current is above the rated or those agreed with contract.

7. **Overheating** of the stator iron or winding may be a result of overloading or operating during certain machine fault. The boundaries are defined by standards [3] and implementation project of each machine.

8. **Extensive vibrations** may be a result of overloading or operating during certain machine fault. The boundaries are defined by standards [3] and implementation project of each machine.

All limit parameters are entered in the system respecting current standards [3], implementation project, and in agreement with the buyer. Depending on the particular machine and operating conditions, parameters can be changed.

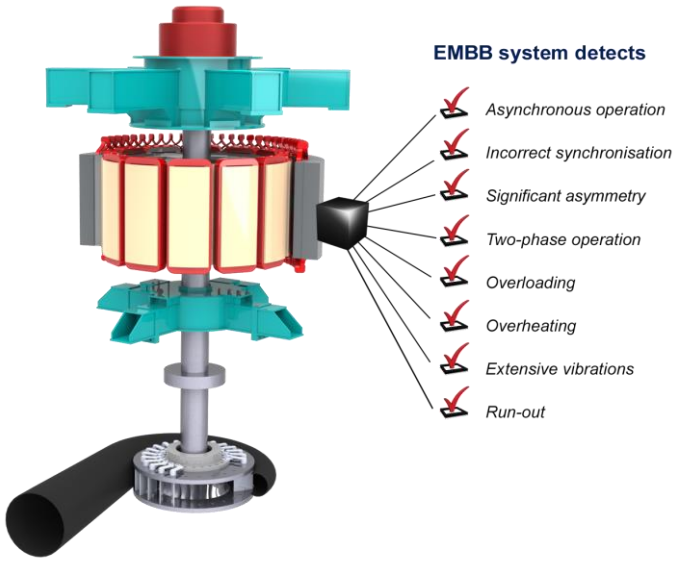

Fig. 1. Harmful working conditions EMBB system detects.

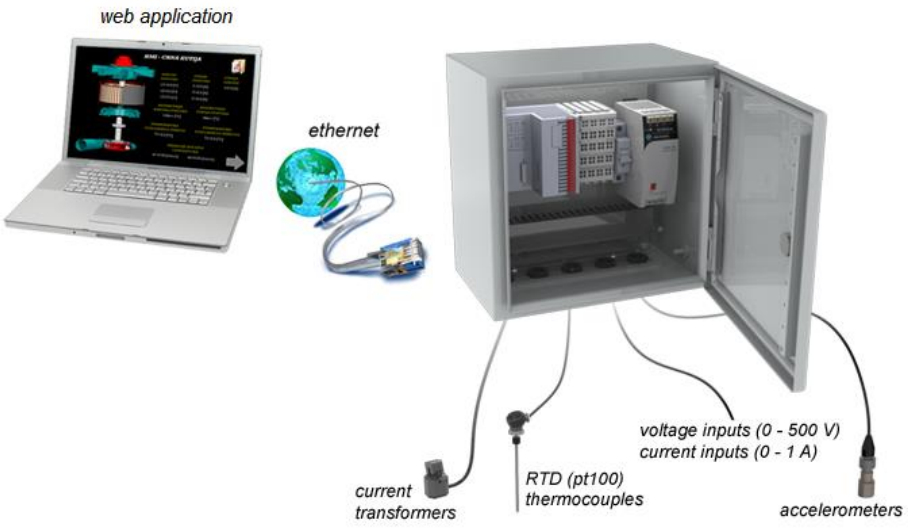

Fig. 2. EMBB system concept and design.

EMBB SYSTEM CONCPET AND DESIGN

EMBB system is realized as a combination of measurement sensors, programmable processing unit associated with measuring modules, application program that manages the process unit and necessary wiring (fig. 2).

Processing unit is a fast and reliable industrial PLC, designed for harsh conditions and environments. It has all the necessary certificates and references to use with electrical machines. Important advantage of the EMBB system is modularity. In combination with PLC there are various measurement modules, so the system can be easily adapted to customer requirements. Fast and reliable EtherCAT (Ethernet for control automation technology) communication, a real-time Ethernet technology from equipment manufacturer provides the EMBB system with outstanding performance, flexible topology and simple configuration.

Important part of the EMBB system and its processing unit is a memory card. It is a standard memory card type and data can be read by standard programs like Microsoft Word, Notepad, etc. Local data access is possible with laptop computer and ethernet cable. Important data can be protected with security password which prevents from unwanted data loss or modifying. Memory card can also be removed and the data can be read on any card reader. Additional security is provided using security labels that reveal removal of the memory card and using security lock on the EMBB system cabinet door.

Measurement sensors used for EMBB system collect important information about electrical machine. Another important characteristic of the EMBB system is simplicity. All of the used sensors are easy to install. There is no need to interrupt machine in operation or make any interventions on the equipment for sensor installation. Complete system for the new machines can be installed in the factory.

Before making application program it was necessary to define parameters of the machine to be measured in order to obtain and calculate all harmful conditions mentioned above. Some of the parameters EMBB measures and monitors are: voltage and stator currents, excitation current, vibrations, temperatures, rotation speed and number of machine start-ups. It took a lot

of experience and expert knowledge of authors and their colleagues in order to obtain the desired informations as quickly and reliably as possible. It is important that all parts of the path: understanding of machines physical nature – installation of appropriate measurement sensors – numerical calculations and fast on-line signal analysis – expert data interpretation, are designed and done carefully. This ensures quality and operational reliability of the product, which affects customer satisfaction.

In contrast to conventional monitoring systems, EMBB records only harmful conditions. It is not necessary to record and store a lot of useless data. Users and manufacturers of electrical machines need to know how many harmful conditions occur during certain period of machine operation time, and after expert data interpretation they can conclude what went wrong and what needs to be done in order to fix the encountered problems.

5. CONCLUSION

Conventional monitoring systems for rotating machines are based on the vibration measurement and they are not designed to detect and identify the above mentioned harmful machine conditions. Their purpose is to record measuring data and to alarm the user when the measured value reaches pre-set value. Except for displaying the current values on user screens, measured values are permanently stored in a database for later complex analysis. Only after expert analysis of large amounts of data it can be concluded about the machine state.

Based on the analysis and experience of many years of work on power plants and working with manufacturers of power equipment, it has been concluded that there is a need for smaller and simpler systems, which using expert knowledge and specific measurements provide specific information about the state of the machine directly to system users, without the need for detailed and expert analysis of the collected data. That kind of system is EMBB system described in this article. A large number of machines and power plants do not have built-in monitoring system in any form. EMBB system because of its specificity and the ratio of price and performance is a good solution for both, power plants without monitoring systems, and power plants that have some kind of monitoring system. Many power plants do not decide to buy complex monitoring systems due to their price, especially the owners and users of smaller and cheaper machines. Because of the price-performance ratio, the EMBB system is a solution for such power facilities.

By equipping synchronous and synchronous machines with EMBB system, owners and users get an additional insight into the harmful working conditions during the machine operation. EMBB enables predictive maintenance of the machine and thus reduces potential damage costs. Long-term data storage, system modularity, data protection, local and remote data access are some of the EMBB system characteristics and advantages that make it easier and safer to use.

It can be concluded that the EMBB system provides insight into the conditions that are not monitored by conventional monitoring systems and thus allows a different and in certain cases an improved asset management. Because of its reliability and performance EMBB provides valuable information to the users and manufacturers of electrical machines for the entire lifetime of the machine.

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