ABSTRACT

thesis for the degree of Doctor of Philosophy (PhD)
in specialty: 6D071800 − Electric power engineering

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Development of the theory of building diagnostic systems for eccentricity of a rotor of the asynchronous motors

The proposed thesis is devoted to the development of the theory of building diagnostic systems for eccentric rotor asynchronous motors.

The relevance of the work. In most cases as electric drive are used asynchronous motors in the power and industrial plants. So in Kazakhstan circa 0.5-0.8 million units are used. Studies show that many of them for a long time work with a static eccentricity of the rotor. As a rule, the displacement of one of the rotor pillars at a distance less than 75-85% of the air gap does not cause an immediate failure of the asynchronous motor system. However, its operational characteristics is significantly deteriorated. The cost of electricity losses for the year could exceed the cost of the asynchronous motor. From this it follows that the control of the eccentricity of the rotor in operation mode in motor is urgently needed. Especially in light of the struggle of the government of the Republic of Kazakhstan for energy savings.

His contribution to the theory of the construction of the rotor eccentricity asynchronous motors diagnostic systems have Geller B., Gamat V., Voldek A.I., Novozhilov A.N., Kletsel M.J., Nikiyan N.G., Weinreb K.B., Hashimov M.A., Rogachev V.A., Surkov D.V., Tonkih V.G., Petukhov V.N., Kryukova E.V., Mirzoyeva S.M ..

Currently, the requirements of diagnosing rotor eccentricity to the greatest extent meets the diagnostic system which as a source of damage data used by the stator current of asynchronous motors, which is controlled by a current transformer, as the information signs of damage - the additional currents, and the dependence of the additional current from the eccentricity of the rotor for each type of asynchronous motor is obtained experimentally.

However, a significant part of asynchronous motors has no current transformers. In addition, not all companies have the opportunity to receive the experimental dependence of the information signs of damage from the values of eccentricity for an existing asynchronous motor. That significantly reduces the area of use of the diagnostic system. In addition, is used in this system an information sign of damage to a certain extent depends of the oscillation of the parameter of supply mains.

Thus, the question of the theory of building diagnostic systems for eccentric of a rotor for asynchronous motors is relevant.

The aim of the work is expansion of the area of use and increase reliability of the diagnostic system of rotor eccentricity by improving the process for the dimension and processing of information about the damage and the development of the mathematical apparatus for construction the dependence between the information signs of damage of asynchronous motor and the eccentricity.

To achieve the objectives were set and solved the following tasks:

- improve the method of acquiring information about the rotor eccentricity of asynchronous motors and has been assessed its potential;
- develope a method for calculating the current in the windings of asynchronous motors when the rotor has eccentricity, accuracy of whom satisfying the requirements of this kind of injury;
- explore the possibilities of developed method of calculation of the currents in the windings of the asynchronous motors with eccentricity of the rotor;
- develop a new method of signal processing to obtain diagnostic sign of the eccentricity of the rotor in conditions of temporary of the oscillation of the parameter of supply mains and oscillation moments of load on its shaft;
- develop a method for producing dependence of the diagnostic sign of the eccentricity of the rotor theoretically;
- evaluate the possibility of using as an analog-to-digital converter built-in sound card for diagnostics system with a new mathematical apparatus of elements of the diagnostic system ;
- work out the issues of practical implementation of the system diagnosis of eccentricity of the rotor of asynchronous motors in connection with a new way of getting information.

The object of research is the area of the rotor eccentricity diagnosis of asynchronous motors dedicated to the development of the theory of building diagnostic systems by developing a more perfect structure of such a system, as well as the mathematical apparatus of some of its structural elements.

The subject of research is the development of the theory of building diagnostic system for eccentric rotor asynchronous motors by developing a more perfect structure of such a system, as well as the mathematical apparatus of some of its structural elements.

Scientific novelty. In the work was researched the known structures of building diagnostic systems, revealed their shortcomings that limit their opportunities, and have made a new, more perfect structure, devoid of these shortcomings. In connection with what has been justified and implemented a new way of getting information about the eccentricity of a rotor asynchronous motors, developed a mathematical model to simulate the eccentricity of a rotor, which allows to calculate the currents in the windings of stator, which have developed new ways of modeling a smooth air gap in the eccentricity of the rotor and magnetic conductivity gear gap. Methods of mathematical modeling of the magnetic field of a gear gap and own and mutual inductances of stator and rotor displacement of the rotor.

A new method for signal processing have made in order to more reliable identification of diagnostic features of the rotor eccentricity of the information signal in a time-variant parameter supply network of asynchronous motors.

The practical value. It was found that the disadvantage that limiting the known structures of constructions diagnostic systems, is the imperfection of the mathematical apparatus of the processing units of the information signal and receiving the information signs of damage, as well as limitations scope of the diagnosis of the imperfection getting of the information signal about the damage. To expand the area of application of diagnostic systems was proposed method of obtaining information about the eccentricity of the rotor of asynchronous motors allows the diagnosis of even those electric machines that do not have current transformers. The developed mathematical model of asynchronous motor to simulate the eccentricity of the rotor, allows the calculation of the currents in the stator windings with an accuracy of about 10-15%. A method of producing the dependence of the diagnostic signs of damage from the value of the eccentricity of the rotor is sufficiently precise by calculation which eliminates the need to obtain it with quite expensive experimentation.

Designed signal processing method allows more reliable allotment of the rotor eccentricity diagnostic features of the information signal by increasing the share of information signs in the resulting data signal from the asynchronous motor.

The results of the work are: a way to obtain information using current pliers; a mathematical model of asynchronous motor, which allowed to simulate the currents in the windings of the stator and rotor in a random mode of work; new method for processing an information signal; proposal to use neural networks or the mean square value given its components for the formation of the diagnostic signs of damage; a method for producing by calculation way dependence to the value of the diagnostic signs of damage from the value of the eccentricity of the rotor; replacement analog-to-digital converter of diagnostic system sound card of personal computer.

The structure and volume of the thesis. The thesis consists of an introduction, three chapters, conclusions, application and list of references. Thesis is presented on 96 pages of computer text includes 39 figures and 7 tables.

In the introduction the topicality is proved, the main aim of the thesis is defined and the scientific novelty and the practical value are stated. The main statements of the thesis are set. The publications, the structure of the thesis and the approbation of results are pointed.

In the first chapter the main causes of the rotor eccentricity and its basic types are considered. It is found that about 30-50% of asynchronous motors being in use operate with the static eccentricity of the rotor for a long time, in which case their technical and economic parameters become worse. Therefore, the energy assumption of asynchronous motors increases by 0,45-3,95%, so, the cost of the excessive consumption of electric power per year can be compared with the cost of the engine. Methods of modeling a magnetic field in the air gap and currents in the

windings of asynchronous motors by the rotor eccentricity are studied, the information characteristics of that case of damage are considered. The known diagnostic systems are analyzed where the most appropriate solution is made, but it has some drawbacks. So, the method of obtaining information from asynchronous motors and the construction method of magnitude dependence of the rotor centricity do not allow performing the diagnostics on a number of asynchronous motors. Besides, the existing diagnostic system has insufficient reliability, since it has no way to tune up the unstable voltage parameters.

In the second chapter a mathematical model with phase coordinates, formed for the delta voltage by the method of loop currents, is used to describe the energy conversion process in the asynchronous motors by the eccentricity. A method for modeling a smooth air gap by the rotor eccentricity is introduced. The comparison of its accuracy with already known shows that the most appropriate method is the method suggested by B. Geller and V. Gamat. It is found that it is better to use the zero and first components of the magnetic conductance of the tooth clearance for modeling the magnetic field in the air gap. It is revealed that the self-inductance of the stator phase depends on both the magnitude of the zero and first components of the magnetic conductance of the tooth clearance and the rotor rotation angle. A mathematical model of asynchronous motors is developed which allows calculating currents in the windings of asynchronous motors with the accuracy of 10-15%.

In the third chapter the enhanced system of diagnostics is presented. In order to remove the data signal the use of upgraded clip-on meter is proposed. And instead of ADC the use of the sound cord of PC is recommended. A new method for processing the information signal is offered which will improve the accuracy of the diagnostic system in conditions of the fluctuation of parameters of the supply main. The possibility to obtain a diagnostic feature of using artificial neural nets is studied.

In the conclusion the main scientific and practical results obtained in the thesis are stated.

Information about publications. Main provisions of the thesis were published in 23 scientific works, including editions recommended by Committee on control and attestation in education and science Republic of Kahahstan - 7, in magazine with a non-zero impact factor and the information included in the company's database Scopus - 2 in international scientific-practical conferences - 8, of them 6 in foreign conferences, 2 - in the journal included in the database Russian Science Citation Index and received three innovation patents of the Republic of Kazakhstan and one patent of the Russian federation.