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ANALYSIS OF DIAGNOSTICS AND PROTECTION METHODS OF ASYNCHRONOUS MOTORS USED IN AGRICULTURE, BY VIBRO-INDICATORS

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Abstract

Nowadays, AC motors are in great demand among most modern manufacturing enterprises. Professional experience shows that they use 80% of all electricity generated in the country, so the stability of their work plays an important role in agriculture and industry. Nowadays, vibration diagnostics is one of the effective tools for solving a wide range of problems of detecting defects in electrical machines, preventing parts from failing, extending their service life and increasing their overhaul periods of operation. Preservation of electrical safety, reliability and durability of the operation of electromechanical equipment of electric drives based on asynchronous motors in the production processes of enterprises in the agricultural industry remains an urgent task of electrical systems.

Keywords: Asynchronous electric motor, insulation, protection, short circuit, vibration, phase loss, analysis, technological process, voltage, current.

QISHLOQ XO'JALIGIDA QO‘LLANILADIGAN ASINXRON MOTORLARNI VIBRATSIYA KO‘RSATKICHLARI BO‘YICHA DIAGNOSTIKA VA HIMOYA QILISH USULLARINI TAHLIL QILISH.

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Annotatsiya.

Hozirgi vaqtda asinxron elektr motorlaridan zamonaviy ishlab chiqarish korxonalari kabi qishloq xo‘jaligi ob’ektlarida keng ko‘lamda qo‘llanib kelinmoqda. Tahlillar shuni ko‘rsatadiki, ular mamlakatimizda ishlab chiqariladigan elektr energiyasining deyarli 80 foizga yaqinidan foydalanadi, shuning uchun ularning ishlash barqarorligi qishloq xo‘jaligi va sanoatda muhim o‘rin tutadi. Hozirgi vaqtda tebranish diagnostikasi elektr mashinalaridagi nuqsonlarni aniqlash, qismlarning ishdan chiqishining oldini olish, ularning xizmat qilish muddatini uzaytirish va ularni kapital ta’mirlash muddatlarini uzaytirish bo‘yicha qator muammolarni hal qilishning samarali vositalaridan biridir. Qishloq xo‘jaligi sanoati korxonalarining ishlab chiqarish jarayonlarida asinxron motorlar asosidagi elektr yuritmalarining elektromexanik uskunalari ishlashining elektr xavfsizligi, ishonchliligi va mustahkamligini saqlash elektr tizimlarining dolzarb vazifasi bo‘lib qolmoqda.

Tayanch so‘zlar: Asinxron elektr dvigatel, izolyatsiya, himoya, qisqa tutashuv, vibratsiya, faza yo‘qolishi, analiz, texnologik jarayon, kuchlanish, tok.

АНАЛИЗ МЕТОДОВ ДИАГНОСТИКИ И ЗАЩИТЫ АСИНХРОННЫХ ДВИГАТЕЛЕЙ, ПРИМЕНЯЕМЫХ В СЕЛЬСКОМ ХОЗЯЙСТВЕ, ПО ВИБРОИНДИКАТОРАМ

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Аннотация

В настоящее время двигатели переменного тока пользуются большим спросом у большинства современных производственных предприятий. Профессиональный опыт показывает, что они используют 80% всей электроэнергии, вырабатываемой в стране, поэтому стабильность их работы играет важную роль в сельском хозяйстве и промышленности. В настоящее время вибродиагностика является одним из эффективных средств решения широкого круга задач по выявлению дефектов электрических машин, предупреждению выхода деталей из строя, продлению срока их службы и увеличению межремонтных сроков эксплуатации. Сохранение электробезопасности, надежности и долговечности работы электромеханического оборудования электроприводов на базе асинхронных двигателей в производственных процессах предприятий сельскохозяйственной отрасли остается актуальной задачей электротехнических систем.

Ключевые слова: Асинхронный электродвигатель, изоляция, защита, короткое замыкание, вибрация, обрыв фазы, анализ, технологический процесс, напряжение, ток.

Introduction. Periodic diagnostics of the state of the equipment helps to identify emerging faults in a timely manner. Asynchronous motors (ACM) in practice show their endurance and simplicity at a relatively low cost. However, during operation, damage to engine elements may occur, which in turn leads to its premature failure. [1]

The main sources of development of damage to an induction motor are:

– overload or overheating of the motor stator – 31%;
– interturn short circuit – 15%;
– bearing damage – 12%;
– damage to stator windings or insulation - 11%;
– uneven air gap between the stator and the rotor – 9%;
– operation of the electric motor in two phases – 8%;
– breaking or loosening of fastening of rods in a squirrel cage – 5%;
– loosening of stator winding fastening – 4%;
– unbalance of the rotor of the electric motor – 3%;
– shaft misalignment – 2%. [2]

In production, a sudden failure of the engine can lead to irreparable consequences. It is very important to detect any defect at an early stage, eliminating the risk of serious engine damage.

Methods. The system of technical diagnostics should include regular monitoring of the technical condition of electric motors, search for defects, damage, determination of the degree of danger of defects and assessment of the residual life of the equipment. For enterprises providing specialized service maintenance of electric motor repairs, the task of diagnosing the state of electric motors is no less relevant. [3]

An ideal modern way of diagnosing electric motors must meet the following requirements:

– high reliability and accuracy of detection of malfunctions and damages of the electric motor;
– the ability to detect all or a significant part of electrical and mechanical damage to the electric motor and related mechanical devices;
– carrying out diagnostic measurements remotely, which is relevant in cases where access to equipment is difficult;
– low labor intensity of diagnostic work
(measurement) and ease of measurement;
– the possibility of analytical processing of the obtained measurement results in a short time, using computational and software tools.[4]

In addition, when operating electric motors that were in poor condition, it can lead to financial losses:

– direct, associated with unpredictable failure of equipment and the disruption of the technological process caused by this;
– significant (up to 5–7%) indirect unproductive costs of electricity due to increased electricity consumption.

This raises the question of the need to diagnose the state of the engine in the process of its operation.

Most modern diagnostic methods are based on the analysis of the vibration of working machines and equipment. These methods form the basis of functional (operational) diagnostics, despite the fact that equipment operation modes can be very different - from steady state (nominal or special) to transient ones, including starting, impulse, etc. The functional diagnostics of machines and equipment by vibration uses information contained in the characteristics of vibrational forces and the properties of the vibrational system. And since, as a rule, there is no sufficiently accurate information about either the vibrational forces or the vibrational system before starting the vibration analysis of the operating equipment, in functional diagnostics the most complex methods of vibration analysis, which is a function of the parameters of the vibrational forces and properties of the oscillatory system. [5]

Solving style. There are a number of factors that affect the validity of using any of the vibration diagnostic methods in each specific case: the mode of operation of the IM, the required accuracy of diagnostics, the conditions under which diagnostic operations are performed, the requirements for vibration measuring and vibration analyzing equipment, power quality.

The most common groups of methods for vibrodiagnostics of an asynchronous motor are:

– Diagnosis of ASM pressure by the mean square value (RMS) of the vibration signal;
– Vibrodiagnostics of ASM pressure with the help of phase portraits (oscillation trajectories);
– Spectral analysis;
– Spectral analysis of the envelope;
– Cepstral analysis;
– Ultrasonic flaw detection and acoustic diagnostics;
– Special diagnostic parameters;
– Wavelet analysis;
– Statistical methods for processing vibration signals;
– Diagnostics based on neural networks. [6]

At present, the method of spectral analysis of the consumed current has become widespread. An important advantage of this approach is that the monitoring of the electric motor current can be performed both directly on it and in the power supply (control) panel. The physical principle underlying this method is that any disturbances in the operation of the electrical and/or mechanical part of the electric motor and associated device lead to changes in the magnetic flux in the gap of the electric machine and, consequently, to weak modulation of the current consumed by the electric motor. The presence of characteristic (and mismatched) frequencies of a certain value in the motor current spectrum indicates the presence of damage to the electrical or mechanical part of the electric motor and the mechanical device associated with it.[7]

To diagnose the state of electric motors by the method of spectral analysis of the consumed current, a measuring (hardware-software) complex is required, including equipment:

1. Electric motor.
2. Mechanical device of the electric motor - pump, compressor, etc.
3. Low-pass filter (signal conditioner).
4. Analog-to-digital converter (ADC).
5. Portable computer (PC) with specialized software for collecting and analyzing information (data).

Results and discussions. We have given the following indicators from the results of experiments conducted in the laboratory of "TIIAME" National Research University. Current signals are recorded for the time necessary to perform spectral analysis with a frequency resolution of at least 0.01–0.02 Hz. The digitized ADC data is transferred to a PC, where the received data is processed: the engine speed and the number of rods of its rotor are determined, then a special spectral analysis of the current signal is carried out.[8]

Let's consider a general example. The figures 1 and 2 shows an increase in frequency bands. This indicates various defects that have formed over 5 years of operation.

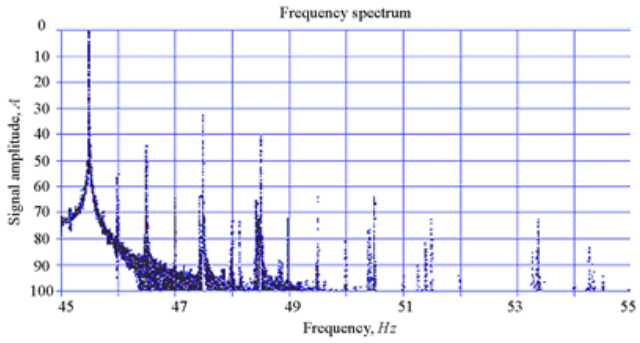

Fig. 1. Spectral analysis of the consumed new electric motor.

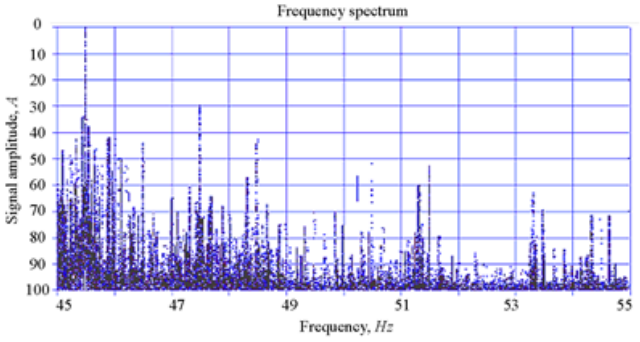

Fig. 2. Spectral analysis of the consumed electric motor, operated for 5 years.

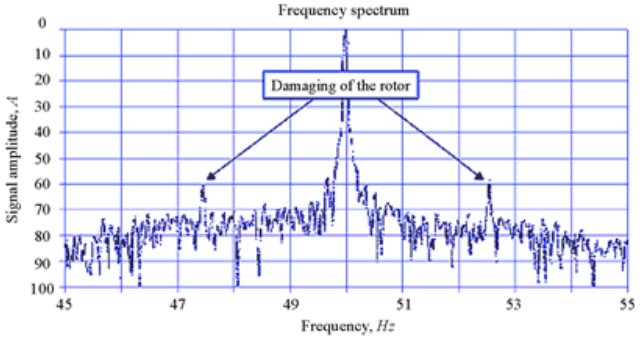

Fig. 3. Frequencies characteristic of rotor damage.

In Figure 3 we can see a more detailed example. Damage to the motor rotor can be detected by the presence of two relatively symmetrical power line frequency peaks in the current spectrum.

Similarly, the presence of such defects as:

- interturn short circuits of the stator windings;
- damage to bearings (data on the bearings of the electric motor and the mechanical device are required);
- unbalance of the rotor of the electric motor;
- weakening of the fastening elements of the electric motor;
– defects in the mechanical parts of devices connected with the electric motor.[9]

Depending on the method of obtaining information, this method can be carried out in two ways: contact and non-contact. In the non-contact method, sensors in the form of current clamps are most often used.

But this method has a drawback - a strong distortion or the appearance of high-frequency harmonics with certain defects. This includes:

- Occurrence of interturn and interphase faults (appearance of high-frequency harmonics in the spectra);
- Defect in the bearing unit (distortion of the spectrum, in particular, the appearance of harmonics with combined frequencies).

To date, diagnostic methods do not allow fully diagnosing equipment in all operating conditions, and therefore do not affect the reduction of costs associated with the failure of the electric motor. Therefore, the development of any new methods, or the use of methods not previously used in diagnostics, is relevant. Let us consider the method of eddy current testing, which is not quite standard for diagnostics. [10]

The physical principle is based on the analysis of the interaction of an external electromagnetic field with the electromagnetic field of eddy currents induced by an exciting coil in an electrically conductive test object. The density of eddy currents in an object depends on the geometric and electromagnetic parameters of the object, as well as on the relative position of the measuring eddy current transducer (ECT) and the object. The electromagnetic field of eddy currents acts on the converter coils, inducing an electromotive force (EMF) in them or changing their electrical impedance. By registering the voltage at the coil terminals or their resistance, one obtains information about the properties of the object.

It should be noted that the design of the converter is extremely simple. The coils are placed in a protective case and filled with compounds. Due to this, they are resistant to mechanical and atmospheric influences, can work in aggressive environments in a wide range of temperatures and pressures, and are also not affected by humidity, radioactive radiation, and pollution of the gaseous environment [11].

The peculiarity of this method also lies in the fact that there is no need for contact between the converter and the object. Their interaction occurs at distances sufficient for the free movement of the transducer relative to the object (from fractions of a millimeter to several millimeters). Therefore, it is possible to obtain good test results with these methods even at high speeds of the movement of objects [12].

In [4], it was experimentally proved that the presence of harmonics in the intensity spectrum, multiples of 3 is a sign of interturn and interphase short circuits, and multiples of 2 is a sign of rotor eccentricity.

Thus, it was found that the occurrence of 4 harmonics - mechanical damage to the engine (a); odd harmonics relative to 1 - in case of electrical faults (b);

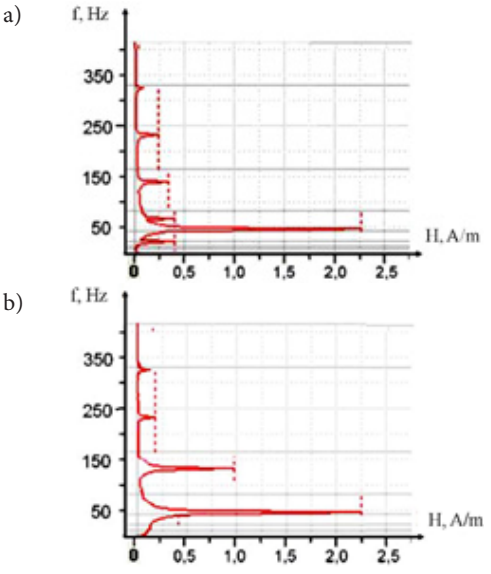

Fig. 4. Spectral composition of the external magnetic field of the IM at the eccentricity of the rotor shaft (a); Spectral composition of the external magnetic field of the AM during interturn circuit (b)

At the same time, it was found that the most informative harmonic is the 3rd harmonic, since it manifests itself both in interturn faults and in phase faults. In addition, by the value of the 3rd harmonic coefficient, it became possible to make a prediction about the technical condition of the electric motor, based on the results of which recommendations can be developed on the further operation of the electric motor, depending on the specific values of the considered diagnostic parameter.

At the same time, the application of the eddy current control method is hampered by the fact that when one parameter is controlled, the others are interfering. To separate the parameters, separate or joint measurements of the phase, frequency and amplitude of the signal of the measuring transducer are used, control is carried out simultaneously at several frequencies [13].

Conclusion. The article considered two modern methods for diagnosing an asynchronous motor: spectral analysis of the consumed current and eddy current control. In addition, against their background, the most widely used methods of processing and analyzing data for the purpose of vibration control were considered. A comparative table has been compiled, which shows that each method has its advantages and disadvantages and can be used in any special cases. The eddy current method is best used to detect turn-to-turn faults. Unlike other types of faults, in order to determine interturn short circuits, it is necessary to know only the coefficient of the 3rd harmonic of the external magnetic field strength, while it will be difficult to determine faults of a different kind by external factors (measurement distance, quality of electrical energy, background electromagnetic fields). In turn, the spectrum of detected faults in the method of spectral analysis of the consumed current will be wider. To detect malfunctions of the electric motor, the characteristic frequencies of the electric motor and related mechanical devices are distinguished. However, it should be noted that the method of spectral analysis of the consumed current is more laborious and expensive than the method of eddy current control.

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