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EXPERIMENTAL STUDY OF INFORMATION TECHNOLOGY OF INTEGRATED INDUCTION MOTORS CONDITION MONITORING

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ABSTRACT

The article is devoted to study the process of induction motors monitoring. In industry conditions, at real technological equipment the experimental researches of information technology were carried out to determine possible induction motors malfunctions, as well as to calculate their operation resource. The alternating current magnetic field induction, measured at induction motor stator, as well as acoustic signals accompanying its work were used as information features.

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Introduction. Electrical machinery drives are used in industrial equipment manufacturing in almost all industries. Their unscheduled stop or sudden failure are accompanied by considerable economic losses. Especially large the losses are at powerful powerplants and facilities, that is why, the technical diagnostics in this field is quite developed and is mandatory to prevent failures and timely repair. Much less attention is paid to diagnosis of medium and low power plants, but their significance in view of development of stand-alone drives and plenty of the latter, is growing. Diagnosis is mainly performed by thermal, electrical and vibroacoustic methods, which in certain situations, such as low temperatures, acoustic interference, etc., are not applicable or do not provide the necessary reliability of information [1-2]. Addressing today's challenges of diagnosis requires the use of innovative methods and tools, including diagnostics of magnetic field distribution at the stator surface, acoustic and even sensory methods, that involve the use of human senses (inspection, listening). This measurement of diagnostic parameters is performed by contactless method and, importantly, in the operating mode. But widespread adoption of such technologies in the industry is hampered by lack of new modeling methods of energy facilities and appropriate software and hardware, that makes urgent and important the research in the field of intellectual promoted comprehensive condition monitoring of induction motors.

Use of diagnosing by the magnetic field distribution on the surface of the engine stator as the main and as additional source of diagnostic information allowes more reliably assess the technical condition and predict failure of electrical machines. The outside indirect diagnostic features are the evidence set [3], which reflect the relationship of internal and external parameters. Such diagnostic features may be the parameters of a stable mode, which vary according to the characteristic laws, depending on the place of origin and type of primary faults. Each specific fault is characterized by one or more external features. In some cases, an external sign directly indicates the presence of a specific fault, in the other cases characterizes the fault only indirectly. That is, for the diagnosis and prediction of electric machine and drive condition, it is necessary to know the nature of parameters change at various primary faults and to choose from them the defining ones.

This task is solved by development of monitoring information technology that provides recognition of the current state of induction motors directly during the technological process. An expert system of electric motors condition estimation at the basis of external diagnostic indicators which includes: temperature of motor elements heating, the case vibration, sound indicators of work, magnetic field induction measured on induction motor stator surface, etc., was developed. The system allows to carry out preliminary motor diagnostics with the issuance of recommendations about possibility of its further operation expediency [7, 9].

Said problem is solved by constructing of information monitoring technology, which provides the induction motors current state monitoring directly during technological process. The developed expert system of electric motors assessment is based on external diagnostic indicators, which include: temperature of engine elements heating, casing vibration, sound parameters, the magnetic field induction, measured at the stator surface, etc., which allows preliminary diagnosis of engine with issuing of recommendations on the possibility and expediency of its further exploitation [7, 9].

Experimental Verification. Experimental studies of information technology were carried out in the production conditions, at the mining and processing enterprise of JSC "Poltava Mining and Processing Works", Horishni Plavni, Ukraine. The induction motor that was inspected was the AKZ-12-39-6UHL4 induction motor with nominal data: power of 320 kW, voltage of 6 kV, rotation speed of 985 rpm, stator current 38.5A. The engine drives the conveyor belt No. 82, the SMS-2 section of the crushing and processing plant (DZF). Conveyor No. 82 has a length of 182 m and a capacity of 3000 t/h. It transports ore from the “Barmak” crushers and drum magnetic separators.

This engine was selected as monitored object for the reason that the service personnel detected the following abnormalities in its operation:

- acoustic oscillations with a periodic change of tone with a low frequency harmonic component;
- the motor speed at rated load is reduced and its variations are felt. This is observed by a slight uneven movement of the conveyor belt;
- the stator current, according to the amperemeter arrow oscillations, has a pulsating character, with the oscillation amplitude being 5-10% of the value of the rated current.

To determine the cause of the motor operation abnormalities the stator phase current and noise created by steady running motor were measured. The current registration was carried out by recording the signal from high-voltage current transformer of induction motor connection cell with digital system of electrical signals registration and visualization "Vizier-3".

Fig. 1 shows a graphical representation of the recorded motor current signal. The measured current signal is very noised by impulse disturbances. Median filters were used to reduce the noise level [4 - 6]. The filtered signals are shown in Fig. 2.

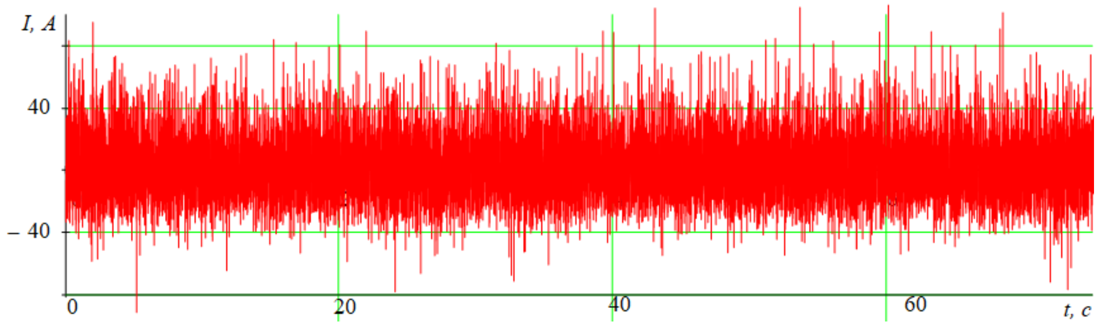

Fig. 1. Recorded motor current signal

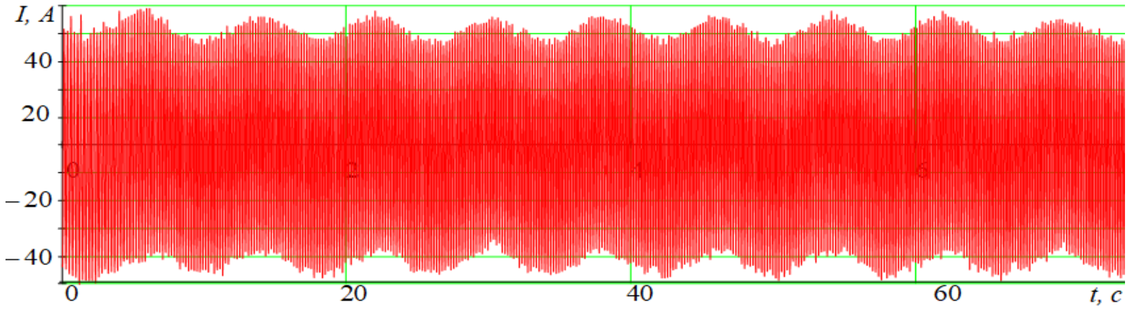

Fig. 2. Filtered motor current signal

As can be seen from Fig. 2, the stator current contains a periodic component which is a diagnostic feature for determining the motor state.

An additional feature is the running motor acoustic background analysis. An electronic sound level meter was used to register it. Acoustic background mapping and analysis was performed using specialized Wavosaur software (Fig. 3, 4).

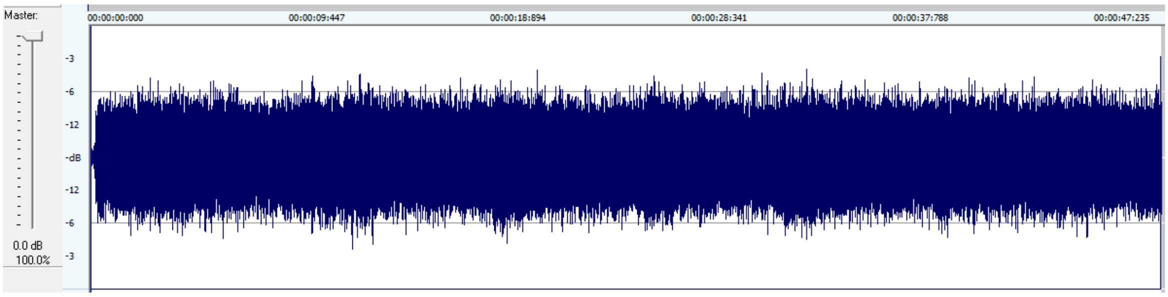

Fig. 3. Signal of running motor acoustic background

It is very difficult to conclude the presence of a periodic component in the acoustic signal visually. So the low-frequency component of the acoustic signal was selected (Fig.4).

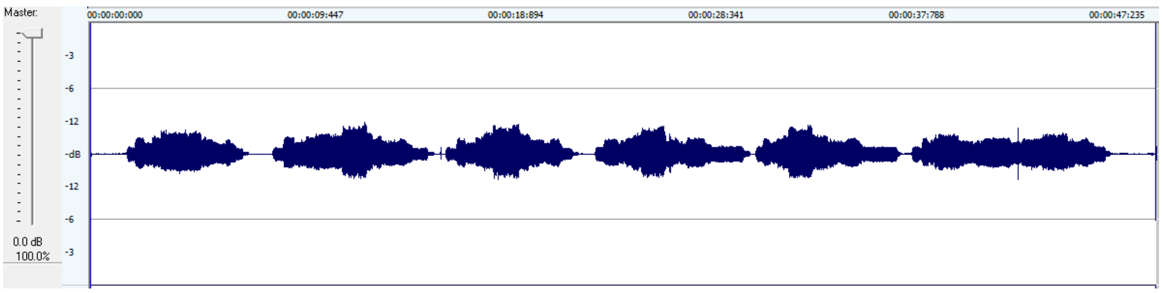

Fig. 4. Low-frequency component of the background acoustic signal

To sum up, we note that obtained data contain diagnostic features: current oscillations, the acoustic signal contains a periodic low-frequency component with a frequency about 0.16 Hz. The spectral components of the phase current and the acoustic signal are almost identical. The slight difference is caused by the shift after filtering, because the filtering algorithms are different. The program window with acoustic signal display and calculation information is shown in fig. 5.

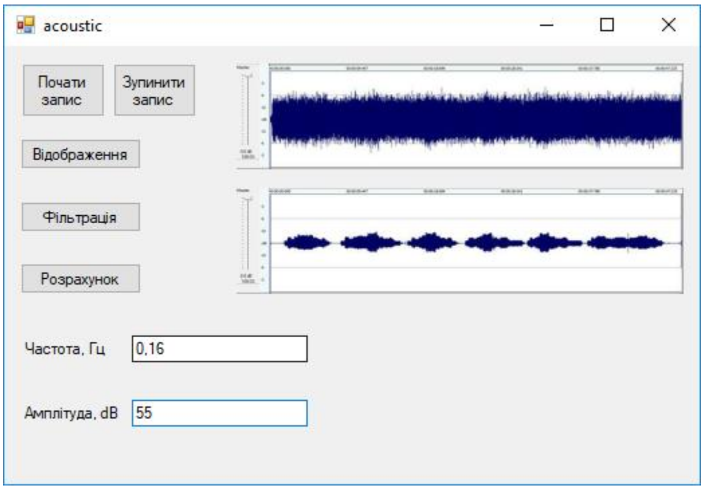

Fig. 5. The window display of the acoustic signal and the calculated information

To diagnose possible malfunction, we use a synthesized expert system. The expert system contains a database of symptoms, causes and recommendations for similar operation mode (Table 1).

Table 1. Symptoms, Causes and Recommendations diagnosed mode.

Symptom	Reason	Recommendation
The rotor speed is reduced and oscillatory; the stator current is pulsating	Poor contact in the rotor circuit:	
	1. Poor contact in the frontal parts windings, the transition resistance between the rods or the connection between parallel groups	check all rotor winding solderings;
	2. bad contact in winding connections with contact rings;	check busducts contacts in the joints of winding and slip rings;
	3. bad contact in the brush machine;	grind brushes, clean contact rings, adjust brush clamp, check contacts of the brush holder and adjust the clamp evenly;
	4. bad contact in connections between contact rings and starting rheostat;	check contacts at the connection points of the stator wires and the starter rheostat
	5. bad contact in the starting rheostat;	insufficient fitting of brushes, check and clean contacts and brushes of starter rheostat;
	6. poor contact between the short-circuited rotor cores and the short-circuiting rings due to the cores separation from the short-circuiting rings or the cores rupture.	find the breakage, solder or replace the bursting rod

The selected features were introduced into the program "Expert System of Electric Motor Failures Diagnostics" and their reasons and recommendations for their elimination were received.

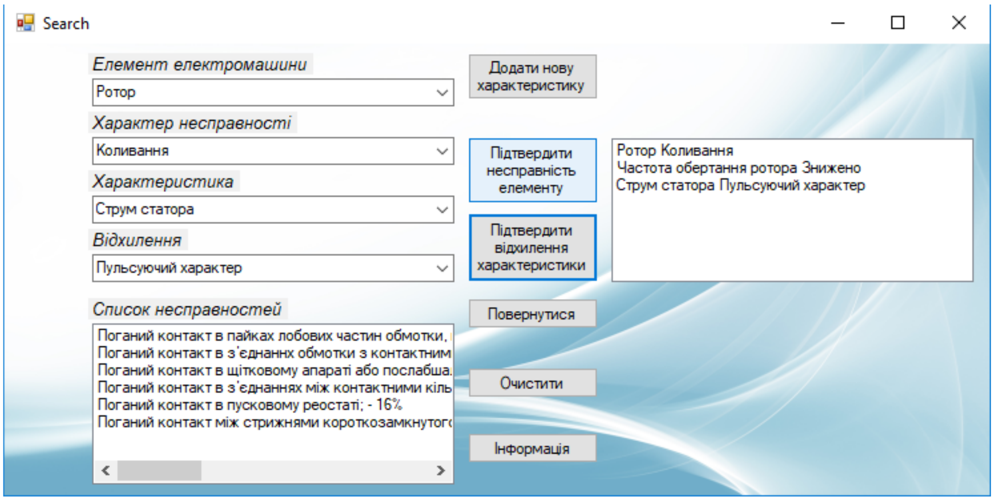

Fig. 6. The results of computer diagnostic system of fault detection

To predict the engine resource and lifetime the magnetic field distribution over the stator was measured according to scheme shown at fig. 8. The measured data are shown in Table. 2.

Table 2. The magnetic field at the inductive motor stator

	Induction, mkT															
Point, *i*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Value	380	190	73	21	81	215	368	118	233	159	24	16	27	138	261	108

The obtained distribution of induction is shown at diagram - Fig. 7b. The points at the diagram correspond to the points in the measurement scheme - Fig. 7a.

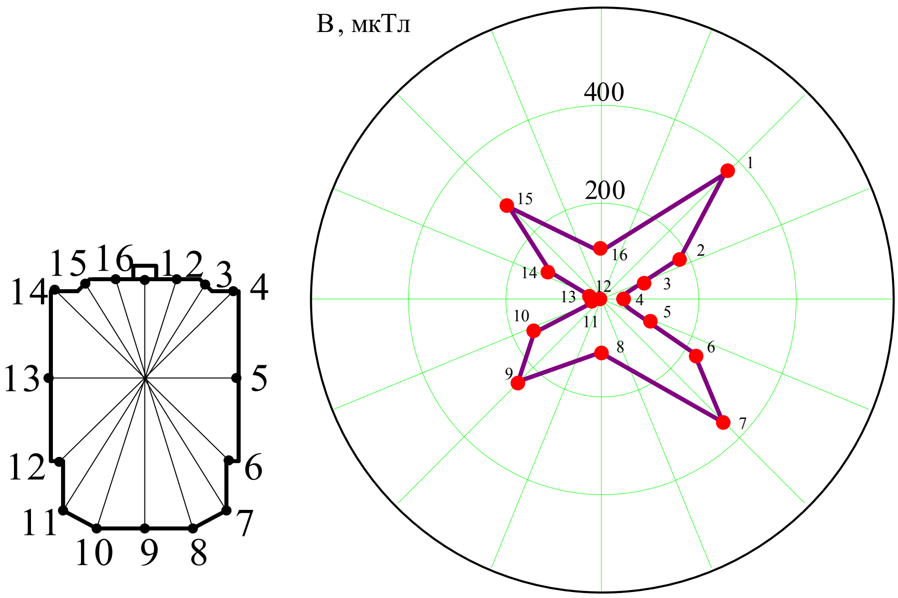

Figure 7. The magnetic field distribution at the induction motor stator: a) diagram of magnetic induction measurements at the induction motor shell surface; b) diagram of distribution.

The program window with magnetic field induction distribution and calculated data is shown at Fig. 8.

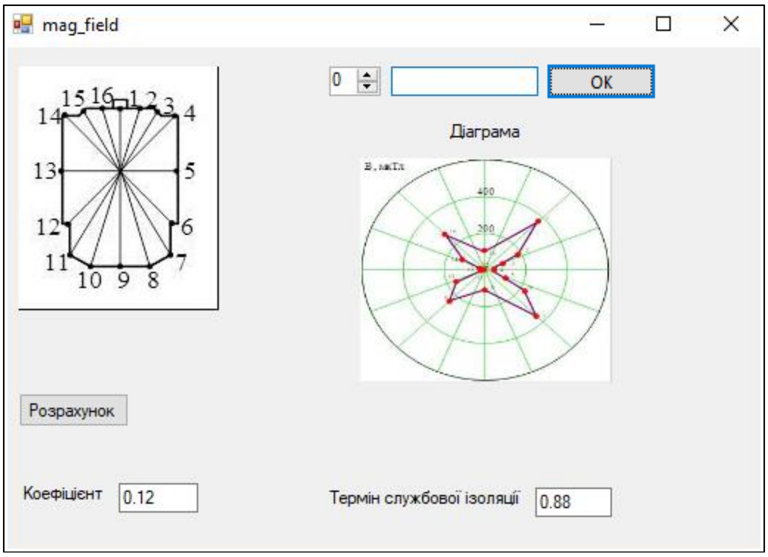

Figure 8. The magnetic field distribution and calculated information

According to obtained data, the value of Buzeman coefficient was calculated by expression [8]:

$$k_b = 0.12$$

Relative life expectancy of induction motor isolation

$$z = 1 - k_b = 1 - 0.12 = 0.88\,.$$

Conclusions. For the induction motor AKZ-12-39-6UHL4 of drive belt conveyor of mining and processing plant PJSC "Poltava Mining and Processing Plant", Gorishni Plavni, Ukraine, at the basis of outward symptoms was found an internal damage, which, by its value of stator current, did not cause the damage protection system switch on.

Based on the developed diagnostic system software and the accepted features of the inductive motor: visual slight decrease in the conveyor belt speed (motor speed), the oscillatory nature of the stator current and presence of the acoustic signal periodic component, that accompanies the rotation of motor, an existence of rotor damage was identified. The cause of the damage is a poor contact at the winding connections, transitions between the rods, the connection between the parallel groups, the brush unit or the starting rheostat.

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