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DIAGNOSTICS OF FAILURES OF ASYNCHRONOUS ELECTRIC MOTORS BY METHODS OF THE POSITION-BINARY ANALYSIS

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Questions of diagnostics of failures of asynchronous electric motors with a short-circuited rotor are considered. A method of diagnostics of asynchronous electric motors technical condition on the basis of the position-binary analysis of cyclic signals is offered.

It is known, that failure of electric motors included to the various complexes in some cases can lead to serious economic losses, especially if it takes place in such strategically important objects as oil-and-gas complexes. Therefore, one of the questions during solving of a problem of diagnostics of electric motors technical condition is fault identification and prediction at the early stage of their occurrence.

For this purpose carrying out of constant remote monitoring of electric motors technical condition in the complex is necessary and use of the methods providing high reliability of diagnosis are advisable at simple enough analysis algorithms and required technology for its maintenance.

It is known, that [1-3] it is possible to detect any damage of a rotor, turn-to-turn short circuit in its stator and other damages by means of analysis of current consumed by asynchronous engine. In normal mode for asynchronous engines with a short-circuited rotor phase currents are symmetric and can be determined according to the following formulas:

$$i_a = I_m \sin(\omega t + \varphi),$$
$$i_b = I_m \sin\left(\omega t + \varphi + 2\pi/3\right),$$
$$i_c = I_m \sin\left(\omega t + \varphi - 2\pi/3\right),$$

where i_a is the current of phase A, i_b is the current of phase B, i_c is the current of phase C, I_m are peak values of the current, ω is angular frequency, φ is an initial corner of the phase, t is time.

These currents at normal faultless work of engines change in identical limits. At occurrence of failure uniformity of their change is broken, that is used as informative attributes.

Let's consider the results of diagnostics with use of position-binary technology of the analysis of signals [4, 5] for a case when changes of stator's current are observed due to turn-to-turn short circuit. The curve of the stator's current in normal condition for three phases I_A, I_B, I_C. is given on Fig.1, in case of turn-to-turn short circuit change of the form of stator's current occurs, Fig.2. As is evident from the figure, appreciable changes of the current are observed in the phase I_A.

Let's construct position-binary components (Fig.3) (PBC) for each of three phases for the normal condition (PBC-NFA1, PBC-NFB1, PBC-NFC1) and accordingly for a case of turn-to-turn short circuits (PBC-MFA1, PBC-MFB1, PBC-MFC1) having chosen the quantity of digitization increments for the period of current signal in this case as N=140, according to algorithms of the position-binary analysis for the periods of current signals.

Now let's find coverings for corresponding pairs PBC and calculate parameter of proximity S_w on the results of covering according to expression.

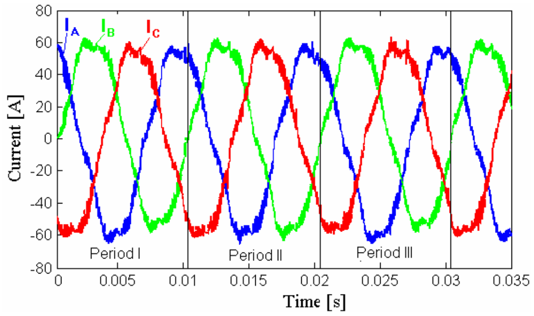

Fig. 1. A curve of in normal condition.

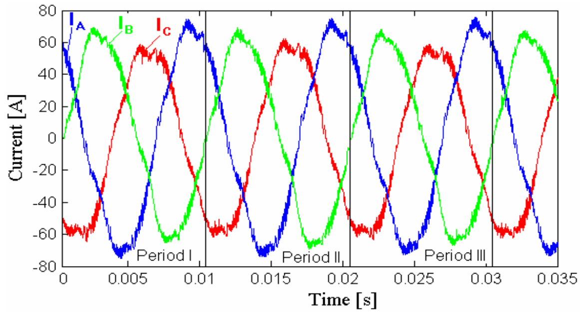

Fig. 2. A curve of asynchronous motor stator's current at turn-to-turn short circuit

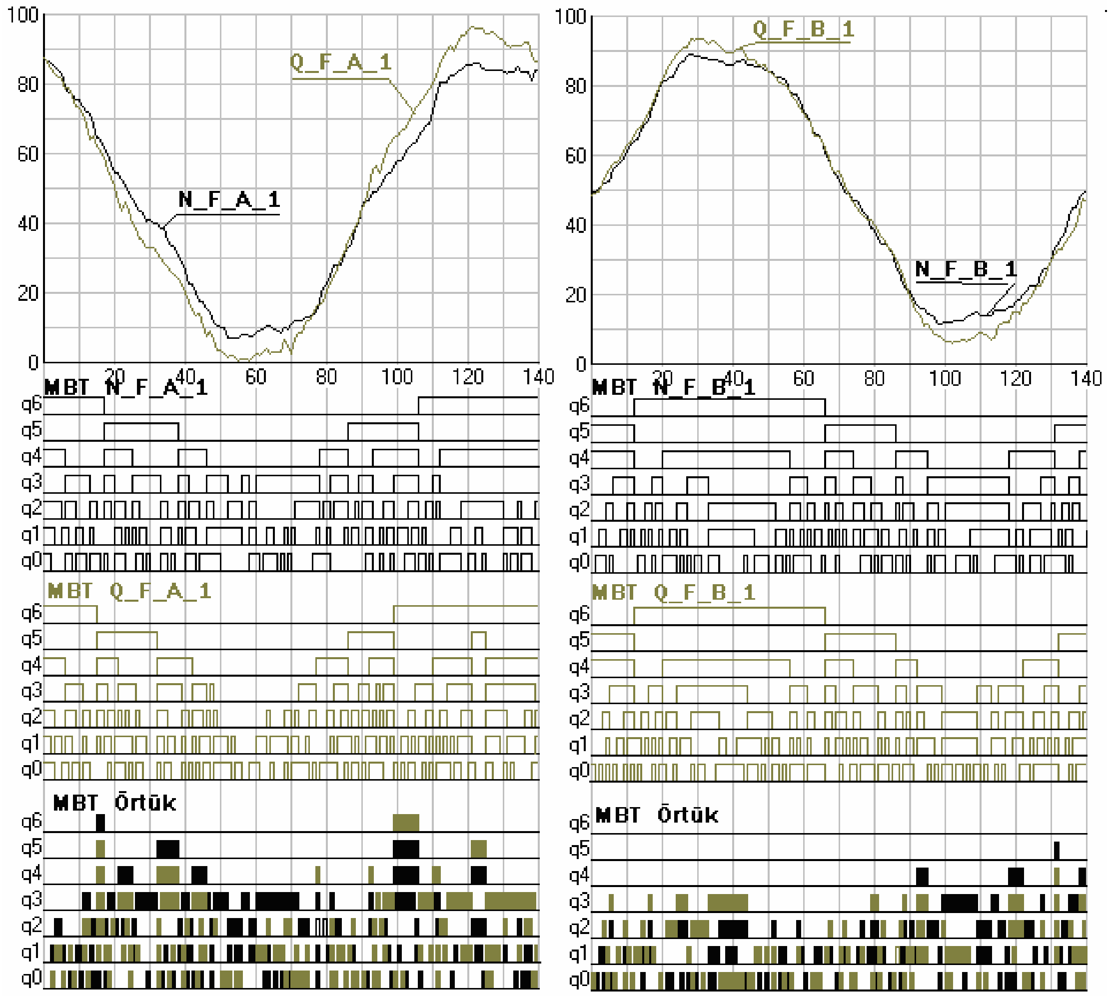

Fig. 3. PBC for A and B phases current

Formation of signals of resultant position-binary components in positions $q_0, q_1, \ldots, q_6$ taking into account weight of positions used as informative attributes is made by digit-by-digit performance of logic operations EXOP (excluding "or") for each of positions of two analyzed signals.

Graphically display of resultant PBC is given on Fig. 3.

Let's define value $\chi = \sum p_+$ and $\eta = \sum p_-$ for formation of numerical proximity parameters p_+, p_- of analyzed pairs of signals on each position $q_0, q_1, \ldots, q_6$. Considering, that diagnostic value of binary elements, is estimated by weight of the positions in which they are located, total duration of components on each position taking into account their weight can be defined as follows:

$$\chi_{q_{(n-1)}} R^{n-1} + \eta_{q_{(n-1)}} R^{n-1},$$
$$\chi_{q_{(n-2)}} R^{n-2} + \eta_{q_{(n-2)}} R^{n-2},$$
$$-----------$$
$$\chi_{q_k} R^{k} + \eta_{q_k} R^{k},$$
$$-------$$
$$\chi_{q_0} R^{0} + \eta_{q_0} R^{0},$$

Here χ is the sum of all p_+, i.e. transitions $(1 \to 0)$; η is the sum of all p_-, i.e. transitions $(0 \to 1)$; R is the basis of notation (*R*= 2), indexes - are numbers of positions.

Values of parameters W_+, W_-, S_w, describing total duration of components, formed by elements p_+ and p_-, taking into account all positions and their weights can be defined by the following formulas:

$$W_+ = \chi_{q_{(n-1)}} R^{n-1} + \chi_{q_{(n-2)}} R^{n-2} + \ldots + \chi_{q_{(0)}} R^{0},$$
$$W_- = \eta_{q_{(n-1)}} R^{n-1} + \eta_{q_{(n-2)}} R^{n-2} + \ldots + \eta_{q_{(0)}} R^{0},$$
$$S_w = W_+ + W_-.$$

The proximity of identifiable signal to the one of reference signals is estimated on relative value of numerical values S_w, obtained according the results of analysis of data of all set of reference signals with identifiable. If $S_{w_1}, S_{w_2}, \ldots, S_{w_\nu}$ are numerical values of set of results, where ν is the quantity of reference signals then the signal with the minimal value $S_{w_{\min}}$ which is the closest one to identifiable signal is to be selected from the set S_w.

Making of a decision on a degree of proximity of identifiable signal to one of reference signals is made on relative value $S_{w_{\min}}$ and selected threshold of recognition.

Let’s make a table of values of W_+, W_- and S_w parameters according to the calculated values S_w for each of signal pairs.

Table 1. Values of parameters for A and B phases

Test	W_+	W_-	П	S_W
N_F_A_1 – Q_F_A_1	1404	1388	16	2792
N_F_B_1 – Q_F_B_2	559	476	83	1035

As it is evident from the table for pair NFA1-MFA1 value S_w=2792 more than twice exceeds values S_w for the subsequent pair S_w=1035, that in this case characterizes high sensitivity of position-binary technology towards change of the form of a signal, and also reliability of diagnostics. Similar operations are carried out for other signal pairs characterizing different types of failures, the general table of values S_w for all pairs of current and corresponding reference signals is made and according to it classification of all types of failure is carried out.

Thus, the position-binary technology of analysis of asynchronous engines technical condition is offered. High sensitivity and reliability is provided by position-binary method of analysis of signals and allows prediction of failures at the early stage of their occurrence.

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