

AC motor diagnostics system based on complex parametric analysis

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Abstract. The article deals with the principle of evaluation of technical condition, based on a comprehensive analysis of the motor parameters which is a main unit in mechanical engineering. Diagnostics system and residential life assessment of electromechanical equipment is presented based on the AC engine and algorithms of its work. The important challenge of diagnostics remains the well-timed faults detection and maintenance and repair organization. The solution of such challenge remains accuracy and reliability of diagnostic systems.

1. Introduction

There are more than 75% of malfunctions presented by machine unit faults on the heavy industry facilities. Consequently the level of its reliability and safety mostly is defined by technical state. Diagnostics of technical devices including electromechanical equipment is an area of technical knowledges that covers theory, methods and means of electric equipment technical state determination in its operation conditions. [1-3]. Diagnostics as an area of science and its practical application located between different sections of science. First of all, this applies to physics and chemistry in terms of behavior and change of materials properties of different kind and the processes that are occurring due to the different factors in them. This also applies to mathematics in terms of experimental data analysis and statistical process control and software to solve complex problems on a computer. Electromechanical equipment exposed to a significant risk of defects and malfunctions, and has a high accident rate. Methods of prevention and detection of faults that are applied today [3] allow only reduce failures in some degree.

The main tasks of diagnostics are [1]:

- Determination of electrical equipment technical state in changing operating conditions,
- Detection of type and degree of defect danger
- Forecasting residual resource and service life.

The decision of which type of diagnosis need to be used, is based on its feasibility study. Such decision is a purely consumer. On the one hand it seeks to objectively determine the condition of the equipment, using a range of diagnostic parameters and their functional connections. On the other hand it is revealed the need for limitation of material resources. So the economy can significantly narrow diagnostic tasks that may affect the objective determination of equipment condition.



2. Diagnostic methods

The most widely spread type of electrical machines are AC motors. The use of induction motors (IM) is constantly growing and, according to the forecast of experts, their share in electrical drive area may reach 85-90% [4-6]. Diagnostics of IM state and assessment of its vital resources is an important practical task.

Well-timed defect detection at earlier stages of their development and violation of individual machine components operation may prevent emergency situation that can lead to negative consequences [7,8].

Currently, diagnosis of induction motor is based on the following methods:

- vibration analysis of individual elements of the machine;
- current and voltage spectral analysis;
- running machine vibrations acoustic analysis;
- air gap magnetic flux analysis;
- secondary magnetic fields analysis;
- separate parts of machine temperature analysis;
- analysis of the iron content in oil;
- insulation state analysis
- signature analysis

The most widespread received methods based on analysis of vibration parameters in different machine spots, electrical parameters of running equipment (current, voltage, consumed power) and thermosvision analysis. However, each method has its own disadvantages that can't let determine the defects and the reasons which caused them [8]. Also due to the complexity of diagnostics that are caused by difficulties of operation conditions, it is necessary to use indirect parameters if it cannot be define by some reasons. Therefore diagnostic system implementation bases on the complex analysis, will improve the accuracy by evaluating the technical condition of AC machines. Since these two methods can diagnose the greatest number of defects in the AC motor[9].

3. Result and discussion

Currently there is no need to prove the usefulness of diagnostic systems, but doesn't solve problems in this area remains reliability, accuracy and assessment quality of the state and residual life. This happens because of the lack of information about the objects (the amount and timing of ongoing repairs and maintenance time and operating modes, et al.) and erroneous conclusions, put forward at the lack of information.

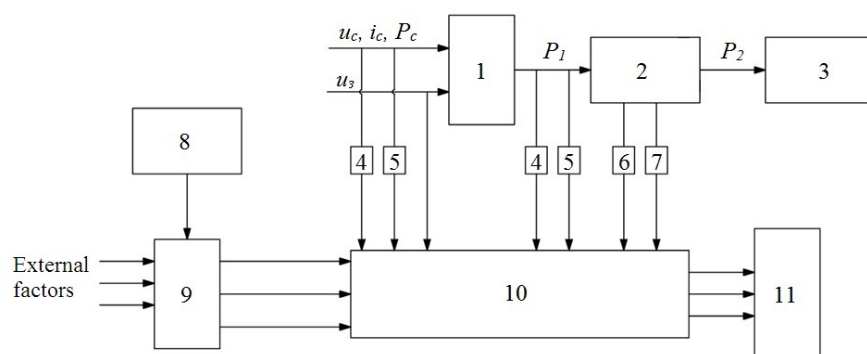


Figure 1. Schematic structure of electromechanical device with induction motor technical condition 1 – static power converter; 2 – electric motor; 3 – executive agency; 4 – current sensors; 5 – voltage sensors; 6 – vibration sensors; 7 – temperature sensor; 8 – process automation system; 9 – data preprocessing unit; 10 – data acquisition board; 11 – personal computer; u_c , i_c – grid current and voltage; P_c – grid power; P_1 – power supplied to the motor; P_2 – power transferred to an executive body; u_s – converter control signal.

Modern automation systems allows electromechanical equipment be equipped by different types of sensors that can allow to determine electrical machine parameters without its stop and installation (is our case this is electrical, vibrating, temperature and indirect parameters). By these parameters it is possible to estimate the actual state of the AC motor. On the basis of a comprehensive analysis of the diagnosis system was developed (Figure 1)

Three-phase voltage and current signals recording from converter input and motor input carried by current sensor 4 and voltage sensor 5. Also the signals from vibration sensors 6 placed on the frame, temperature sensor 7 and converter reference signal are recording. The system also takes into account the process parameters and indirect factors (ambient temperature, humidity, human factor) form the basis of circumstantial evidence in the data preprocessing unit, which complements the main. All received data goes on data acquisition board, where the man database of the motor parameters is forming with further software processing on a personal computer. Each parameter x_i , depending on the area to which it refers (electrical, vibration, temperature, indirect) is determined by the relative weight value of $X_1, X_2, X_3, \dots, X_n$, showing the levels of development of the defect (Figure 2).

Depending on parameters value they is need to be divided on following state values:

- passport (reference), parameters after commissioning works;
- normal, when parameters stay within the permissible range;
- pre-alarm, when the value of at least one of the parameters exceeds the permissible level, and the other area closer to a threshold value and there is no violations of technical and technological capabilities. In this case it is possible to return to normal by taking precautionary measures (load changes, reducing productivity, etc.);
- emergency, when inflated all or almost all indicators that separate normal and emergency conditions, and the suspension of production becomes inevitable.

Electrical parameters																		
Per unik level of parameters / Defects	Winding insulation damage on shell	Phase-to-phase insulation damage	Winding shoit circuit	Stator winding defect	Stator winding short cicituit	Rotor winding defect	Bearing damage	Rotor damage	Rotor core flux guive damage	Stator core flux guive damage	Dinamic eccentricity	Static eccentricity	Contact connection defect	Rotor masses disbalance	Mechanical weakenings	Reducer defect	Shafts misalignment	
	Passport	0,3	0,09	0,1	0,1	0,08	0,09	0,1	0,1	0,14	0,1	0,09	0,1	0,1	0,12	0,1	0,06	0,04
	Normal state	0,52	0,1	0,12	0,1	0,08	0,1	0,1	0,1	0,2	0,12	0,1	0,1	0,1	0,16	0,12	0,04	0
	Emergency state	0,6	0,18	0,2	0,2	0,16	0,18	0,2	0,2	0,28	0,2	0,18	0,2	0,2	0,24	0,2	0,12	0,08
	Emergency state	0,68	0,26	0,28	0,3	0,24	0,26	0,3	0,3	0,36	0,28	0,26	0,3	0,3	0,32	0,28	0,2	0,16

Figure 2. Example of relative weight levels table upon electrical, vibration, temperature and indirect parameters indications.

Summary relative parameter X determined for each state (passport, normal, pre-emergency and emergency), and each defect (1), and is a qualitative indicator of the technical condition of the electric motor.

$$X = X_1 + X_2 + X_3 + \dots + X_n \quad (1)$$

Technical diagnostics system is a collection of objects and tools needed to carry out the diagnosis by the rules established in the normative and technical documentation.

Block diagram of the diagnostics system is multilayered and can be represented in the form of its three functional units (subsystems), figure3.

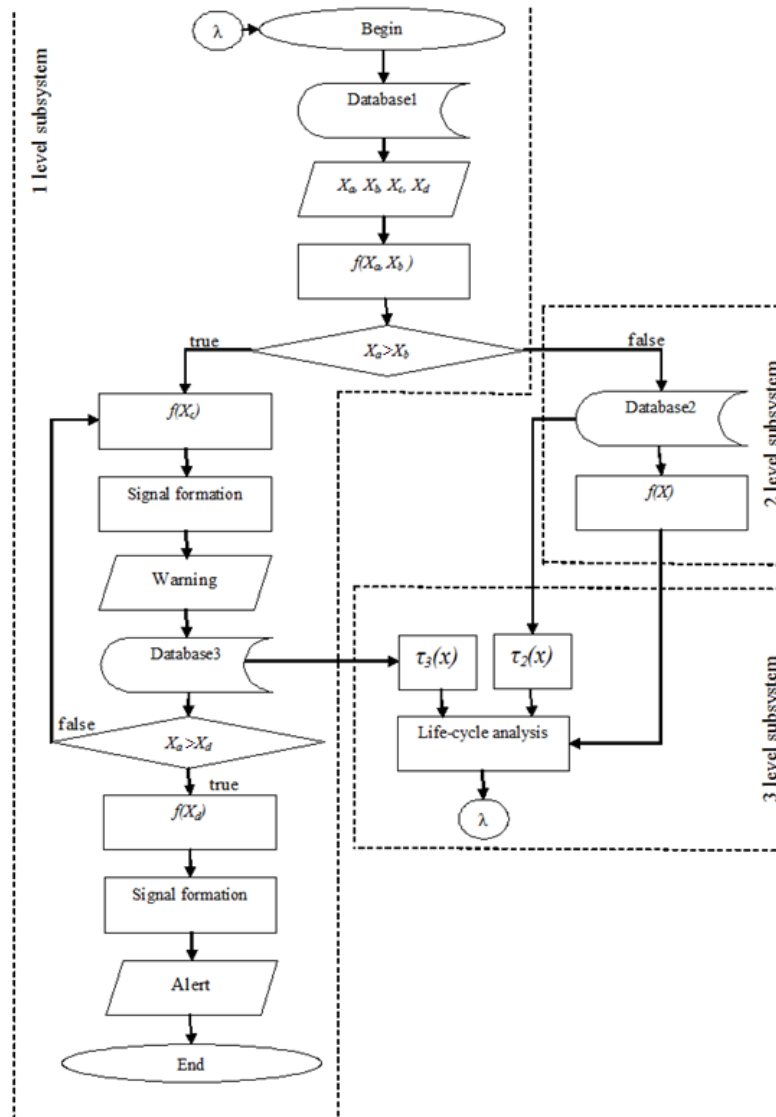


Figure 3. Block diagram of the diagnostic system

Subsystem of 1st level, provides:

- storage of informative parameters;
- measuring of diagnostic parameters;
- processing of measured diagnostic parameters by representing them in normalized form and transmitting the results of measurement in processed form to database
- determination of compliance with the values of measured parameters normalized values and the formation of conclusions about the technical condition of the object;
- alert signal formation in excess of the measured parameters
- receiving command signals to change the sensor sensitivity, duration and frequency measurement and synchronization;

In 1st level subsystem retrospective database (Figure 2) is presented which is reflecting a probability value of diagnosed parameters characterizing the degree of influence of the parameter on the technical condition and trends.

Subsystem of 2nd level provides:

- determination the type and level of developing defects;
- calculation of derivatives and dynamic diagnostic parameters;
- defining the retrospective diagnostic parameters;
- defining danger degree of developing parameters;
- subsystem algorithm change by top-level command;
- transmitting calculation results and the analysis to the database;
- forming the signal to change the operating mode of the object;

The evaluation of actual technical state is carried as it follows by (1).

Subsystem of the 3rd level provides an assessment of residual life of the object.

Based on the main tasks of technical diagnostics, primary act should be to identify the type of technical condition. When determine whether a fault and defect, next step is aimed on the determination of type of effect and the danger either to determine reasons of malfunction.

The object can be formed and develop explicit and implicit types of defects, but only obvious defects can be diagnosed. The implicit defect category refers to defect which cannot be determine due to the lack of method and means of detection.

Definition of the technical condition of parts and pieces of equipment and all kinds of disturbances in their functioning occurs with the use of diagnostic parameters. Diagnostic parameters are presented as a coefficient K, which is taking into account the step change in the boundaries of the parameter over time (Figure 4) and let forecasted parameter value can be estimated. Consequently, the amount of residual life of the electric drive τ defined as:

$$\tau = K_1 \cdot X_1 + K_2 \cdot X_2 + K_3 \cdot X_3 + \dots + K_n \cdot X_n \quad (2)$$

Where K_i – coefficient which is taking into account borders statement of i -th parameter with taking into account the defects detected at time t , and depending on the passport (reference) normal, pre-emergency and emergency conditions.

The databases of technical parameters of AC drive and dynamics of changes over time, the actual technical condition assessment and predictive value of the residual life will be the results of diagnostic system based on parametric analysis.

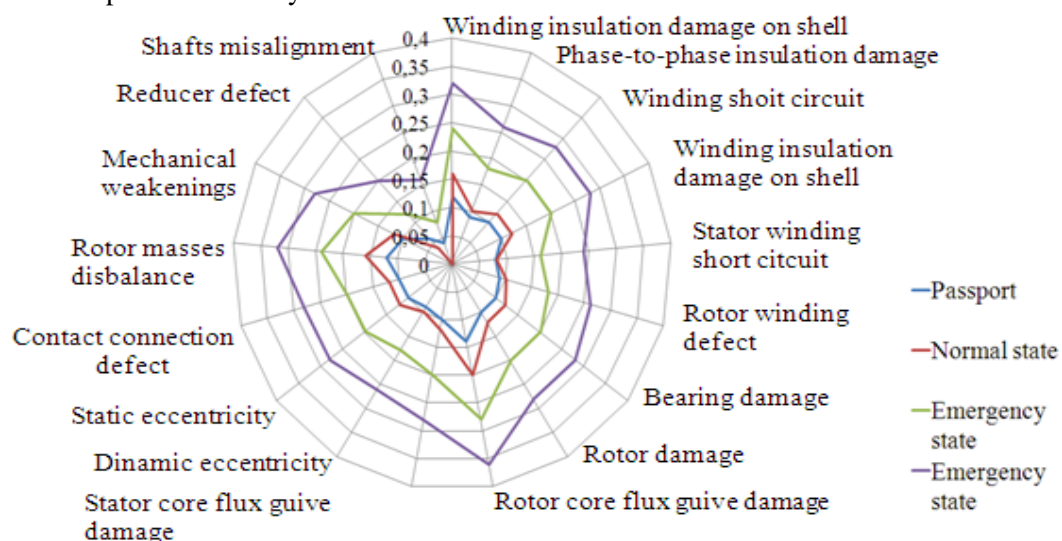


Figure 4. Electrical drive technical condition diagram

4. Economic feasibility.

Substantiation of economic efficiency is performed in the planning of monitoring and diagnostics of technical condition of electrical equipment. The basis of cost-effectiveness study is a technical and economic assessment in two variants of object exploitation: equipped with a system for monitoring and evaluation of residual life without additional equipment. The main indicators for determining the feasibility of the technical condition of the monitoring system and the reduction of production costs, are as follows:

- Forecasted derating of failure risk;
- lowering the cost of production due to the economic effect for maintenance

The effectiveness of implementation of monitoring and diagnostic system is evaluated against the value of reducing the total financial damage from possible accidents for the predicted time operation of the facility equipped with the monitoring system, to the value of its implementation and maintenance costs over the same period (figure 5). If the cost efficiency is not sufficient, then the re-development of the monitoring system to achieve acceptable performance for economic enterprise, provided that the security level is not reduced object, characterized by an indicator of risk.

The main costs in the implementation of the monitoring system:

- for purchasing and installation of the system on site;
- for the organization of an information control center to work with the data;
- for purchasing the appropriate computer equipment to the information center;

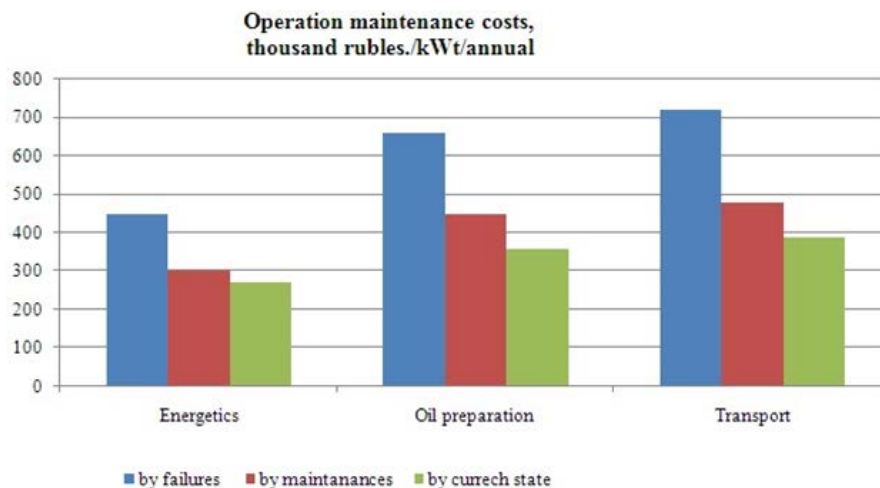


Figure 5. Specific operational costs for industries of basic equipment

5. Conclusion

The effectiveness of diagnostic systems depends on its equipment with devices for control of direct and indirect factors of loss of the resource that leads to the failure, and by the quality of the system, providing a high percentage of defects and damage detection and the keeping demanded operation efficiency.

The transition to a complex diagnostic system of electromechanical equipment with considering external factors will improve accuracy of the technical condition and residual life assessment, by conclusion of which the repairs and maintenance can be well-to-scheduled. Also it is economically feasible to extend the life of equipment.

Implementation of diagnostic system sand assessment of residual life of AC motor that leading today in electrical drive area of use, reducing enterprise costs of maintenance and repair, emergency response and operation of pre-emergency equipment.

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