Method for determining the power of squirrel-cage induction motors

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Abstract. Squirrel-cage induction motors are the main type of electric motors used for the electric motor drive of the working mechanism of industrial processes. The task of the electrical service of the enterprise is to control the engine power during operation and to prevent overloads or inefficient operations. In order to do that a non-contact method for determining the power of squirrel-cage induction motors is proposed. The method is based on the property of the mechanical characteristics of an induction motor, when with increasing the moment of resistance on the drive shaft, the rotor speed decreases in proportion to the load. Therefore, by measuring the rotor speed of the engine, it is possible to judge the degree of its load. To confirm this, experimental studies of axial fans were carried out. Linear supply voltage, winding current, active power, power factor and engine speed were used as the analyzed parameters of the motors. For more information about the state of the motor, in addition to analyzing the stator current, an analysis of the frequency of the supply voltage, as well as the input power, which is directly related to the current and supply voltage, was made. In the course of the experiments, a number of functional dependences of engine performance on its speed were obtained. It was established that tests are necessary for not only repaired engines, but also new ones to determine the optimal modes of its operation and identify production defects.

1. Introduction

Most electric motor drives of technical processes use squirrel-cage induction motors. More than half of these motors are loaded on average by 50-60 %, which leads to unproductive energy consumption [1, 2]. Furthermore, the inefficient use of induction motors is hindered by their irrational operation, overloads, and insufficient level of maintenance and repair. When using electric motors in agricultural production, an aggressive environment has a great influence on their reliability, as evidenced by the results of studies reported in some authors’ works [3].

In most cases all of these things lead to overheating of the engine, which most often occurs due to its overload by electric current, therefore, when the load is exceeded, it is necessary to reduce it to nominal, and when choosing an electric motor for the drive, ensure its rational loading. The task of the
The electrical service of the enterprise is to diagnose the engines during operation and prevent sudden failures, which in most cases lead to the shutdown of the entire technological process. Nowadays, a large number of methods and ways of their implementation [4-7], various stationary, built-in and portable diagnostic devices and diagnostic tools for electric motors and their individual elements have been developed [8-11].

Having analyzed the methods and ways for diagnosing failures of induction motors in various industries of their use, one can say that the diagnostics of motors during operation is quite time-consuming and in most cases access to the power supply of the motor or its shutdown for connecting devices is required.

In general, monitoring the current or power consumption of the motor allows not only to evaluate its efficiency, but also the technical condition. The assessment of engine power consumption during operation directly at the installation site without shutting down, for example, when controlling axial fans of livestock and poultry facilities, access to which in most cases is difficult, is a promising area of the research.

2. Materials and methods

To measure power in practice, special instruments are used [12, 13]. The simplest way to assess the load of an electric motor is to install an amperimeter in one of the phases or use current clamps. If the rated current is exceeded by 5%, continuous operation of the electric motor is unacceptable under the condition of heating. The difficulty of installing an amperimeter is one of the disadvantages of this method, since access to the terminal box or to the power supply for connecting devices is required.

Stationary appliances are mainly used for high power engines.

We have developed a method for determining the power of squirrel-cage induction motors during operation [14]. This method is based on the property of the mechanical characteristics of an induction motor, when with increasing the engine load, the rotor speed decreases, that is, the rotor slip increases and, as a result, the power consumption increases figure 1.

**Figure 1.** Mechanical characteristic of an induction motor with a designation of the investigated area.

Figure 1 shows the mechanical characteristic of an induction motor with a designation of the area under study and the main parameters. To assess the load, we propose to use such an indicator as “load degree $\varepsilon$”, which is calculated based on the measured operating speed of the induction motor.

The indicator is determined by the following formula:

$$\varepsilon = \frac{n_0 - n_{oper}}{n_0 - n_{nom}}$$  \hspace{1cm} (1)
where \( n_0 \) – synchronous speed, \( \min^{-1} \); \( n_{\text{oper}} \) – operating speed, \( \min^{-1} \); \( n_{\text{nom}} \) – nominal speed, \( \min^{-1} \).

This indicator “degree of loading \( \varepsilon \)” allows assessing the engine load in the process in relative units.

To identify the relationship of the proposed indicator \( \varepsilon \) with the performance of an induction motor, AIR71A6 motors with a power of 0.37 kW and a synchronous speed of 1000 \( \min^{-1} \) were selected. It is designed for continuous operation and is widely used to drive low-pressure fans of the VO series, which are most often used in ventilation outside the duct network of livestock buildings.

As a load, three-bladed, four-bladed and six-bladed fans made of aluminum and plastic were used (figure 2).

**Figure 2.** The appearance of the experimental setup.

Supply voltage, winding current, active power, network frequency, power factor and engine speed were analyzed as the studied parameters.

For experimental research, a set of diagnostic equipment was used, consisting of electric energy quality indicators (RESURS-UF2M) and a non-contact laser tachometer (MEGEON).

3. Results

According to the data obtained as a result of the researches, the functional dependences of power, current strength, power factor \( \cos \phi \) and the proposed indicator of the degree of load \( \varepsilon \) from the rotor speed of the engine were revealed. Figure 3 and figure 4 show the most informative interrelations of the obtained characteristics of an induction motor.

**Figure 3.** The value of the developed power of the engine and the degree on the rotor speed.
It is established that the rotor speed of the motor is directly proportional to its power on the drive shaft, as well as the current strength in the windings. Therefore, the use of the proposed indicator “degree of loading ε” will allow with a minimum error to evaluate the efficiency of the electric motor even at idle, since the power consumption in this case does not reflect its actual load. The dependence of the engine power factor on its speed is approximated by a polynomial dependence of the second degree with a high correlation coefficient.

4. Conclusion
The ability to control induction motors installed in inaccessible places simplifies the work of electrical personnel. Using the obtained functional dependences, it is possible to calculate the operation parameters of an induction motor from the engine speed with a sufficiently high reliability and predict failures. Not only engines in operation, but also new ones, need to be monitored to determine the optimal modes of their operation and to identify production defects. The proposed method for determining the power of squirrel-cage induction motors is simple to use: for an electrician it is enough to measure the rotor speed of a serviced motor using a non-contact tachometer and correlate it with the rated one regardless of its power and technical characteristics.

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