THE AMBIENT TEMPERATURE INFLUENCE ON INDUCTION MOTOR TIME-CURRENT CHARACTERISTICS

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Abstract. The article deals with the ambient temperature influence on acceptable operating time during induction motor overload. There were given recommendations to choose the setting for protection devices and diagnosing abnormal operating modes of induction motors.
Keywords: ambient temperature, induction motor, overload, time-current curve, electric power losses.

Introduction. The induction electric motors with a short-circuit rotor are widely used as drives of technological equipment. Therefore, the working machine reliability is more dependent on the electric motor reliability. Reliability is an important technical and economic indicator of the electric machine quality and determines its ability to reliably perform the functions assigned to it with unchanged technical characteristics for a given period of time under certain operating conditions. An induction motor has a fairly high reliability, however, they fail due to specific operating conditions, operating modes, wrong choice or hidden defects. As a result, the induction electric motor failure brings notable material loss.

Ambient temperature is an important factor affecting the operational an induction motor reliability, since it affects stator winding insulation thermal wear. The calculated temperature value is considered to be the excess of the ambient temperature ϑ_c = 40 °C. As a rule, at induction motor rated load and the ambient temperature up to ϑ_c the permitted insulation thermal wear does not exceed the standard value. However, in combination with the current overloads arising for various reasons, increased insulation thermal wear is possible even at temperatures significantly below 40 °C, which leads to its early failure.

To prevent the induction motor failure, protection and functional diagnostics devices are used. Their operation is based on various methods, however, the protection device must turn off the electric motor before the stator winding temperature rise reaches the permitted value τ_p, regardless the load multiplicity k. This dependence $\tau_p = f(k)$ is an overload characteristic [1]. To ensure the correct operation of protection devices it is important to establish the effect of ambient temperature on it.

The **main purpose** of the research is to establish the ambient temperature effect on induction motor overload characteristic and required recommendations for protection devices.

Outline of the main research material. A significant part of processes that affect the electric motor reliability leads to an increase in insulation temperature and its aging. The winding temperature affects the state of the electrical machine insulation resistance and determines its service life. The induction motor heating equation is determined by the equation [2]:

$$\tau = \tau_e\left(1-\exp\left(-\frac{t}{T}\right)\right)+\tau_0\exp\left(-\frac{t}{T}\right), \quad (1)$$

where τ_e – established exceedances of the winding temperature (°C); t – current time (s); T – time constant of heating winding (s); τ_0 – initial temperature rise of the electric motor, (°C).

If to set the permitted temperature rise value of the motor winding τ_e, then with a greater multiplicity of the load current, the temperature rise will reach in a shorter time. To calculate this dependence let us accept values $\tau = \tau_p$, $t = t_p$, $\tau_0 = 0$ and substitute it to (1):

$$\tau_p = \tau_e \left(1 - \exp\left(-\frac{t_p}{T}\right)\right), \tag{2}$$

$$t_p = T \ln \frac{\tau_e}{\tau_e - \tau_p}. \tag{3}$$

The expression for the established temperature rise of the electric motor, in which the influence of the ambient temperature is taken into account, has the form:

$$\tau_e = \tau_n \frac{a + k^2\left(1 + \alpha(\vartheta_a - \vartheta_c)\right)}{a + 1 - \alpha\tau_n k^2}, \tag{4}$$

where a – motor loss factor; k – load multiplicity; α – temperature coefficient (1/°C); ϑ_a – ambient temperature (°C); τ_n – rated temperature rise of the motor (°C).

$$a = \frac{\Delta P_n}{3\gamma r_{1n} I_n^2} - 1, \tag{5}$$

where ΔP_n – induction motor active power losses in nominal mode [3] (W); γ – active power loss factor in the rotor winding; r_{1n} – resistance of the phase winding (Ohm); I_n – rated current of the electric motor (A).

Active power losses in nominal mode is determined by the equation:

$$\Delta P_n = \frac{P_{2n}}{\eta_n} - P_{2n}, \tag{6}$$

where P_{2n} – rated power (W); η_n – rated efficiency.

Induction motor load multiplicity:

$$k = \frac{I}{I_n}, \tag{7}$$

where I – effective value of electric current (A); I_n – rated effective value of electric current (A).

Permitted temperature rise equation is

$$\tau_p = 1{,}05 \cdot \tau_n. \tag{8}$$

Taking into account the above algorithm, the time-current curves $\tau_p = f(k)$ of the electric motor at different ambient temperatures ϑ_a are calculated. As an example, the overload characteristics of the motor АИР180М4У3 are shown at Fig. 1.

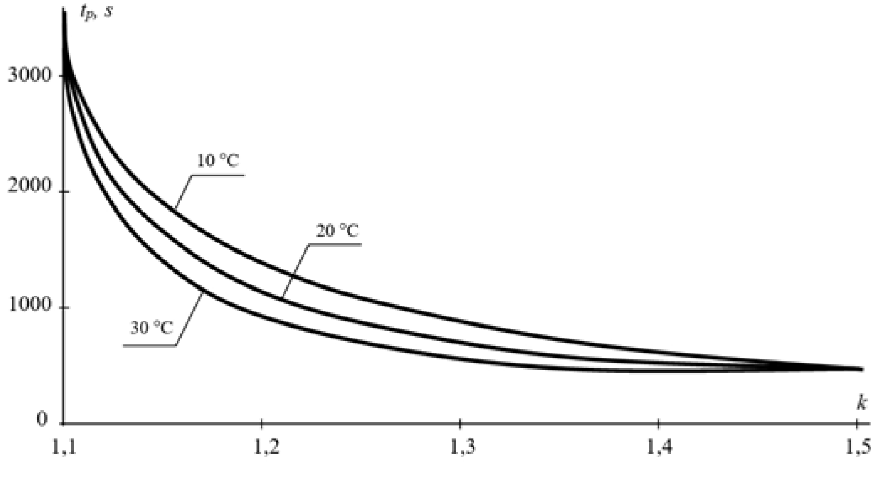

Fig. 1. The induction motor time-current curves $\tau_p = f(k)$

Conclusions. As can be seen from the obtained curves $\tau_p = f(k)$ at lower ambient temperatures, higher overloads are allowed. For example, the difference in the permitted operating time t_p at ϑ_a = 10 °C and 30 °C under load multiplicity k = 1,25 reaches 200-300 s. So it is possible to allow 5% overload for every 10 °C at ambient temperatures below 40 °C and put this correction when calculating the response time of motor protection devices. There is practically no difference at high overloads and temperature correction may not be counted.

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