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ANALYSIS OF THE ELECTRIC PARAMETER OF THE ELECTRIC MOTOR IN ORDER TO INCREASE ENERGY EFFICIENCY

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Abstract:
The article covers the analysis of electric parameter of the electric motor, values of energy consumption in implementation of mechanical engineering technological processes and the algorithm of automatic control.

Keywords: Technological process, energy consumption, compensation current, automated control algorithm, energy efficiency, energy intensity, active and inductive resistance, L-shaped circuit, electric motor power

The problem of increasing energy efficiency is relevant mainly for energy-intensive industries. In this article, we will analyze the electrical parameters of the electric motor, first of all, the values of power consumption during the implementation of machine-building technological processes of mechanical engineering production, the currents consumed in this case and the power coefficients on the L-shaped equivalent circuit for one phase of the electric motor (Fig. 1), considering the electromagnetic processes occurring in the motor (x_0,x_1,x_2'), thermal processes in the core and its windings (r_0,r_1,r_2') and the load on its shaft (S) [2].

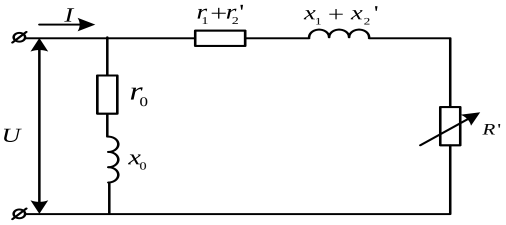

Fig. 1. L-shaped equivalent circuit of asynchronous motor

where $R' = r_2'*(1-s)/s$, $s = (n_0 - n)/ n_0$ is sliding, $n_0 = 60*f/p$ is synchronous speed, f is supply voltage frequency, p is number of pole pairs, n is motor rotation speed, U is phase voltage, and I is phase current.

To simulate the process, we determine the active and inductive resistance of the magnetizing circuit of the asynchronous motor.

$$q_0 = \frac{r_0}{r_0^2+x_0^2} \quad ; \quad b_0 = \frac{x_0}{r_0^2+x_0^2}.$$

Next, we determine the total active resistance of the stator phase and the rotor resistance reduced to the stator winding, as well as the total inductive phase resistance of the stator winding and the rotor inductive reactance reduced to the stator winding.

$$q_1 = \frac{r_1+r_2'+R\prime}{\left(r_1+r_2'+R\prime\right)^2+\left(x_1+x_2'\right)^2} \quad ; \quad b_1 = \frac{x_1+x_2'}{\left(r_1+r_2'+R\prime\right)^2+\left(x_1+x_2'\right)^2}.$$

After that, we will determine the total active and inductive resistances of the L-shaped equivalent circuit of the asynchronous motor.

$$q_\Sigma = q_0 + q_1 = \frac{r_0}{r_0^2+x_0^2} + \frac{x_1+x_2'}{(r_1+r_2'+R')^2+(x_1+x_2')^2},$$
$$b_\Sigma = b_0 + b_1 = \frac{x_0}{r_0^2+x_0^2} + \frac{x_1+x_2'}{(r_1+r_2'+R')^2+(x_1+x_2')^2}.$$

After that, the equivalent values of the active and reactive resistance of this circuit, determined by the following dependencies

$$R_э = \frac{q_\Sigma}{{q_\Sigma}^2+{b_\Sigma}^2}, \qquad X_э = \frac{b_\Sigma}{{q_\Sigma}^2+{b_\Sigma}^2}.$$

After the transformation, the values of the equivalent active ($R_э$) and reactive ($X_э$) resistances of this circuit have been obtained.

$$R_э = \frac{r_0[(r_1 + r_2{}' + R')^2 + (x_1 + x_2{}')^2] + (r_1 + r_2{}' + R')(r_0^2 + x_0^2)}{(r_1 + r_2{}' + R')^2 + (x_1 + x_2{}')^2 + r_0^2 + x_0^2 + 2r_0(r_1 + r_2{}' + R') + 4x_0x_1},$$

$$X_э = \frac{x_0[(r_1 + r_2{}' + R')^2 + (x_1 + x_2{}')^2] + 2x_0(r_0^2 + x_0^2)}{(r_1 + r_2{}' + R')^2 + (x_1 + x_2{}')^2 + r_0^2 + x_0^2 + 2r_0(r_1 + r_2{}' + R') + 4x_0x_1}.$$

Further, based on the simplified dependences of the values of the energy consumption parameters given below, it is possible to analyze the impact of reducing the load on these parameters [1].

$$I = \frac{U}{\sqrt{R_э{}^2 + X_э{}^2}} \quad ; \quad cos\varphi = \frac{R_э}{\sqrt{R_э{}^2 + X_э{}^2}} \; ; S = \sqrt{3} \times I \times U \quad ; \quad P = \sqrt{3} \times I \times U \times cos\varphi.$$

These values allows analyzing the electrical parameters of electric motor, under the assumption that the working section of the mechanical characteristic was taken to be straight. The analysis was carried out using the Mathcad program and showed that with a decrease in the load relative to the nominal load by 2 times, with a general decrease in the current consumed for the implementation of the technological process from 20.20A to 12.17A, its excess relative to the required value was 23% (the excess at nominal load was 13 %). At the same time, the energy intensity of the technological process increased by 29%. Thus, with a general decrease in currents consumed for the implementation of technological processes, relative to the nominal values, the energy intensity of technological processes increases, since the relative value of the reactive component of these currents increases. To build an algorithm for the functioning of an automated energy saving control system, the power coefficient was chosen as a control parameter. To determine the values of the power coefficient, it is necessary to determine the values of the consumed current and voltage in the network, and it is necessary to know the value of the phase angle between these parameters. To implement the algorithm for the automated control of energy saving of technological processes of shaping, it is necessary to determine the specified power coefficients: the required value - at which the implementation of the technological process will take place in the mode of maximum energy efficiency, the critical value - the value of which the power coefficient should not exceed. The latter is necessary to avoid the overcompensation effect, which in turn leads to a decrease in energy efficiency of the process and increase in losses.

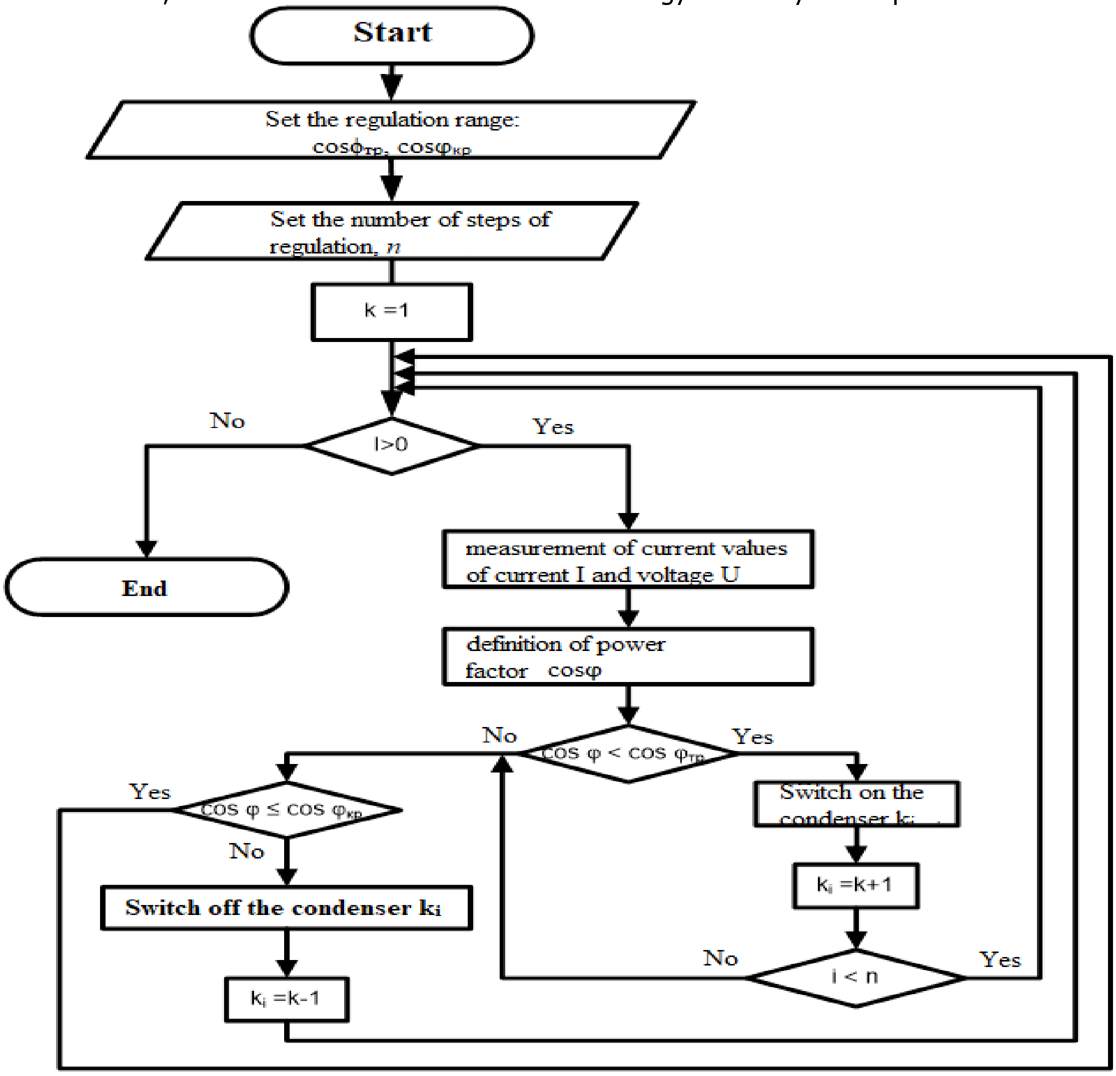

Fig. 1 Algorithm of automated control of energy intensity of mechanical engineering technological processes.

Regulating range is determined by the minimum value of the power coefficient (at no load of the electric motor of the machine) and the required value. This range is divided into n steps of regulation, each of which is assigned a corresponding capacitor capacity. The obtained value of the power coefficient is compared with the required value and, if it is lower, a capacitor is connected. The new values of the power coefficient are read out and, if necessary, additional capacitors are connected [3]. In cases where the current value of the power coefficient is greater than or evenly required, as well as in cases where all capacitors are already connected, it is necessary to check for exceeding its critical value. If the critical value is exceeded, it is necessary to disconnect the capacitor. This is necessary in order to avoid the overcompensation effect, which leads to a decrease in the energy efficiency of the technological process. With the correct selection of the capacitance of the capacitors and the number of control steps, the efficiency of the proposed circuit should tend to 100%, i.e. the power coefficient of the technological process of shaping should tend to 1. The proposed algorithm can significantly increase the energy efficiency of technological processes of shaping, by reducing the reactive component of the power consumption, and as a result, increasing the power coefficient. This algorithm allows considering such a feature of technological processes as a wide spread of load characteristics during their implementation and to avoid the effect of overcompensation. Besides, this algorithm can be used by local automated energy management systems, i.e. in relation to specific units of machine tool equipment

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