ROTATION ADJUSTING METHODS OF AN ASYNCHRONOUS MOTOR WITH A WOUND ROTOR

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Introduction. Asynchronous motors are the basis of modern alternative current (AC) electric drives. The operating efficiency of this electric drive is largely determined by the speed control capabilities. The capabilities of asynchronous motors with regard to regulating the rotor speed are determined by the slip definition expression. From this expression it follows that the rotation speed can be controlled in three ways: by changing the frequency, the number of pole pairs and slip [1].

Asynchronous motors have a three-phase stator winding (three separate windings), which can form a different number of pairs of magnetic poles depending on its design, which in turn affects the rated speed of the motor at the rated frequency of the three-phase supply voltage. At the same time, the rotors of motors of this type may differ, and for asynchronous motors they can be squirrel-cage or phase.

The alternating current passing through the stator windings, generating a rotating magnetic field, induces current in the closed circuits of the “squirrel cage” and the entire rotor begins to rotate, since at each moment of time different pairs of rotor rods will have different induced currents: some rods are large currents, some smaller, depending on the position of certain rods relative to the field. And the moments will never balance the rotor, so it will rotate while alternating current flows through the stator windings.

Asynchronous motors are always characterized by slip, which occurs due to the fact that the synchronous frequency of the rotating magnetic field of the stator is higher than the actual rotor speed.

If the rotor rotated at the synchronous frequency of the stator's magnetic field, then no current would be induced in the rotor bars, and the rotor simply would not rotate. Therefore, the rotor in an asynchronous motor never reaches the synchronous rotation speed of the stator magnetic field, and always lags at least slightly (even if the load on the shaft is critically small) behind the synchronous frequency.

Asynchronous motors with a wound rotor, unlike asynchronous motors with a squirrel-cage rotor, have a full three-phase winding on the rotor. Just as a three-phase winding is laid on the stator, a three-phase winding is laid in the slots of the phase rotor.

The terminals of the wound rotor winding are connected to slip rings mounted on the shaft and isolated from each other and from the shaft. The wound rotor winding consists of three parts - each for its own phase - which are most often connected in a star configuration [2].

An adjusting rheostat is connected to the rotor winding through slip rings and brushes. Cranes and elevators, for example, are started under load, and here it is necessary to develop a significant operating torque. Despite the complexity of the design, asynchronous motors with a wound rotor have better adjustment capabilities regarding the operating torque on the shaft than asynchronous motors with a squirrel-cage rotor, which require an industrial frequency converter.

The stator winding of an asynchronous motor with a wound rotor is carried out in the same way as on the stators of asynchronous motors with a squirrel-cage rotor, and in a similar way creates, depending on the number of coils (three, six, nine or more coils), two, four, etc. poles. The stator coils are shifted among themselves by 120, 60, 40, etc. degrees. In this case, the wound rotor has the same number of poles as the stator.

In practice, for each type of asynchronous motors, preference is given to certain methods of speed control [3].

The aim of the work is to compare the possible methods for regulating the rotation frequency at the same values of demand on the application of an asynchronous motor with a wound rotor by using calculations for the characteristics *M(n)* for regulation methods which were choosen.

Materials of research. The core power of an asynchronous motor is the mechanical tension, which is determined through mechanical parameters

$$P_2 = M \times \Omega = \frac{2\pi \times M \times n}{60}$$

Simultaneously, the characteristics of the stator $n(I_2)$ winding are analyzed, which means the active support of the stator winding is

$$R_2 = \frac{M_N \times \Omega_0 \times s_N}{3I_{2N}^2}$$

For the purpose of the characteristics, the value of the flow is adjusted when changing the value of the sliding from 0 to 1.

To expand the artificial characteristics consider using the Kloss formula when changing the value of the sliding in the same range.

The calculation of the *M(n)* characteristic when changing the value of the input voltage U_1 is determined by the formulas

$$U_1' = U_1 \times q_1$$

$$M_{max}' = M_{max} \times q_1^2$$

which show that for a given value of sliding the change of the input voltage does not affect the rotation frequency of the rotor, but rather flows to the value of the rotational moment, which is in quadratic occurrence.

The calculation of the characteristics when entering the rotor winding of the rotor additional resistance is carried out according to the formulas

$$s_{max}' = \frac{s_{max}}{(R_2 + R_{ad})}$$

$$n_{max}' = n_0(1 - s_{max}')$$

from which it is seen that the critical sliding and the critical speed of rotation depend on the change in the magnitude of additional resistance, and the value of the maximum moment does not depend. Therefore, with an arbitrary change in the magnitude of the additional resistance of the maximum and nominal moments of the asynchronous engine remain unchanged. In the work area the characteristic becomes more soft and the value of the critical speed of rotation decreases ($n_{max}' < n_{max}$).

The calculation of the characteristic *M(n)* when changing the frequency of the current of the power source and the constancy of the ratio of the input voltage to the specified frequency (those a change of the value of the frequency automatically causes a change of the value of the voltage) is carried out according to the formulas

$$M_{max} = \frac{3U_1^2}{2\Omega_0\left(R_1 + \sqrt{(R_1^2 + X_k^2)}\right)} = \frac{3U_1^2}{2\Omega_0 \times X_k} = \frac{K \times U_1^2}{f_1^2}$$

$$\Omega_0 = \frac{2\pi n_0}{60} = \frac{2\pi f_1}{p}$$

$$X_k = X_1 + X_2' = \omega L = 2\pi f_1 L$$

where n_0 is the frequency of rotation of the magnetic field, f_1 is the frequency of the current in the power supply network, p is the number of pairs of poles in the asynchronous motor for which we are calculating, Ω_0 is the angular frequency of rotation of the magnetic field.

As can be seen from the formula the rotation frequency of the field is directly proportional to the current frequency in the network, that is, with a decrease in the current frequency, the rotation frequency also decreases.

When adjusting the rotation frequency it is desirable that the value of the maximum moment remains unchanged. For this puprose it is necessary to simultaneously reduce the frequency of the current in the network to reduce the input voltage in such a way that $U_1/f_1=const$.

At the same time, the values of the maximum and nominal moments, and therefore their ratios $\lambda=M_{max}/M_N$ will remain unchanged.

Conclusions. Based on the results of the researches, the following conclusions can be made: 1) on the example of an asynchronous motor with a phase rotor, it is shown that the speed control option for the indicated type of motors, in contrast to the type of motors with a short-circuited rotor, most often involves the inclusion of additional resistance in the rotor winding circle; 2) the main methods of regulating the rotation speed of asynchronous motors with a phase rotor include: changing the voltage of the power source, changing the frequency of the current of the power network, introducing additional resistance into the rotor winding circle; 3) for a given value of sliding the change of the input voltage does not affect the rotation frequency of the rotor, but rather flows to the value of the rotational moment, which is in quadratic occurrence; 4) with an arbitrary change in the magnitude of the additional resistance of the maximum and nominal moments of the asynchronous engine remain unchanged and in the work area the characteristic becomes more soft and the value of the critical speed of rotation decreases ($n_{max}'<n_{max}$); 5) with a decrease of the current frequency, the rotation frequency also decreases; it is necessary to reduce the input voltage in way of $U_1/f_1=const$.

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