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DETERMINATION OF THE MAXIMUM TIME OF DISCONNECTION OF AN INDUCTION MOTOR FROM THE MAINS IN THE EVENT OF VOLTAGE FAILURE

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Annotation. *The work investigated the behavior of an induction motor when the supply voltage disappears and its value changes. Analysis of the results shows that the permissible time of voltage dip depends on the total moment of inertia of the moving parts, and to a large extent on the magnitude of the voltage dip. Even in the complete absence of voltage during the dip period, the permissible time interval is not zero due to the presence of a moment of inertia, which prevents the engine rotor from stopping instantly.*

Keywords*: induction motor, torque, rotation speed, motor supply voltage, voltage dip.*

With a sudden temporary decrease in voltage supplied to an induction squirrel-cage motor operating at rated load, a decrease in the electromagnetic torque occurs. A decrease in torque leads to braking of the rotor under the influence of a load torque that is constant in magnitude. If the reduced electromagnetic torque becomes less than the load torque, then the angular velocity begins to decrease [1]. The slip increases and exceeds the nominal value. When the voltage is restored to the nominal value, the full electromagnetic torque appears and the motor accelerates again. This is possible if the speed loss is not too great and the restored torque value is greater than the load torque.

Naturally, the problem arises of determining the limit of permissible speed loss, which corresponds to the moment M_x and a certain slip value s_x. The angular speed of the motor is determined by the excess torque, which is calculated as [2]

$$\Delta(\omega) = Mn - Mx$$

With a constant load resistance, the change in dynamic torque is $\Delta(\omega) = Jd\omega/dt$, where J is the sum of the moments of inertia of all rotating masses reduced to the axis of rotation of the rotor [3].

The dependence of time on angular velocity has the form $t = J\int d\omega/\Delta(\omega)$. In relative units we obtain $t = J\omega_n/M_n\int d(\omega/\omega_n)/\Delta(\omega/\omega_n)$, where $J\omega_n/M_n$ - depends on the parameters of the engine and the mechanisms coupled to it, has the dimension of time. The ratio $J\omega_n / M_n$ can be represented as a time constant (T_a). If $\omega/\omega_n = \upsilon$ is the relative angular velocity, then the time is found as $t = T_a \int d\upsilon/\Delta(\upsilon)$, here T_a is the time constant associated with the change in angular velocity.

Because the rotor acceleration is equal to $ds/dt = - d\upsilon/dt$, then we can determine the time required to change the angular velocity or slide from s_n to s_x under the influence of an excess torque in the load resistance over the torque . The duration of the voltage change should not exceed this interval, otherwise the engine will stop. The required limiting time is determined from the expression $t = -T_a \int ds/\Delta(\omega)$, within the limits of the slip change from s_n to s_x [4, 5]. *The* value

$$\Delta(\omega) = M\text{н} - Mx = M\text{н} \cdot (1 - Mx / M\text{н})$$

should be associated with the critical moment $M\text{кр}$ and the ratio $M/ M\text{кр}$.

As the voltage decreases, the ratio of torques is proportional to the ratio of the squares of the corresponding voltages

$$M_x / M_n = (U_x / U_n)^2 .$$

Then

$$M_x / M_n = M_{cr} / M_n \cdot (U_x / U_n)^2 \cdot 2 / [s / s_{cr} + s_{cr} / s] = 2\mathbf{k} / [s / s_{cr} + s_{cr} / s] .$$

The value $\mathbf{k} = M_{cr} / M_n \cdot (U_x / U_n)^2$ means the ratio of the maximum torque at reduced voltage to the torque at full voltage [6]. Putting the obtained relations into the formula for determining the required time, we obtain $t = T_a \cdot \tau$, where τ is a coefficient equal to the relative time of speed loss, depending on $\mathbf{k}$ *,* as well as on the ratios and values of slip and critical slip.

However, it is enough to equate Mn to the moment of load resistance, we arrive at the equation

$$s / s_{cr} + s_{cr} / s = 2 M_{cr} / M_x \text{ or } s^2 - 2 M_{cr} / M_x \cdot s_{cr} s + s^2_{cr} = 0$$

The solution to a quadratic equation has two roots s_n and s_x :

$$s_{n,x} = s_{cr} M_{cr} / M_x \pm \sqrt{(s_{cr} M_{cr} / M_x)^2 - s^2_{cr}} .$$

The angular velocity may decrease significantly from its original value and then automatically increase to its previous value after restoration of the rated voltage.

Analysis of the relationship for τ shows that the relative time of speed loss depends only on M_{cr} / M_x and on the coefficient $\mathbf{k}$. The value of $\mathbf{k}$ is determined by the values of the relative maximum torque at full voltage and the relative decrease in voltage.

A 4A250M4 engine with a power of 160 kW was taken for analysis.

The calculation was carried out for the mechanical moments of inertia of the moving parts, equal to the double value of the moments of inertia of the motor rotor in the first case and the maximum permissible value calculated according to [1] for the second case:

$$J_{d.\,max} = k \cdot k_m \cdot P_{nom}^{\ v} \cdot p^{\,y} ,$$

where P_{nom} - rated engine power;

p – number of pairs of poles, equal to 2 for all cases;

k , k_m , v , y - coefficients and exponents are taken according to table 3.6 [1].

The calculation procedure is as follows:

- based on the engine characteristics, the maximum and nominal value of the mechanical torque, nominal and critical slip are calculated;
- the voltage is calculated at which the maximum motor torque will be less than

the rated load torque;

- at a certain value of the moment of inertia for the voltage range from 0 to that obtained in the previous paragraph, the permissible duration of the voltage dip is calculated;
- the next value of the moment of inertia is accepted, the calculation is repeated.

In Figure 1 shows the dependences of the mechanical characteristics at various stress values. The limiting voltage is 0.6Unom.

Figure 2 shows the acceleration characteristics of the motor at various voltages. You can determine the start time and the value of the rotor speed at any time. Figure 3 shows how much the rotor speed will decrease when the motor supply voltage disappears at different load moments.

Analysis of the results shows that the permissible time of voltage dip depends on the total moment of inertia of the moving parts, and to a large extent on the magnitude of the voltage dip.

Even in the complete absence of voltage during the dip period, the permissible time interval is not zero due to the presence of a moment of inertia, which prevents the engine rotor from stopping instantly.

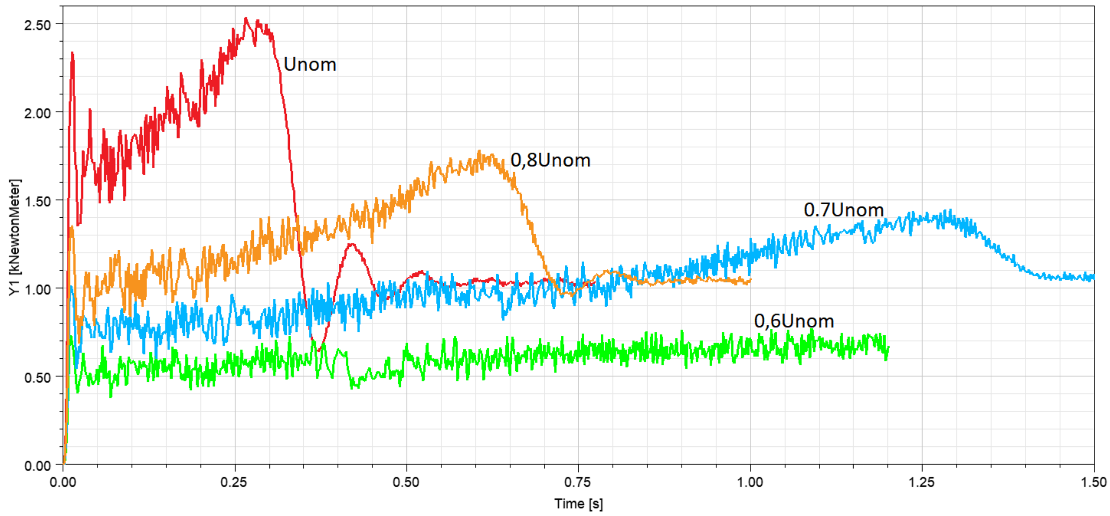

Fig.1. Mechanical characteristics at various voltages

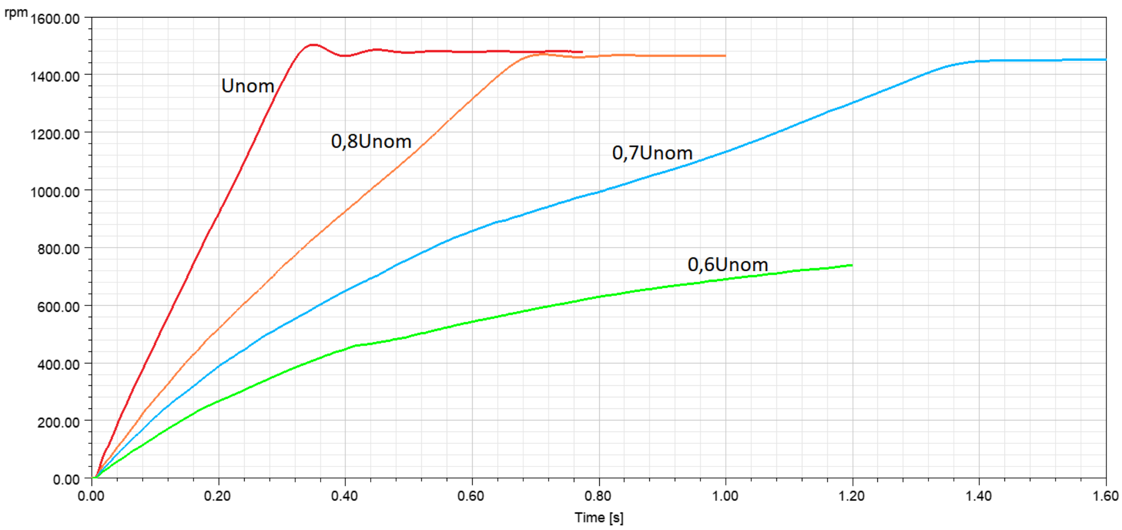

Fig.2. Starting characteristics at various voltages

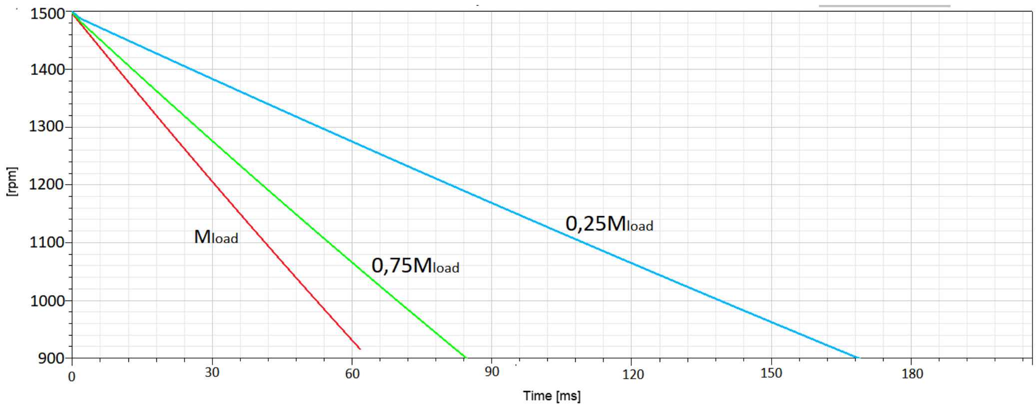

Fig.3. Characteristics for determining the rotor speed during a power failure

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