Modeling the dynamic characteristics of a high voltage asynchronous electric motor

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Abstract. Mathematical models of the individual modules of the complex electrical load node are considered. A review of the well-known method of calculating the dynamic characteristics of the asynchronous motor (AM) supplemented with new analytical dependencies allowed us to explore the process of its launch with compensating devices in different voltage values in the power networks for supply and distribution. The analysis of the results of mathematical modeling of the dynamic characteristics and electromagnetic compatibility of the asynchronous motors of the extruder large unit capacity of 5.7 MW in steady and transient conditions with other power consumers considered node load.

1. Formulation of the problem
Ensuring the necessary electromagnetic compatibility of power consumers connected to one node entails a reduction in the loss of electric energy in the steady state and a saving in financial costs for these losses while maintaining the technological mode of the company. Presented are results of modeling the dynamic characteristics of a high-voltage asynchronous electric motor (the same type which created the need for this research because of problems that arise when it is started up) and to develop measures to ensure electromagnetic compatibility with other electrical receivers.

As an object of research, an electric load unit was selected, shown in figure 1, from which can be marked modules of an extruder with a capacity of 5700 kW, a cooling tower water pump with a capacity of 500 kW, a cooling tower fan with a capacity of 75 kW. At the same time, the research object and individual modules retain all the functional properties and communications in a hierarchical order with the general power supply system of the enterprise.

In the distribution electric network, it is proposed to additionally connect the devices of the series compensation at the end of the cable lines of the plots Ab and dg, and the device of the transverse compensation in points d, g, j, and an equivalent electrical load in points d and f.
2. Simulation results

As a result of mathematical modeling of the voltage mode and power consumption of high-voltage AM, a rational voltage level is determined equal \( U_R = 0.997 \approx 1.0 \) r.u., which is advisable to automatically stabilize the power supply center (point A, Fig. 1) with a dead-band of \( \pm 2\% \) [2].

When realized, the automatic stabilization of a rational level of voltage in the power center, it is necessary to check the possibility of a guaranteed start-up and electromagnetic compatibility of the drives of the electrical complexes of the load node at the lower and upper voltage limits determined by the dead zone of the regulator drive under load. To solve the task, the systems of differential equations are made that describe the equivalent circuits of electrical complexes of the extruder, water pump and cooling tower fan, taking into account new elements and their connections.

The general system of differential equations, taking into account the influence of compensating settings, will look like [1]:

\[
\begin{align*}
\vec{U}_c &= \vec{U}_s; \\
\vec{U}_0 &= R_L \vec{I}_0 + L_L \left( \frac{d}{dt} \vec{I}_0 + j\omega_0 \vec{I}_0 \right) + \vec{U}_{DSC} + \vec{U}_c; \\
\vec{I}_0 &= C_{DSC} \left( \frac{d}{dt} \vec{U}_{DSC} + j\omega_0 \vec{U}_{DSC} \right); \\
\vec{I}_s &= \vec{I}_0 - C_c \left( \frac{d}{dt} \vec{U}_c + j\omega_0 \vec{U}_c \right).
\end{align*}
\]

Figure 1. Single-line power supply scheme of the object of research: DSC - the device of the series compensation; DTC - the device of the transverse compensation; AM - asynchronous motor.
\[
\vec{U}_c = \vec{I}_r \vec{R}_s + \frac{d\vec{\psi}_s}{dt} + j\omega\vec{\psi}_s; \quad 0 = \vec{I}_r \vec{R}_r + \frac{d\vec{\psi}_r}{dt} + j\omega\vec{\psi}_r.
\]

As a result of the mathematical modeling of the direct start-up process of the high-voltage AM 5700 kW, we obtained graphs of the dependences of current, and electromagnetic moment for the given parameters: voltage level and resistance moment. The results of this mathematical simulation are presented in the form of dependency graph (figure 2), which determine the time the asynchronous motor reaches the steady state, and the duration of the voltage dip.

![Figure 2. The graph of the current when starting a high-voltage asynchronous motor 5700 kW at rated voltage.](image1)

![Figure 3. The graph of the current dependence of a 500 kW high-voltage asynchronous motor with a voltage dip in the distribution network of up to 30% at the time of completion of the start-up of this motor without compensation.](image2)
Figure 4. The graph of the current dependence of a 500 kW high-voltage asynchronous motor with a voltage dip in the distribution network of up to 30% at the time of completion of the start-up of this in the presence of compensating devices.

Figure 5. The graph of the current dependence of a 75 kW low-voltage asynchronous motor with a voltage dip in the distribution network of up to 30% at the time of completion of the start-up of this motor without compensation.

Figure 6. The graph of the current dependence of a 75 kW low-voltage asynchronous motor with a voltage dip in the distribution network of up to 30% at the time of completion of the start-up of this in the presence of compensating devices.
The analysis of the obtained dependency graphs shows that stable operation of engines with a power of 500 kW and 75 kW is guaranteed, while taking into account the voltage drop in the network by 30% due to the start of the high-voltage asynchronous motor of the extruder in the presence of compensating devices in the circuit. In the absence of these compensation devices, the engines stall at the time of starting the asynchronous motor of the extruder.

References
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