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DEVELOPMENT AND VERIFICATION OF DYNAMIC ELECTROMAGNETIC MODEL OF ASYNCHRONOUS MOTOR OPERATING IN TERMS OF POOR-QUALITY ELECTRIC POWER

Several approaches are known which help take into consideration parameters of supply voltage while modeling processes in electromechanical systems [1]. In terms of nonsinusoidality of supply voltage in classic variant, its spectrum analysis is performed; then, the required equations are represented for each harmonic taking into account its amplitude and phase. Those equations are solved either analytically or numerically; the necessary value is found as a geometrical total of all the harmonic constituents.

In case of asymmetry of supply voltage, symmetrical component method is applied. Disadvantage of the approach is in considerable complication of the system of equations describing the object. Besides, in case of nonsinusoidal power, it is required to determine symmetric constituents for each considered harmonic. Then, if there will be, for instance, 10 of them in terms of asymmetric power, we will have to develop 30 equations for each basic equation describing the system. To simplify their representation, it is proposed to use differential equations set down relative to space-time complexes (STC) [2].

Space-time complex, so-called generalized vector, is calculated for each variable value Y as follows:

$$\mathrm{Y} = \frac{2}{3}\left(\mathrm{Y}_\mathrm{A} + \alpha \mathrm{Y}_\mathrm{B} + \alpha^2 \mathrm{Y}_\mathrm{C}\right), \tag{1}$$

where Y_A, Y_B, Y_C are values of the considered variable in terms of phases. Projections of that complex within the axis of phases correspond to the indicated values.

Being set down relative to STC, Park-Gorev equations [2] which are the basis for a known AM models are of as follows:

$$\underline{\mathrm{U}}_1 = \underline{\mathrm{I}}_1 \mathrm{R}_1 + \underline{\mathrm{I}}_0 \mathrm{R}_0 + \frac{d\underline{\Psi}_1}{dt}, \tag{2}$$

$$0 = \underline{\mathrm{I}}_2 \mathrm{R}_2 + \underline{\mathrm{I}}_0 \mathrm{R}_0 + \frac{d\underline{\Psi}_2}{dt} - j\omega_\mathrm{m} \underline{\Psi}_2, \tag{3}$$

where $\underline{U}_1$ is STC of stator voltage, $\underline{I}_1, \underline{I}_2, \underline{I}_0$ are STC of currents of stator, rotor, and magnetizing current, $\underline{\Psi}_1, \underline{\Psi}_2$ are STC of stator and rotor flux linkages, ω_m is angular velocity of AM rotation, and R_1, R_2 are active stator and rotor resistances.

It should be taken into consideration that core saturation effects considerably both dynamic and power indicators of asynchronous motors. A phenomenon of saturation is stipulated by boundary orientation of magnetic dipoles within the material of the latter and, thus, termination of the magnetic flux increase along with the growth of magnetizing current as it is shown in Fig.1 [3].

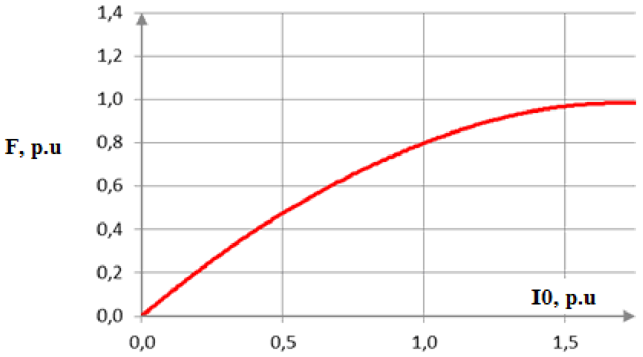

Fig. 1 Dependence of main magnetic flux upon magnetizing current

There are various methods to consider that effect [4]. Use of dependence of main mutual induction upon a value of magnetizing current L_{12}=f(I0) makes up the best combination of accuracy and simplicity of the calculation. For instance, [5] represents dependence of induction upon magnetizing current for asynchronous motors of general-purpose industrial version (Fig.2).

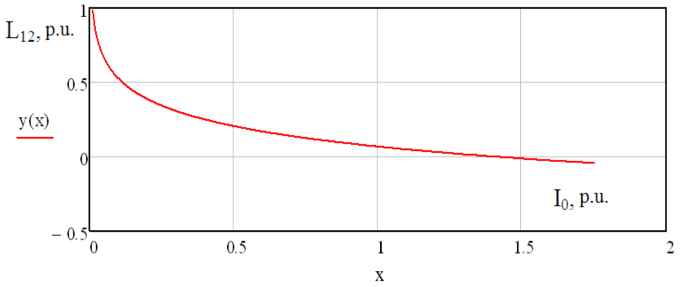

Fig. 2 Dependence of main induction upon magnetizing current

Such dependence may be described by polynomial functions of even degrees [5]. Induction value of a magnetizing branch without consideration of saturation effect is represented in reference literature or it may be determined roughly according to the results of no load test . Determination of coefficients of polynomial induction dependence upon the value of magnetizing current is an independent task. We took equation from [6] to perform modeling.

Thus, it is necessary to set down following things in the equation for flux linkage determination:

$$\underline{\Psi}_1 = \underline{I}_1 \cdot L_1 + L_{12}\left(I_0\right) \cdot \underline{I}_2 , \tag{4}$$

$$\underline{\Psi}_2 = \underline{I}_2 \cdot L_2 + L_{12}\left(I_0\right) \cdot \underline{I}_1 \tag{5}$$

Fig. 3 demonstrates structural diagram of the modeling object; the diagram expresses equations (2) and (3) taking into account (4) and (5).

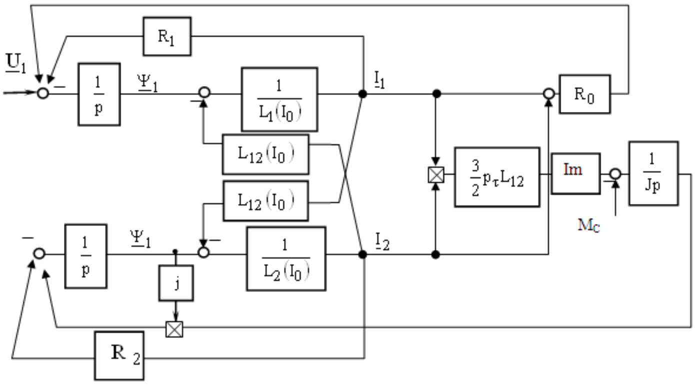

Fig.3 Structural diagram of asynchronous motor as a modeling object

Use of time-space complexes is characteristic for numerous models. Since they take into consideration instantaneous currents and voltages, there is no necessity in spectrum analysis and setting down equations for each harmonic. In addition, as such equations are contract representation of the three phases, they take into account possible asymmetry of supply voltage as well. The system under consideration is, actually, a universal model making it possible to analyze processes both in steady-state and transient modes (pulse, running-down, load change).

Analytical solution of system of equations (2) and (3) is complicated and connected with a series of considerable assumptions. In such cases, known numerical methods are used; their essence is in representation of infinitesimal increments of the required function by certain finite increments (Euler method) and representation of the equations in Cauchy form .

Velocity of asynchronous motor as well as space-time complexes of stator and rotor flux linkage are state variables of the modeled object in the considered case. To find them, initial system of equations is complemented by the known dependences

$$M = \frac{3}{2} p_\tau L_{12} \,\mathrm{Im}(\underline{I}_1^* \underline{I}_2), \qquad (6)$$

$$M - M_c = J \frac{d\omega_m}{dt}, \qquad (7)$$

where M_c is static moment; J is moment of inertia of a mechanical drive part; and p_τ is number of pole pairs.

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