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LINEARIZED MATHEMATICAL MODEL OF ELECTRIC MOTOR DRIVES AND DEVELOPMENT OF CONTROL STRUCTURES

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Abstract:
Ensuring the harmonic form of currents and voltages in the system elements allows us to obtain an energy-saving operating mode of electric motor drives with inverters, the reactive elements of which form many interconnected oscillatory circuits with nonlinear elements. The issues of studying the mutual influence of nonlinear characteristics of elements and ways to eliminate or reduce their negative effects on the operating modes of electric drives with frequency adjustment are relevant.

Keywords: electromagnetic vibration motors, vibration machines, dynamic mode, electric drive, scalar control, nonlinear differential equation.

Solving the equations of the mathematical model of electric motors is possible only with the help of a computer, since they include changes in frequency over time and this leads to difficulties in solving this problem. The cyclic variation of this equation was solved in the chapter above and conclusions were drawn. In order to apply known correction methods in relation to the developed automated electric drive, it is necessary to linearize the mathematical model of the electric drive. It should be noted that this equation is linear and based on the phase portrait of this equation, the system is stable. To do this, we will use the calculations given in [16, p. 196] and propose that in the dynamics of the electric motor there are deviations in the vicinity of the operating point:

$$U(t) = U_0 + \Delta U \quad (1)$$

In the output coordinates of the EMVD A(t) = A+ΔA

$$i(t) = I_0 + \Delta I \quad (2)$$

In vibration-exciting force

$$f(t) = f_0 + \Delta f \quad (3)$$

We believe that the variables Δx, ΔA, Δφ and ΔU are small deviations in the vicinity of the operating point. Then for inductance

$$L = L_0\left[\frac{1}{1+\Delta\chi/\chi_0}\right] \quad (4)$$

Expression (4) can be expanded into a Taylor series in the vicinity of the point X0 and, discarding components of order higher than the second, can be written as:

$$L = L_{0\left[1-\frac{\Delta\chi}{\chi_0}\right]}$$

$$\frac{dL}{d\Delta x} = \frac{L_0}{x_0}\left[1-\frac{\Delta x}{x_0}\right] \quad (5)$$

Substituting voltage into the equation

$$U(t) = Ri - L(x)\frac{di}{dt} - l\frac{dL}{dx} - \frac{dx}{dt} \quad (6)$$

And into the equation the movement of the r.o. EMVD

$$mp^2X + PpX + KX = \frac{1}{2}t^2\frac{dL}{\mathrm{dX}} \quad (7)$$

The values of Δx and dL/[d(Δx)] from (1) and (5), discarding components of small quantities above the second order, we write the linearized equations

$$U_0 + \Delta U = L_0R + \Delta iR + I_0\frac{d(\Delta t)}{dt} - \frac{I_0L_0}{X_0}\cdot\frac{d(\Delta t)}{dt} \quad (8)$$

$$F_{\text{п}} + \Delta f = mp^2(X)PpX + K(X_0 - X) + K\Delta X + \frac{1}{2}\frac{I_0^2L_0}{X_0} + \frac{I_0^2L_0}{X_0}\Delta t - \frac{I_0^2L_0}{X_0}\Delta X \quad (9)$$

Equations (8) and (9) determine the steady-state value of the operating point and the oscillation around this point. By equating small deviations Δf, Δx, ΔU and Δf to zero, we can obtain the operating point equations

$$U_0 = I_0R \quad (10)$$

$$F_0 = K(X_0 - X_k) + \frac{1}{2}\frac{I_0L_0}{2} \quad (11)$$

Equations (8) and (9) are linearized equations of the electric motor with simultaneous action on the electric motor of alternating ΔU and constant U0 voltages. Subtracting from (8) expression (10) from (11), (12), we obtain equations with constant coefficients that describe the dynamics of the electric motor in the vicinity of the operating point in operator form;

$$U = b_0i + b_1pi - a_1px \quad (12)$$

$$f_b = a_2p^2X + d_1pX + a_0X + a_1i \quad (13)$$

Где $b_0=R$ $b_1=L_0$; $a_1=I_0L_0/\chi_0$; $a_2=m$; $a_1`=p$; $a_0=K-I_0^2L_0/\chi_0^2$; $b_0=a$

Based on the found equations (12) and (13), a block diagram of a linearized mathematical model of the EMVD of the control object was constructed, the transfer function of which was divided into two parts - electrical.

$$W_э(p) = \frac{1/R}{Tp+1} = \frac{K}{Tp+1} \quad (14)$$

And the mechanical part

$$W_M(p) = \frac{K_m}{T_m^2 p^2 + 2\xi T_m p + 1} \tag{15}$$

The influence of mechanical vibrations working part to electromagnetic quantities are determined by the transfer function $W_c(p)=a_1p$

Где, $T_э = Tэ(I_0X_0)$; $T_M=T_M(I_0X_0)$ - time constants depending on operating modes and types of electric motors,

Linearization of the mathematical model of electric motors is necessary not only for the development of electric motors with automatic control of tuning to resonance, but also for calculating the dynamics of electric motors. This follows from the fact that such motors are widely used in various industries, their production and operation are much simpler than VMs with a rotating shaft, and then there is a need to estimate the motor current and the amplitude of oscillations of the r.o. EMVD especially in conditions of parameter deviations.To draw up a block diagram of an automated electric drive, it is necessary to determine the transfer functions (t.f.) of the ACS elements. Transmission function control object - EMVD is determined for the electrical part according to (4.15) and the mechanical part according to (15) Transmission function PWM pulse width converter.

$$W_b(p) = \frac{K_B}{T_B p + 1} \tag{16}$$

We write the transfer function of the meter, the difference in the squares of frequencies, as for a first-order aperiodic link

$$W_{ркч}(p) = \frac{K_{ркч}}{T_{ркч} p + 1} \tag{17}$$

$$W_A(p) = \frac{K_A}{T_A p + 1} \tag{18}$$

The block diagram of the automatic control system for tuning and resonance for simultaneous control of the maximum amplitude frequency response with feedback on the amplitude of oscillations (speed or acceleration) of the working body is shown in (Fig. 1).

Taking into account the extreme nature of the change in the amplitude frequency response of the electric motor, we determine the dynamic stability for three characteristic points of the amplitude frequency response - pre-resonance (ω=0.95ω0), resonant (ω=ω0) and post-resonance (ω=1.03ω) regions. Transfer function of a closed automatic control system.

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$$W(p) = \frac{K \cdot p}{a_0 p^6 + a_1 p^5 + a_2 p^4 + a_3 p^3 + a_4 p^2 + a_5 p + a_6} \qquad (19)$$

and we use the Liener-Shipart stability criterion, according to which at all points under study of the amplitude frequency characteristics of single-cycle and push-pull electric motors, the automatic control system is dynamically stable, since when

$$a_0>, a_1>0, \ldots . a_6>0$$

(20)

All odd Gurwin determinants are positive.

In the absence of feedback on the amplitude of oscillations (speed or acceleration), the working body. the denominator of the transfer function of a new closed-loop automatic control system takes the form of a fourth-degree polynomial. Then, repeating the stability studies, we find that in the over-resonance region of the amplitude frequency response of single-cycle electric motors, unstable modes are observed, since when conditions (20) are met, Gurin's second determinant is negative. This is explained by the fact that the resonant zone of the amplitude frequency response in single-cycle electric motors is characterized by either a steeply falling part (dashed line in Fig. 2), where when the electric motor is configured in the resonant mode, the vertical straight line from the abscissa axis intersects the amplitude frequency characteristic at several points, t .e. one value and correspond to several values of amplitudes A1, A2 and A3.

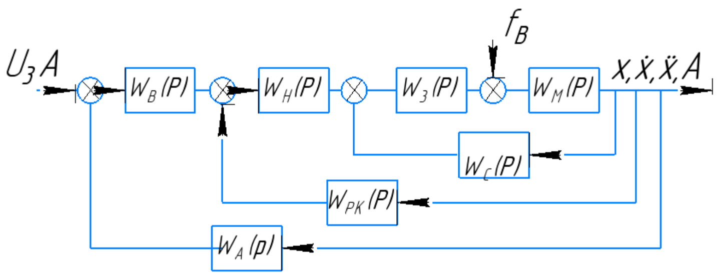

Fig.1. Block diagram of an automatic control system for tuning to resonance and maximum amplitude frequency response.

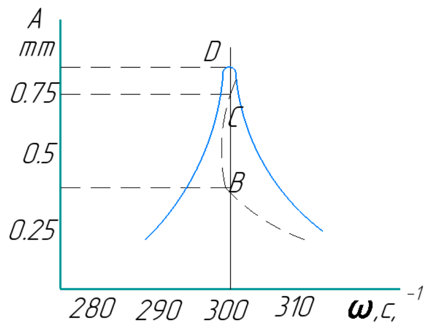

Fig.2. amplitude-frequency characteristic of a single-cycle electric motor.

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This mathematical model is described using the transfer characteristic. The mathematical model is implemented using the MATLAB Simulink software package (Fig. 3. As noted above, the system includes transfer characteristics such as a pulse-width converter, the electrical part of the electric drive, the mechanical part of the electric drive, taking into account the nonlinear characteristics of the electric drive and other control units, as well as amplitude feedback.

This model includes a model of the influence of nonlinear characteristics of the electric motor, shown in Fig. 4.

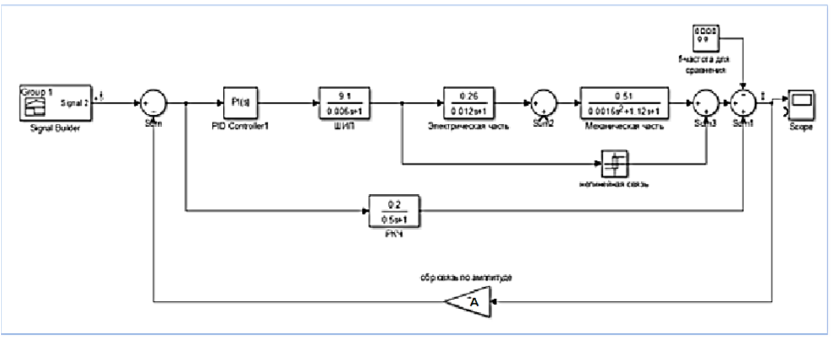


Рис.3. Математический модель в программным пакете MATLAB Simulink

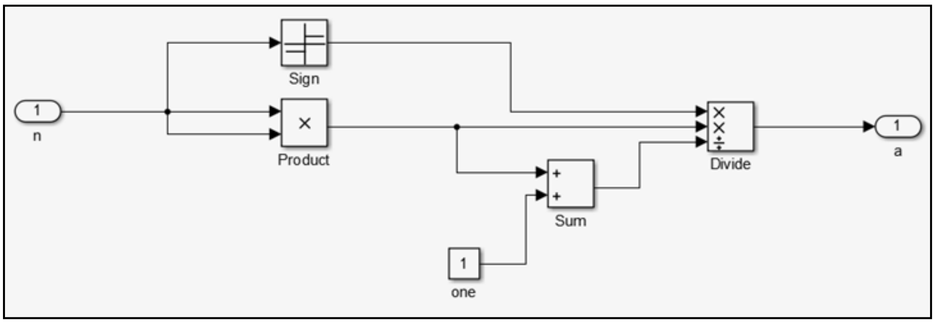
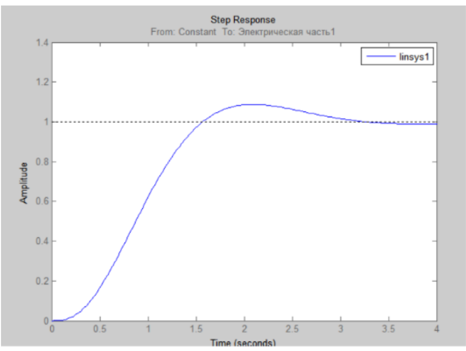
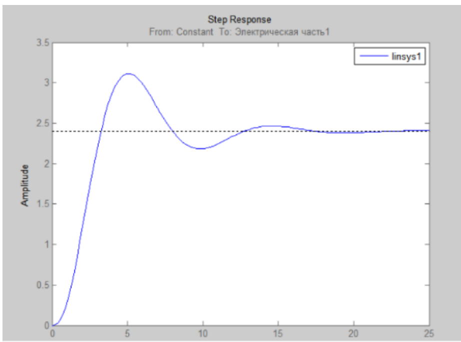


Fig.4. Under the system of nonlinear characteristics of the electric motor drive.

Using an oscillogram, the results of a mathematical model describing the operation of the electric motor were obtained.



а)



б)

Rice. 5. Results of the oscillogram of the mathematical model of the electric motor a) taking into account the p.f of the feedback circuit for the amplitude of the oscillations of the p.o.

Rice. 5.b taking into account the p.f. feedback circuit for the amplitude of oscillations of the p.o., nonlinear connections between the mechanical and electrical parts of the electric motor.

From the results obtained, we can state that the system is stable and meets all quality indicators. A signal having the required resonant frequency f=50 Hz is supplied to the input of the model. At the beginning of the model's launch time, it accelerates and tpp = 2 seconds reaches the set mode. During acceleration, the system has a frequency of at least 65 Hz, i.e. does not exceed 0.05* tpp, and thus meets the quality control criteria of the facility.

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