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TRANSIENT PROCESS OF ELECTRICAL DRIVE OF A SHIP MOORING CONTROLLED BY A FREQUENCY CONVERTER

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Abstract- The transition process of the electric drive of the ship mooring (capstan) controlled by a frequency converter was studied in the paper. For this purpose, a mathematical model of the electric drive of the mooring controlled by the frequency converter was created in the Simulink section of the MATLAB program, and the oscillograms of the direct start of the electric motor at the rated load at different values of the frequency were constructed.

Keywords: Ship, Mooring Installation, Electric Drive, Frequency Converter, Switching Process.

1. INTRODUCTION

Capstans by their purpose are anchor-mooring, mooring and some capstans perform both tasks. The capstans are driven by both electric motor and electro-hydraulic motors. Capstans also have a solenoid brake, and when the electric motor is energized, the brake solenoid compresses the springs and the motor actuates the spindle of capstan. As soon as the feed is stopped, the electromagnetic force is lost and the springs actuate the brake disc. This stops the movement of the spindle. Recently, ballerless capstans are more widely used in modern transport ships. The load axis of this mechanism is set vertically on the deck. Ballerless capstans have the following advantages [1].

- Since the electric motor and reducer are located inside the head of the capstan, they are compact sized;
- Since the belt is not driving, the efficiency becomes high;
- It requires little effort during installation as there is no centering operation;
- Since there are few parts, the price is 20-40% cheaper;
- Since the reducer with the electric motor is placed inside the body of the capstan, the size of the capstan significantly decreases;
- Such capstans have high efficiency due to the application of cylindrical gear drive.

For calculation of the power of the anchor capstan's actuating motor, it is necessary to determine the rated tractive force on the mooring rope and the ship's mooring speed. In the calculation, the tractive force and the mooring speed are taken to be constant.

According to the given norms, when performing the mooring operation with the rated tractive force (when the structure is controlled by hand), the rated rope winding speed should not exceed v_{ny}=0.2÷0.3 m/sec [4].

2. MAIN PART

The problem of studying of asynchronous motor at changes in voltage and frequency, taking into account the modes of operation of the drive of the ship's mooring on the basis of a mathematical model was set in the paper [3]. On the other hand, the presence in the scheme of a frequency converter based on semiconductor elements, which has become widespread and has a high efficiency, small dimensions, the possibility of separately changing the amplitude and frequency of the voltage supplied to the motor, also imposes some peculiarities on the nature of the study and expands the scope of the issue under study. The study is performed using the complete equations of the asynchronous motor. As it is known, three forms of writing the equations of an asynchronous machine are most common [7]:

- Equation in space-fixed coordinate systems α, β, 0;
- Equation in axes rotating in space with the speed of the rotor d, q, 0;
- Equation in synchronously rotating axes d_s, q_s.

When drawing up the structural scheme of the problem, it is necessary to choose a rational form of writing the equations of the asynchronous motor in order to be able to modulate the amplitude and frequency changes of the voltage supplied to the motor relatively easily with the smallest number of operating elements. When writing the equations of synchronous rotating axes, the projections of the network voltage on the axes rotating at a synchronous speed are constant values and only values of their amplitudes can be changed in the model, which is not sufficient for studying a frequency-controlled induction motor.

When choosing coordinate systems rigidly connected to the rotor, the projection of the voltage vector is a function of the angle of rotation of the rotor, and therefore it is difficult to model the change in the amplitude and frequency of the voltage supplied to the motor.

Therefore, the most acceptable is a form of writing equations in space-fixed coordinate system. In this case, by linking an autonomous scheme for realizing the change in voltage and frequency as a function of time with a scheme that describes the equations directly of asynchronous electric drive, the desired effect and simplicity of solutions are achieved. Thus, the equations of the asynchronous motor are taken as a basis of the modeling, written in the space-fixed axes α, β, 0;

Equation of voltages [3]:

$$\begin{aligned} &U_{s\alpha} = P\psi_{s\alpha} + r_s i_{s\alpha}; \quad U_{s\beta} = P\psi_{s\beta} + r_s i_{s\beta}; \\ &0 = P\psi_{r\alpha} + \psi_{r\beta}\omega_r + r_r i_{r\alpha}; \quad 0 = P\psi_{r\beta} - \psi_{r\alpha}\omega_r + r_r i_{r\beta}; \end{aligned} \qquad (1)$$

Equations of flux linkages:

$$\begin{aligned} &\psi_{s\alpha} = X_s i_{s\alpha} + X_m i_{r\alpha}; \quad \psi_{s\beta} = X_s i_{s\beta} + X_m i_{r\beta}; \\ &\psi_{r\alpha} = X_r i_{r\alpha} + X_m i_{s\alpha}; \quad \psi_{r\beta} = X_r i_{r\beta} + X_m i_{r\beta}; \end{aligned} \qquad (2)$$

Equation of the electromagnetic moment

$$M_{el} = (\psi_{r\beta} i_{r\alpha} - \psi_{r\alpha} i_{r\beta}) \qquad (3)$$

Equation of motion of electric drive [8]:

$$M_e - M_s = I\frac{d\omega_r}{dt}\ , \ I = 0.2 \text{ kqm}^2\ , \ M_e - M_s = IP\omega_r \qquad (4)$$

In Equations (1)-(4) all values are expressed in relative units and the following designations are accepted:

$U_{s\alpha}$, $U_{s\beta}$ are projections of the voltage vector U_s with a time-varying amplitude and frequency on the corresponding axes;

- r_s, r_r are active resistances of the stator and rotor;
- x_s, x_r are total inductive reactance of the stator and rotor;
- X_m is mutual induction resistance;
- $\psi_{s\alpha}$, $\psi_{s\beta}$, $\psi_{r\alpha}$, $\psi_{r\beta}$ are projections of the flux linkages of the stator and rotor circuits on the corresponding axes;
- $i_{s\alpha}$, $i_{s\beta}$, $i_{r\alpha}$, $i_{r\beta}$ are projections of currents on the corresponding axes;
- I is moment of inertia of the rotor;
- m_s static moment of resistance;
- $P = I\dfrac{d}{dt}$ is synchronous time differentiation symbol;
- ω_r is electric speed of the rotor.

In Equation (1), the voltage amplitude and frequency change with time, so projections $U_{s\alpha}$, $U_{s\beta}$ will look like:

$$\begin{aligned} &U_{s\alpha} = U_s(\tau)\cos[K_f(\tau) + \psi] \\ &U_{s\beta} = U_s(\tau)\sin[K_p(\tau) + \psi] \end{aligned} \qquad (5)$$

where, $K_f(\tau) = \dfrac{f(\tau)}{f_n}$ is relative frequency as a function of time; $U_s(\tau) = \dfrac{U(\tau)}{U_n}$ is relative voltage as a function of time.

To draw up a structural diagram of a programmable task, it is necessary to write the Equation (1) for the relative the flux linkages:

$$\begin{aligned} &P\psi_{s\alpha} = U_{s\alpha} - r_s i_{s\alpha}; \quad P\psi_{s\beta} = U_{s\beta} - r_s i_{s\beta}; \\ &P\psi_{r\alpha} = -\psi_{r\beta}\omega_r - r_r i_{r\alpha}; \quad P\psi_{r\beta} = \psi_{r\alpha}\omega_r - r_r i_{r\beta}; \end{aligned} \qquad (6)$$

Thus, from Equation (6) is obvious that the flux linkages on the machine must be worked out by a single integration. Accordingly, Equation (2) are resolved with respect to currents:

$$\begin{aligned} &i_{s\alpha} = a\psi_{s\alpha} - b\psi_{r\alpha}; \quad i_{s\beta} = a\psi_{s\beta} - b\psi_{r\beta}; \\ &i_{r\alpha} = c\psi_{r\alpha} - b\psi_{s\alpha}; \quad i_{r\beta} = c\psi_{r\beta} - b\psi_{s\beta}; \end{aligned} \qquad (7)$$

where, $a = \dfrac{X_r}{X_1 X_r - X_m^2}$; $b = \dfrac{X_m}{X_1 X_r - X_m^2}$; $c = \dfrac{X_1}{X_1 X_r - X_m^2}$;

The equation of moment (3) remains unchanged. The equations of motion (3) are represented in the form

$$P\omega_r = \frac{1}{I}(m_e - m_s) \qquad (8)$$

For modeling, an asynchronous motor was used with the following data [5]:

- TYPE 4AC16054 Y3

- Rated power is $P_n = 17$ kW
- Synchronous rotation speed is $n_{syn} = 1500$ rev/min
- Active power coefficient is $\cos\phi = 85$

Parameters of equivalent circuit in relative units:

- $r_s^* = 0.045$ is active resistance of the stator
- $r_r^* = 0.064$ is active resistance of the rotor
- $x_{1\sigma}^* = 0.082$ is inductive reactance of stator dispersion
- $x_{2\sigma}^* = 0.13$ is inductive reactance of the rotor dispersion
- $x_m^* = 3.17$ is inductive reactance of the magnetization

Let's determine the basic resistance of this motor:

$$P = 3U_f \times I_f \cos\phi$$

$$I_f = \frac{P \times 10^3}{3U_f \times \cos\phi} = \frac{17 \times 10^3}{3 \times 220 \times 0.85} = 30.3 \text{ A}$$

$$Z_n = \frac{U_n}{I_n} = \frac{220}{30.3} = 7.26 \ \Omega$$

$$r_s = r_s^* \times Z_n = 0.045 \times 7.26 = 0.327 \ \Omega$$

$$r_r' = r_r'^* \times Z_n = 0.064 \times 7.26 = 0.465 \ \Omega$$

$$x_{1\sigma} = x_{1\sigma}^* \times Z_n = 0.082 \times 7.26 = 0.6 \ \Omega$$

$$x_{2\sigma} = x_{2\sigma}^* \times Z_n = 0.13 \times 7.26 = 0.94 \ \Omega$$

$$x_m = x_m^* \times Z_n = 3.17 \times 7.26 = 26.9 \ \Omega$$

Total inductive reactance of the stator:

$$x_1 = x_{1\sigma} + x_m = 0.6 + 26.9 = 27.5 \ \Omega$$

$$x_r = x_{2\sigma} + x_m = 0.94 + 26.9 = 27.84 \ \Omega$$

Knowing the inductive reactance of the asynchronous motor, we determine the coefficients of the Equation (7):

$$a = \frac{x_r}{x_1 x_r - x_m^2} = \frac{27.84}{27.5 \times 27.84 - 26.9^2} = 0.66$$

$$b = \frac{x_m}{x_1 x_r - x_m^2} = \frac{26.9}{27.5 \times 27.84 - 26.9^2} = 0.64$$

$$c = \frac{x_1}{x_1 x_r - x_m^2} = \frac{27.5}{27.5 \times 27.84 - 26.9^2} = 0.65$$

Equations (1)-(7), taking into account the active resistances of the windings of the asynchronous motor of the capstan and the coefficients a, b, c are written in the following form:

$$U_{s\alpha}=\frac{d\psi_{s\alpha}}{dt}+0.327i_{sa}\ ;\ U_{s\beta}=\frac{d\psi_{s\beta}}{dt}+0.327i_{s\beta}$$

$$0=\frac{d\psi_{r\alpha}}{dt}+\psi_{r\beta}\omega_r+0.465i_{r\alpha} \tag{9}$$

$$0=\frac{d\psi_{r\beta}}{dt}+\psi_{r\alpha}\omega_r+0.465i_{r\beta}$$

When studying the dynamic modes, the mutual influence of the three phases of the motor is taken into account by the increase in mutual inductance 3/2 times compared to the inductance of the magnetizing circuit

$$L_\mu=\frac{x_\mu}{\omega_{sn}}=\frac{24.9}{157}=0.158\ \text{Hn}$$

Accordingly, the total inductance of the stator

$$L_s=\frac{x_1+x_\mu}{\omega_{sn}}=\frac{0.57+24.9}{157}=0.162\ \text{Hn}$$

Reduced total inductance of the rotor

$$L_r'=\frac{x_r+x_\mu}{\omega_{sn}}=\frac{0.87+24.9}{157}=0.164\ \text{Hn}$$

When studying the dynamic modes of asynchronous motors, two-phase mathematical models are used that adequately reflect the processes occurring in a real machine. The most general form of mathematical description of two-phase models is a system of differential and algebraic equations:

$$\left.\begin{aligned}
U_{s\alpha}&=\frac{d\psi_{\alpha s}}{dt}+r_s i_{s\alpha}+\psi_{\beta s}\omega_k\\
U_{s\beta}&=\frac{d\psi_{\beta s}}{dt}+r_s i_{s\beta}+\psi_{\alpha s}\omega_k\\
u_{\alpha r}'&=\frac{d\psi_{\alpha r}}{dt}+r_r' i_{\alpha r}'+\psi_{\beta r}(\omega_k-\omega)\\
u_{\beta r}'&=\frac{d\psi_{\beta r}}{dt}+r_r' i_{\beta r}'+\psi_{\alpha r}(\omega_k-\omega)\\
M&=\frac{3}{2}L_\mu Ap(\psi_{as}\psi_{\beta r}-\psi_{\beta s}\psi_{ar})\\
M-M_c&=(\frac{1}{p})\frac{d\omega}{dt}\\
i_{\alpha s}&=A(\psi_{\alpha s}L_r'-\psi_{\alpha r}L_\mu)\\
i_{\beta s}&=A(\psi_{\beta s}L_r'-\psi_{\beta r}L_\mu)\\
i_{\alpha r}'&=A(\psi_{\alpha r}L_s-\psi_{\alpha s}L_\mu)\\
i_{\beta r}'&=A(\psi_{\beta r}L_s-\psi_{\beta s}L_\mu)
\end{aligned}\right\} \tag{10}$$

where, $A=\dfrac{1}{L_sL_r'-L_\mu^2}$ and ω_k is the rotation speed of the coordinate orthogonal system in which the two-phase model is being studied. When using a fixed coordinate system ω_k=0.

$$A=\frac{1}{L_sL_r'-L_\mu^2}=\frac{1}{0.162\times0.164-0.158^2}=588$$

$$A\times r_s\times L_r'=588\times0.327\times0.164=31.5$$

$$A\times r_s\times L_\mu=588\times0.327\times0.158=30.4$$

$$A\times r_r'\times L_s=588\times0.465\times0.162=44.3$$

$$A\times r_r'\times L_\mu=588\times0.465\times0.158=43.2$$

$$M=\frac{3}{2}L_\mu Ap=\frac{3}{2}\times0.158\times588\times2=278.7$$

In this example, a squirrel-cage induction motor is considered in a fixed coordinate system, therefore, the expressions for voltages take the form:

$$U_{s\alpha}=U_m\cos\omega_s t=\sqrt{2}U_n\cos\omega_s t=220\times\cos314.15t$$

$$U_{\beta\alpha}=-U_m\sin\omega_s t=-\sqrt{2}U_n\sin\omega_s t=-220\times\sin314.15t$$

$$U_{\alpha r}=0;\ U_{\beta r}=0$$

where, ω_s is angular frequency of supply voltage. Starting of the motor in idle mode with a rated moment of inertia is carried out at M_s=0, I=I_n. Taking into account the above, the system of Equation (10), after reducing them to the Cauchy form, takes the form [3]:

$$\left.\begin{aligned}
\frac{d\psi_{\alpha s}}{dt}&=\sqrt{2}U_n\cos\omega_s t-Ar_s(\psi_{as}L_r'-\psi_{\alpha r}L_\mu)\\
\frac{d\psi_{\beta s}}{dt}&=-\sqrt{2}U_n\sin\omega_s t-Ar_s(\psi_{\beta s}L_r'-\psi_{\beta r}L_\mu)\\
\frac{d\psi_{\alpha r}}{dt}&=-Ar_r'(\psi_{\alpha r}L_s-\psi_{\alpha s}L_\mu)+\psi_{\beta r}\omega\\
\frac{d\psi_{\beta r}}{dt}&=-Ar_r'(\psi_{\beta r}L_s-\psi_{\alpha r}L_\mu)-\psi_{\alpha r}\omega\\
M&=\frac{3}{2}pL_\mu A(\psi_{\alpha s}\psi_{\beta r}-\psi_{\alpha r}\psi_{\beta s})\\
\frac{d\omega}{t}&=\frac{pM}{I_n}
\end{aligned}\right\} \tag{11}$$

After substituting the numerical values, taking into account p=2, the system of design equations finally takes the form:

$$\left.\begin{aligned}
\frac{d\psi_{\alpha s}}{dt}&=220\cos314.15t-31.5\psi_{\alpha s}+26\psi_{\alpha r}\\
\frac{d\psi_{\beta s}}{dt}&=-220\sin314.15t-31.5\psi_{\beta s}+26\psi_{\beta r}\\
\frac{d\psi_{\alpha r}}{dt}&=-44.3\psi_{\alpha r}+43.2\psi_{\alpha s}+\psi_{\beta r}\omega\\
\frac{d\psi_{\beta r}}{dt}&=-44.3\psi_{\beta r}+43.2\psi_{\beta s}-\psi_{\alpha r}\omega\\
M&=278.7\times(\psi_{\alpha s}\psi_{\beta r}-\psi_{\beta s}\psi_{\alpha r})\\
\frac{d\omega}{dt}&=6.0
\end{aligned}\right\} \tag{12}$$

The solution of Equation (12) for frequency starting and for various modes of operation of the frequency controlled electric drive of the mooring is performed in a personal computer using the MATLAB/Simulink program [6, 10].

2.1. Study of the Transition Process of the Electric Drive of the Mooring Capstan Controlled by the Frequency Converter

Elements used to create the mathematical model (Figure 1): Sinewive sinusoidal signal source, amplitude 220 V, phase shift 0, frequency 157 rad/sec, 2nd Sinewive sinusoidal signal source, amplitude 220 V, phase shift 1.57 radian, and frequency is 157 rad/sec. The differential values (derivatives) of the parameters are calculated using an integrator [12]. The coefficients of the variable are written in the Gain (amplifier) block and their characteristics are described on the oscillograph (scope). The Scope functional block was used to describe the time dependence form of any parameter. The start-up time of the model is 1.4 sec.

Based on the expression (12) and the calculations, a mathematical model of the asynchronous motor under study was built in the Simulink section of the MATLAB program. The Mux block was used to describe the characteristics in one coordinate system, the Product block was used to find the product of summation (Sum) parameters, and the Step block (step time 0.1, final value 1) was used as a signal source in the calculation of the motor speed.

The purpose of studying the model of the starting process of the given motor is to obtain the optimal starting laws of the motor, taking into account the possibility of individual changes in the frequency and amplitude of the voltage supplied to the motor, in order to ensure the reliable operation of the semiconductor elements of the static frequency converter and to improve the technical and economic indicators of the drive-in transition modes [11, 13].

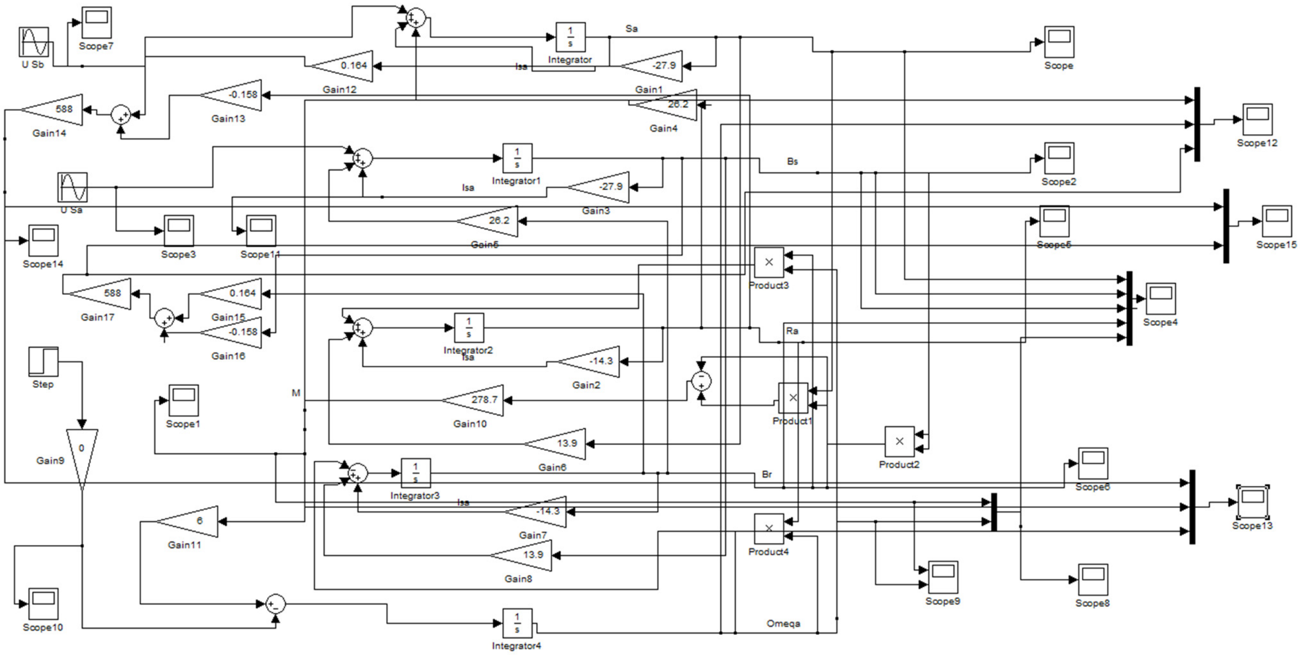

Figure 1. Mathematical model of Equation (12) constructed in Simulink section of MATLAB program

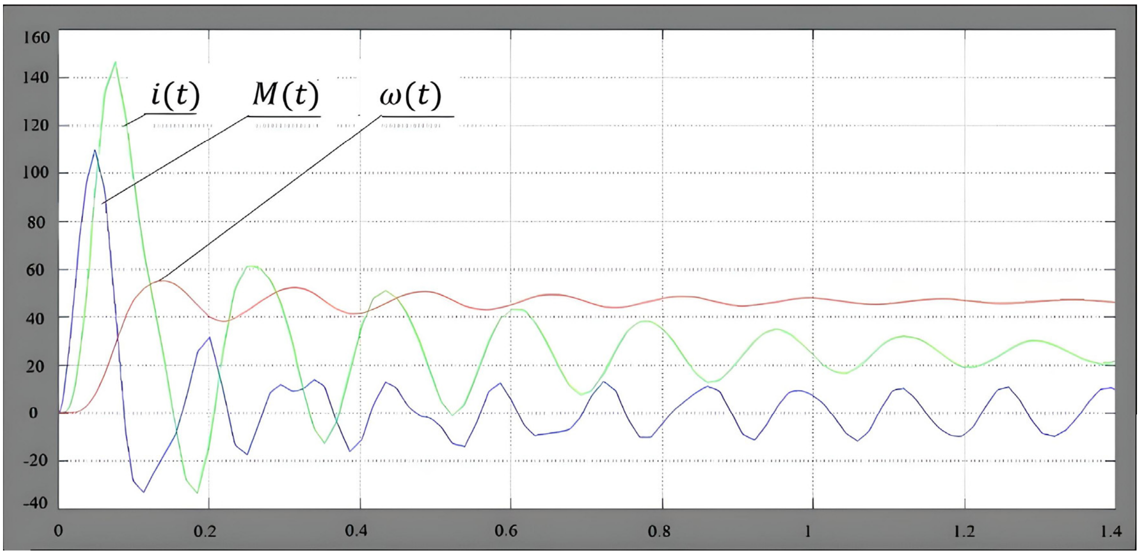

Figure 2. $i(t)$, $M(t)$ and $\omega(t)$ relationships when M_c=M_n during start-up - $f = 15$ Hz, $U = 66$ V, $\omega = 47.1$ rad/sec

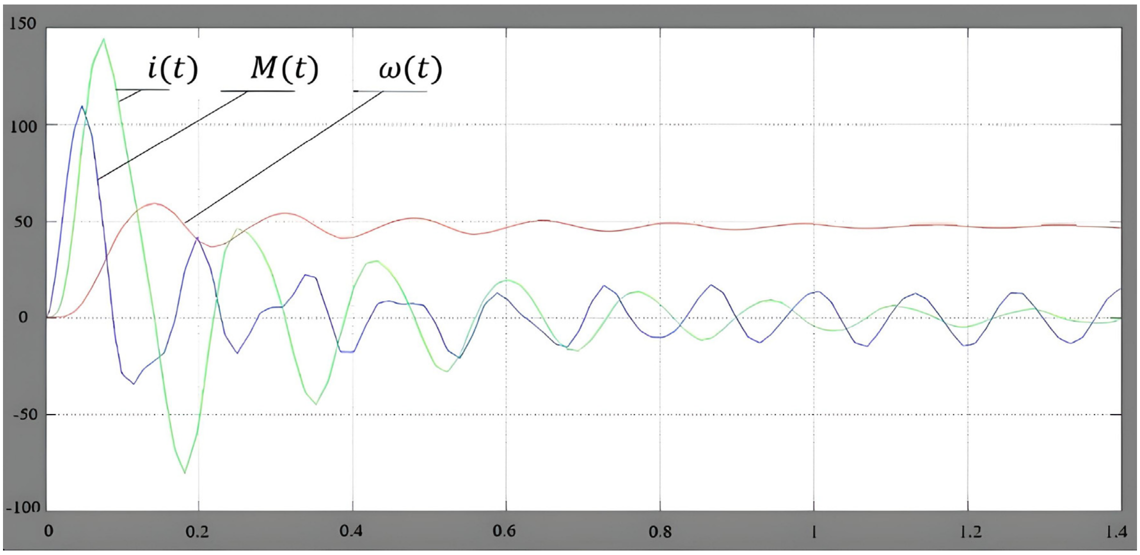

Figure 3. $i(t)$, $M(t)$ and $\omega(t)$ relationships when M_c=M_o during start-up - $f = 15$ Hz, $U = 66$ V, $\omega = 47.1$ rad/sec

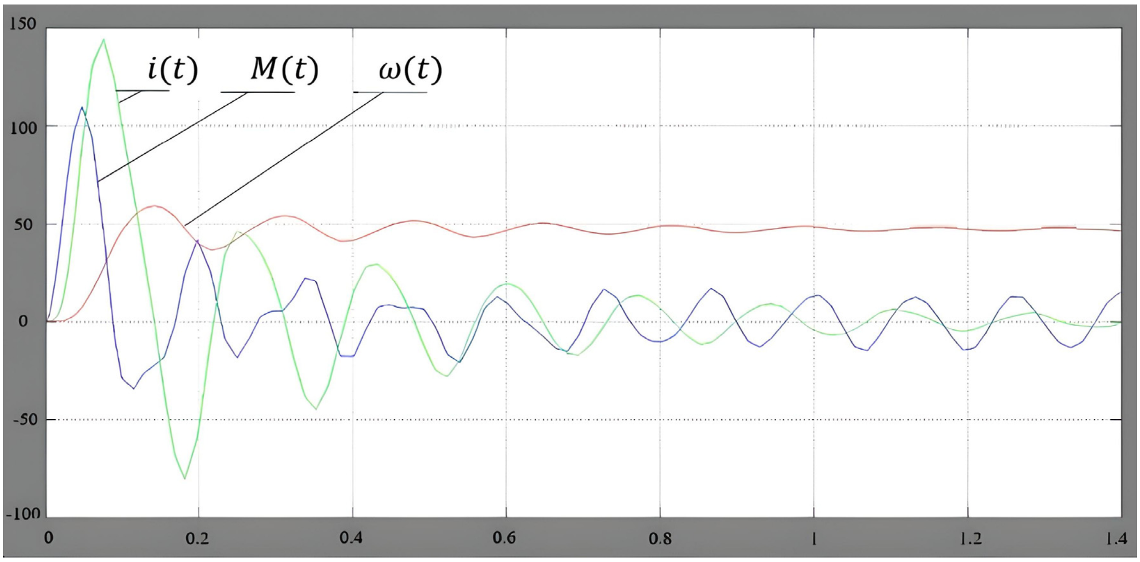

Figure 4. $i(t)$, $M(t)$ and $\omega(t)$ relationships when M_c=M_n during start-up - $f = 30$ Hz, $U = 132$ V, $\omega = 92.2$ rad/sec

It should be noted that the starting process of the studied drive can be carried out in different modes and depending on the tension of the mooring rope, which characterizes the load on the motor shaft. The motor under study can be started without load, loaded and under rated load. In addition, the given motor should operate at a reduced speed (usually f=20÷30 Hs) near the mooring object. At that, it is possible to start the motor at low frequencies [2, 9].

Oscillograms of direct starting of the electric motor at nominal load (M_c=M_n) at frequencies f=15, 30, 40, 50 and 70 Hs are shown in Figures 2, 4, 5, 6 and 7. As can be seen from the oscillograms, the frequency of the current decreases compared to the direct start at the frequency f=50 Hs, but the motor start-up time increases ($i_{op.s}$=3.5 Inom, $t_{op.s}$=0.8). Despite the reduction of the starting current during start-up with a proportional change of frequency and voltage ($i_{op.s}$=3I_{nom}), the start-up time of the motor increases by approximately 2 times. The oscillogram of the motor start-up is shown in Figure 2 with following values: the frequency given to the motor is f=15 Hs, the voltage U=66 V, and the angular velocity ω=47.1 rad/sec and moment on the shaft.

In Figure 3, $t_{op.s}$=0.35 sec and the maximum value of the starting current is 4.81 times larger than the rated current. The maximum value of the electromagnetic torque of the electric motor is 134.8% of its rated torque. The effective value of the load current in the motor's steady operation mode under load (M_c=M_n) is 14.3 times higher than in the no-load operation mode (M_c=0).

The direct start oscillogram of the electric motor at frequency f=15 Hs, the voltage U=66 V and M_c=0 is shown in Figure 3. The maximum value of the starting current is 4.81 times larger than the rated current. The maximum value of the electromagnetic torque of the electric motor is 134.8% of its rated torque.

The oscillogram of the motor start-up is shown in Figure 4 with the following values: the frequency given to the motor is f=30 Hs, voltage U=132 V, and angular velocity ω=92.2 rad/sec and moment on shaft (M_c=M_n).

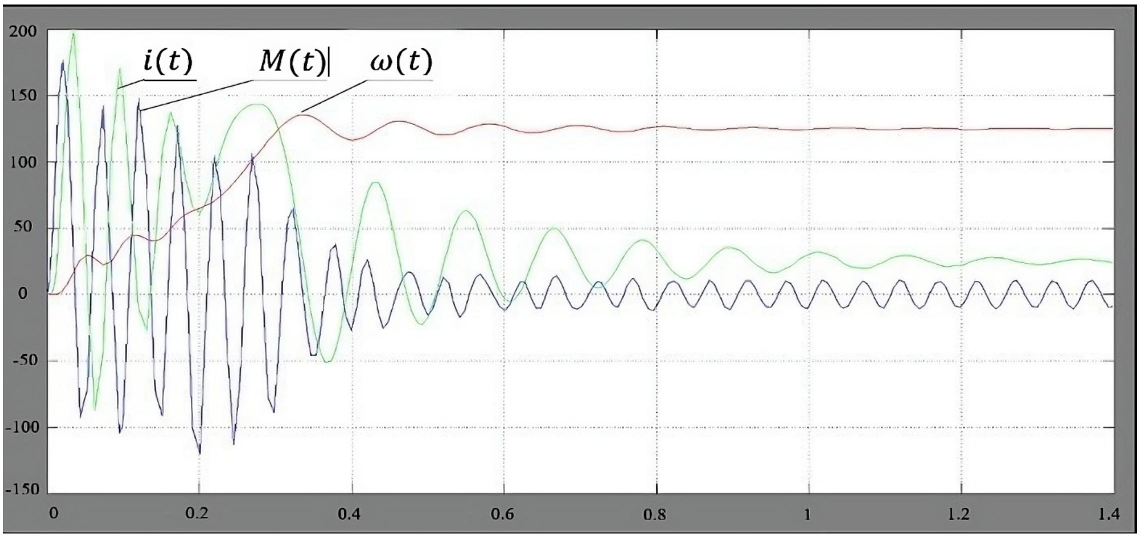

Figure 5. $i(t)$, $M(t)$ and $\omega(t)$ relationships when M_c=M_n during start-up - $f=40$ Hz, $U=176$ V, $\omega=125.6$ rad/sec

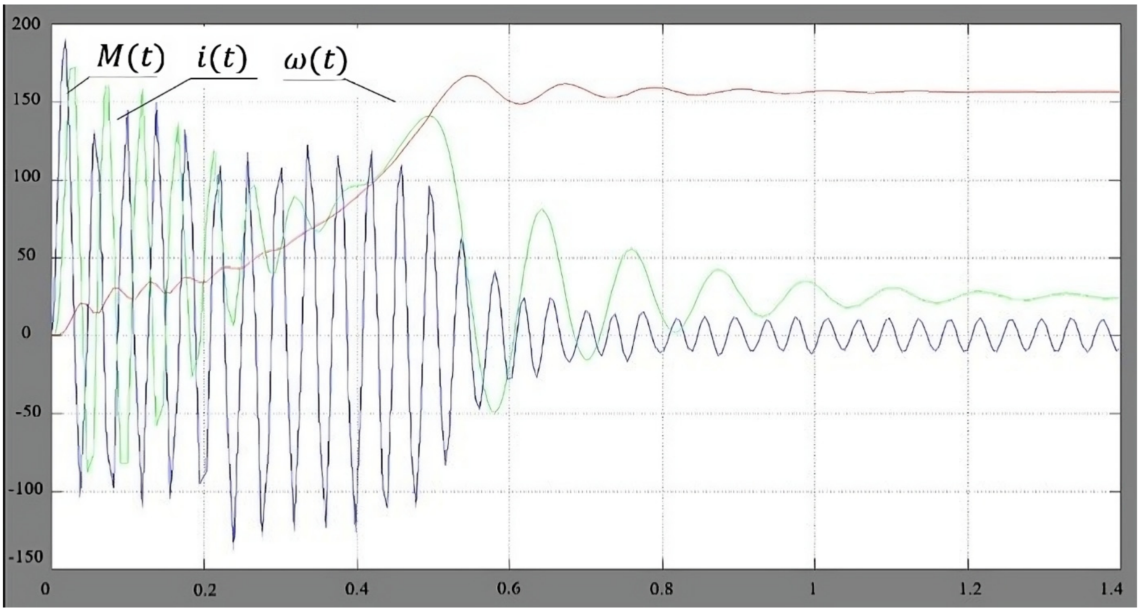

Figure 6. $i(t)$, $M(t)$ and $\omega(t)$ relationships when M_c=M_n during start-up - $f=50$ Hz, $U=220$ V, $\omega=157$ rad/sec

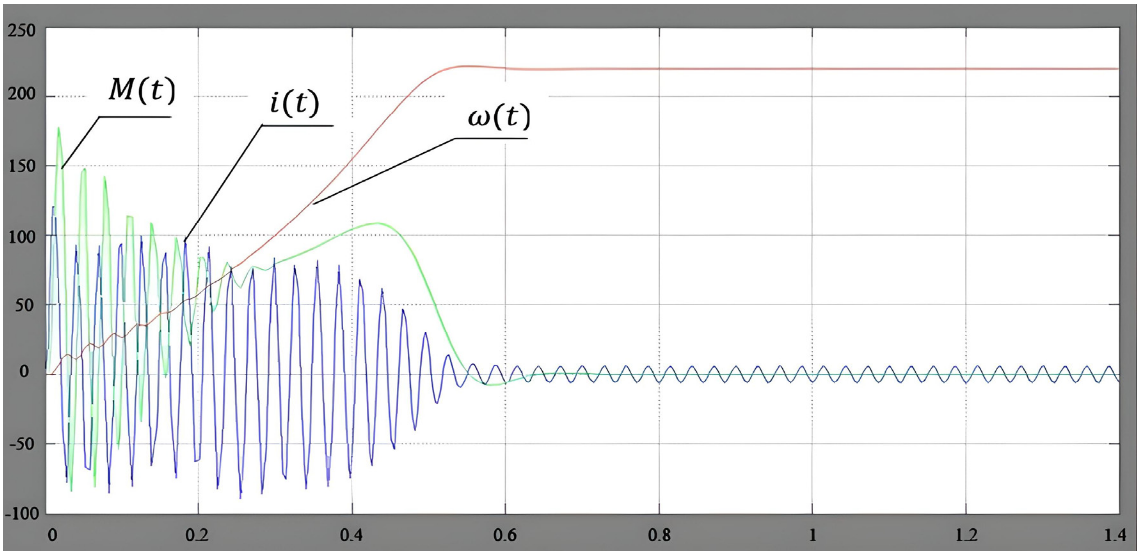

Figure 7. i(t), M(t) and ω(t) relationships when M_c=0 during start-up - $f=70$ Hz, $U=220$ V, $\omega=219.8$ rad/sec

In Figure 4, $t_{op.s}$=0.35 sec and the maximum value of the starting current is 6.7 times larger than the rated current. The maximum value of the electromagnetic torque of the electric motor is 143.1% of its rated torque. As can be seen from the figure, the parameters of the motor reach the rated value in approximately 0.6 sec.

The oscillogram of the motor start-up is shown in Figure 5 with the following values: the frequency given to the motor is f=40 Hs, the voltage U=176 V, and the angular velocity ω=125.6 rad/sec and moment on the shaft (M_c=M_n).

In Figure 5, $t_{op.s}$=0.6 sec and the maximum value of the starting current is 6.6 times larger than the rated current. The maximum value of the electromagnetic torque of the electric motor is 143% of its rated torque. The effective value of the load current in the motor's steady operation mode under load (M_c=M_n) is 4.3 times higher than in the no-load operation mode (M_c=0).

The oscillogram of the motor start-up is shown in Figure 6 with the following values: the frequency given to the motor is f=50 Hs, the voltage U=220 V and angular velocity ω=157 rad/sec and moment on shaft (M_c=M_n).

In Figure 6, $t_{op.s}$=0.8 sec and the maximum value of the starting current is 6.2 times larger than the rated current. The maximum value of the electromagnetic torque of the electric motor is 166.3% of its rated torque. The effective value of the load current in the motor's steady operation mode under load (M_c=M_n) is 3.4 times higher than in the no-load operation mode (M_c=0).

The oscillogram of the motor start-up is shown in Figure 7 with the following values: the frequency given to the motor is f=70 Hs, the voltage U=220 V, and the angular velocity ω=219.8 rad/sec and moment on the shaft (M_c=M_n).

In Figure 7, $t_{op.s}$=1.35 sec and the maximum value of the starting current is 4.9 times larger than the rated current. The maximum value of the electromagnetic torque of the electric motor is 83.1% of its rated torque. The value of the no-load operating current (M_c=0) in the steady state of operation of the motor is about 7.12 A. After starting the motor, the voltage remains constant equal to the rated value, and the frequency increases by 1.4 times compared to the rated value. This is necessary to remove the hanging part (gap) of the mooring rope.

3. CONCLUSIONS

Mathematical model of the electric drive of the ship mooring (capstan) controlled by a frequency converter realized in the time function of the voltage and frequency in the Simulink package of the MATLAB program is compiled in the paper. It is possible to determine the optimal starting characteristic of the motor during various loadings by means of this method. It was also found that when controlling the electrical drive of the mooring with the frequency converter, one-winding motors can be used instead of two- and three-winding motors, as a result of which the control would become smooth, the circuit simplify and the size and weight of the motor decrease. The study of the transient process of single-winding three-phase rotor of the mooring capstan of a short-circuited asynchronous motor shows that the time spent on the transient process of such electric drive is less than 1 second. This indicator makes it possible to prevent accidents that may occur during the mooring process.

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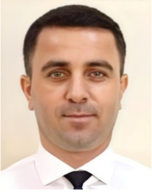

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