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EXPERIMENTAL STUDIES OF STARTS MODES THE FREQUENCY-CONTROLLED ELECTRIC DRIVE OF PUMP UNIT

Abstract: The article deals with experimental studies of starting modes of frequency-controlled electric drive of the pumping unit. Starting modes of pumping units are studied taking into account the position of the valve in the pressure pipeline. The conditions of selection of the starting frequency converters of the "motor-pump" system with centrifugal pumps by asynchronous electric drive at the pump starts on the open and closed valve of the pipeline are revealed.

Keywords: start-up, frequency Converter, motor, current, power, pump unit, valve, pressure pipeline.

To automate the operation of pumping units, an important issue is to determine the start conditions: open or closed valve. The trigger mode determines the degree of difficulty and the cost of automatic management of pump installations. In this regard, we consider the mode of operation of the pumping unit at a frequency start with an open and closed valve and determine the rational start mode.

– To study the features of the pump in a system with a frequency-controlled electric pipeline network, it is necessary to know the limits of the required torque in the control frequency range from 0 to f_n.

The mechanical characteristics of a centrifugal pump are influenced by the following factors:

– state of the valve in the discharge pipeline (valve is open or closed);

– characteristics of the pipeline network to which the pump operates;

If the pipeline is short, without the height of the geodetic lift, then basically it is necessary to overcome the frictional resistance, with a long pipeline – the back pressure of the network. With a long pipeline, the mass of fluid that needs to be pumped is so great that the time required to communicate the acceleration fluid is much longer than the motor's acceleration time to the nominal speed of rotation[1].

When the pump is started on a closed valve, the effect of back pressure and hydraulic shock on the transition mode is eliminated. The starting characteristic in this case can be defined as follows

$$M_C = M_{MF} + M_O\left(\frac{f}{f_n}\right)^2, \qquad (1)$$

Where is $M_O = 975\frac{P_O}{n_n}$ the moment of resistance when the pump operates at the rated speed with the latch closed; P_o – power consumed by the pump at $n = n_n$, $Q = 0$; n – speed of rotation of the pump shaft; f – frequency of control. Parameters with the index "n" correspond to the nominal value, without the index – to the current one.

Characteristics of the pump when starting with an open valve, when there is a back pressure is described by the dependence

$$M_S = \left(\frac{975}{102}\frac{Q\left(N_{SP} + RQ^2\right)}{n} - M_{MF}\right)\frac{1}{\eta} + M_{MF}, \qquad (2)$$

When starting with an open valve, in the presence of back pressure, the starting characteristic is determined by two formulas: until the pump has overcome the counter pressure N_{SP} and its capacity is zero, the characteristic is determined by formula (1), because the work under such conditions is similar to working on a closed latch [2]. From the moment when the pressure is greater than N_{SP} and the liquid supply begins, the characteristic is determined by (2). The starting characteristic of the pump with the open valve of the pipeline when operating on a network without back pressure, i.e. $N_{SP} = 0$ is expressed in dependence

$$M_S = M_{MF} + 0{,}95M_N\left(\frac{f}{f_n}\right)^2, \qquad (3)$$

where is M_N – the nominal moment of the centrifugal pump.

Where Q – is the performance at a given rotational speed n; N_{SP} – static pressure; R – is the resistance of the pipeline; η – is the efficiency of the pump. According to [2], for the straight pipeline section $R = 0.083\lambda lQ^2/d^5$ and for local resistances $R = 0.083\varphi Q^2/d^4$; here $\lambda = 0.02 \div 0.03$ is the coefficient of friction of water against the walls of the pipeline; l – is the length of the pipeline; d – is the diameter of the pipeline; φ – is the coefficient of local resistance equal to for valves $\varphi = 0.5$; for a 90°– rounded elbow, $\varphi = 0.3$ for a check valve $\varphi = 5.0$. The coefficient 0.083 has the dimension c^2/m.

We accept that the pressure developed by a centrifugal pump is proportional to the second power of frequency

$$\frac{N}{N_1} = \left(\frac{f}{f_1}\right)^2. \qquad (4)$$

Expression (4) is valid under the condition of unchanged pump capacity Q.

At the nominal frequency f_n and nominal pressure, H_n defined by the intersection point of the characteristic Q-N pump at a frequency f_n, then the pressure developed at frequency f, is equal to

$$N = \frac{N_n}{f_n^2} f^2. \qquad (5)$$

The calculation of the starting time can be performed using the drive equation of motion:

$$M - M_S = J\frac{d\omega}{dt}, \qquad (6)$$

where does that

$$t = J\int_{\omega_1}^{\omega_2} \phi(\omega) d\omega. \qquad (7)$$

where $\phi(\omega) = \frac{1}{M - M_S}$ – is the function of speed at frequency start; M – is the motor torque; J – total moment of inertia of the drive; ω – rotation frequency [1].

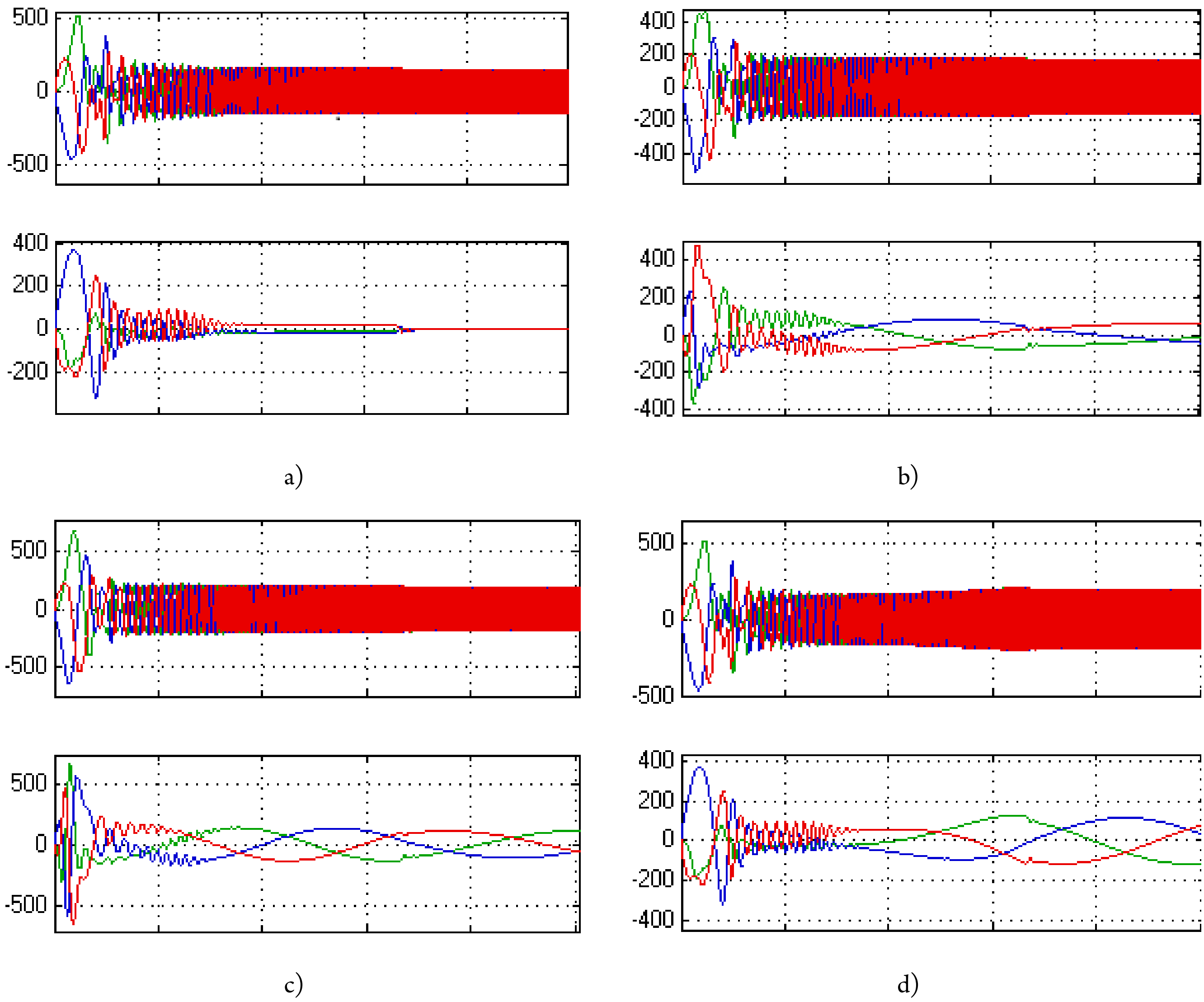

Figure1. Changes in the stator i_{1abc} and rotor currents i^1_{1abc} at a frequency start as a function of time: a) $M_S = 0$; b) $M_S = 0.5$; c) $M_S = 0.95$; d) $M_S = \omega^2$

We have examined experimental studies of the start-up of pumping units with asynchronous motors using the example of pumping units of the Chirchik pumping station in the Tashkent region.

The results of instrumental measurements of the electric drive of the equipment feeding from the frequency converter with a power of 160 kW are of interest. According to the measurements, a plot of water lifting from the pump to the water outlet from the pressure pipeline was constructed (Fig. 2).

In this case, the operation mode of the pump unit on the pressure pipeline is divided into six sections. 1-section – pump acceleration with the latch closed from the motor fed from the frequency converter. The stator current increases until the gate is opened; 2-site – the beginning of the opening until the valve is fully open; Section 3 – the process of filling the pipeline with the angle of rise of the pressure pipeline at the angle α1 is in progress; 4-section – the process of filling the pipeline with the angle of rise of the pressure pipeline by an angle α2; 5-section – is characterized by the fact that the outlet of water from the pressure pipeline begins; 6-section the beginning of water supply within the limits $Q = 0 \div Q_{nom}$ depending on the speed of the pump from the frequency-controlled electric drive.

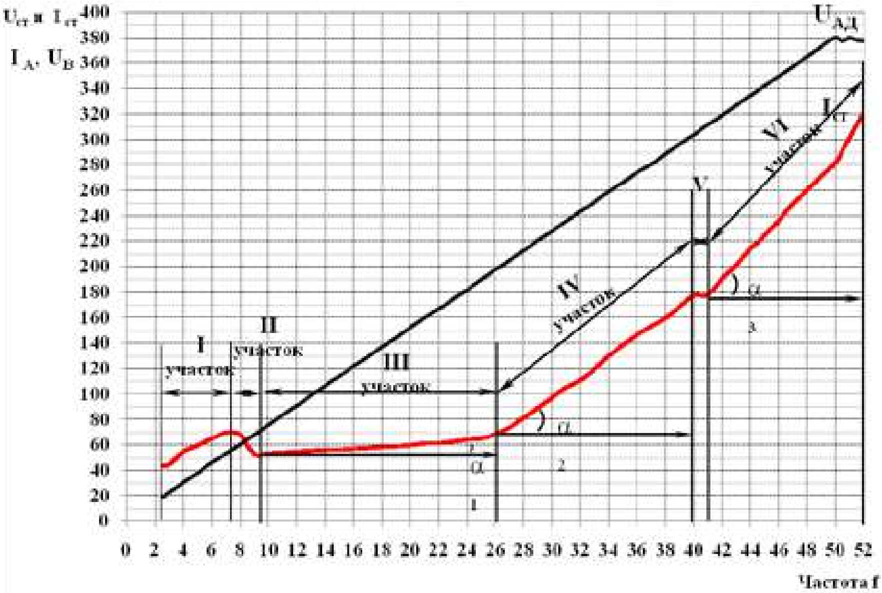

Figure 2. Graph of water lifting from the pump to the water outlet from the pressure pipeline

As seen in the process of accelerating the pump with the latch closed, there is an increase in the stator current of the motor. At the moment the valve opens, the stator current decreases and the stator current increases in the subsequent full opening of the valve, depending on the angle of inclination of the discharge pipeline. As the slope of the pipeline increases, the stator current increases until the water exits the pressure pipeline.

In conclusion, it should be noted:

– It has been established that the most rational frequency start-up of an asynchronous motor of a pump installation is a start-up with the intensity of frequency change in which the transient process and losses are minimal.

– It was revealed that with a frequency start with a given intensity and different load on the motor shaft, the dependence of the electromagnetic moment on time almost does not change. Electromagnetic transients are completely damped to a speed corresponding to the critical slip on a static mechanical characteristic.

– The shock electromagnetic moment at frequency start-up reaches its maximum at all loads on the shaft approximately at the same time. The maximum magnitude of the shock electromagnetic moment will change depending on the load from *0.8* at $M_c = 0$ to *2.1* at $M_c = 0.95$.

– It was determined that with a frequency start on a closed valve, the duration of the transition process is $t = 0.6$ *sec*. When starting with the open valve, the duration is $t = 0.9$ *sec*. The longest start-up is the start with the open valve when working on the network without backpressure.

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