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Analysis of Self-Starting Modes of Pumping Motors

Abidov K.G., Zaripov O.O., Nazrullayeva O.A.
Senior Research Fellow, Department of Energy, Tashkent State Technical University, Uzbekistan

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Abstract
Considered transients in coasting modes when the pump lost the drive, as well as self-starting asynchronous electric drive of the pump unit. In order to improve the technical and operational indicators of meliorative pumping stations, the necessity of using the self-starting mode of electric drives of pumping plants is justified. The results of field studies of unsteady processes during self-starting electric motors at pumping stations are presented. The simulation of transient processes in self-starting modes of an asynchronous electric drive of a pump unit is considered with the aim of identifying the nature of the change in supply, head and moment of resistance on the pump shaft in the marked modes

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I. INTRODUCTION

It is known that high-lying arrays are irrigated by water supplied by pumping stations of small, medium and high power. The last years in the republics of Central Asia, especially in Uzbekistan, a large number of land-reclamation pumping stations and cascade pumping stations have been built. Currently, more than 2,000 pumping stations and more than 900 vertical drainage wells operating for irrigation are in operation, including large pumping stations of the Karshi Main Canal with pumping stations with a capacity of 200 m3 / s. Along with large, many medium and small pumping stations are being operated. In Uzbekistan itself, using pumping stations, it irrigates about 2 million hectares of land with a consumption of 8 billion kWh of electricity, which is about 17% of the electricity generated in the republic in one year.

At pumping stations, synchronous and asynchronous short-circuited and with a phase-rotor motors are usually used. For water-lifting pumping stations, the Uralelectrotyazhmash plant produces special synchronous and asynchronous motors of the ВСДН series and the ВСД 260-ВДС375. Each pump unit can work on one pressure pipeline or combine several of them into a common pressure pipeline. With this arrangement, pumping units operate in parallel in a common pipeline. To cover a significant static pressure is used sequential inclusion of pumping units. Along with this, several pumping units can be connected to the common pressure pipe in series-parallel. For these options, as a rule, apply electric drive with centrifugal pumps. For two pressure pipelines for joint and series-parallel work can combine 2-5 pump units.

II. SIGNIFICANCEOFTHESYSTEM

A characteristic feature of the power supply of pumping stations, located mainly in rural areas, is the relatively frequent occurrence of short-term power interruptions due to a short circuit or a deep landing voltage in the power system. In this case, all engines are automatically shut off with the help of protection, the valves do not have time to close and the pumping units operate in the hijacking mode. This adversely affects the individual units of the unit, fail gland packings, mounting fasteners relax. Due to such outages at the pumping station line, some pumping stations stop for 2-3 days for repairs, which requires additional costs. In this regard, the use of self-start mode in meliorative pumping stations is also an important problem. As a rule, the process of self-starting is divided into two stages. The first stage is the shutdown of the units (single or group). Single - this is when one electric motor is disconnected from the network and from others, or when other engines, electrically connected with it, do not have a noticeable effect on the coasting process. If the mutual influence of disconnected from the power sources of engines is large, such a coasting is called a group. The second stage is acceleration and restoration of the operating mode.

III. LITERATURESURVEY

To assess the possibility of self-starting, we will analyze the transient modes of single and group coasting of asynchronous motors of pumping units of the Amu-Zang pumping station of the first lift of the first and second stages. Figure 1 shows the curves of the run-away time versus the rotational speed and the number of pumping units based on the processing of the experimental recorded waveforms, which were taken at the Amu-Zang pumping station of the first lift of the first stage. Curve 1 in Figure 1- for a single run of the pump unit No. 3. Shutdown was made when only one pump No. 3 was working for one common collector. The total run-out time of this unit is 5.25 s. The value of the maximum reverse theft speed of the pump unit n backward = 650 rpm. Curve 2 in Fig. 1 for group run-on of pumping unit No. 3, when two pumping units worked on one collector — No. 3 and No. 4. The total time of the group run-on of the pumping unit is 6.0 s. Curve 3 in Fig. 1 for group run-on of pumping unit No. 10, when pump units No. 9,10,11,12 (four units) worked on one collector. Run out time 8.45 s. The maximum value of the inverse of the hijacking speed n is the inverse hijacking = 650 rpm
Analysis of the experimental data shows that the run-on time of the pumping unit is minimal when one unit is working for a common collector, with the increase in the number of pumping units running, the run-out time increases.

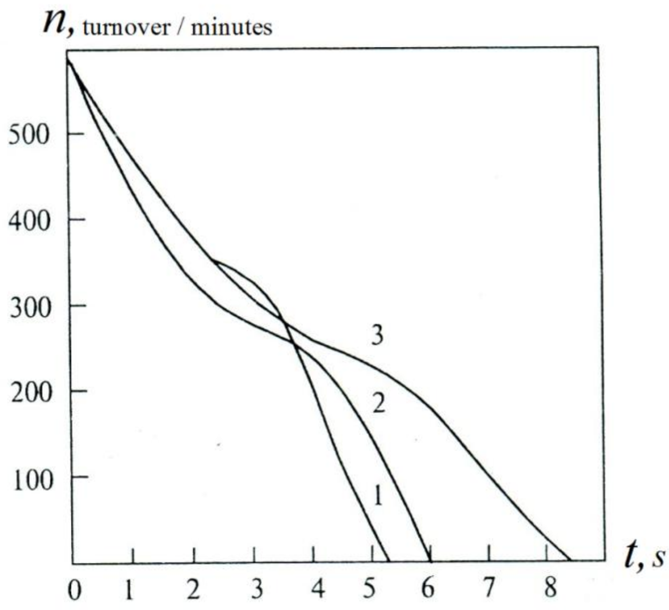

Fig.1. Oscillogram of pumping unit shutdown, power 630 KW

IV. METHODOLOGY

Transients in self-starting pumping units with asynchronous electric drives are described by a system of equations that includes a mathematical description of the dynamic, mechanical characteristics of an asynchronous motor in fixed axes α, β, the equation of motion of the rotor of the unit, the balance equation of the full head of the pump and system, the filling equation of the pre-gate chamber or the pressure water conduit:

$$u_{1\alpha} = R_1 i_{1\alpha} + \frac{d\psi_{1\alpha}}{dt};$$
$$u_{1\beta} = R_1 i_{1\beta} + \frac{d\psi_{1\beta}}{dt};$$
$$0 = R_2 i_{2\alpha} + \frac{d\psi_{2\alpha}}{dt} + \omega_{el}\psi_{2\alpha};$$
$$0 = R_2 i_{2\beta} + \frac{d\psi_{2\beta}}{dt} + \omega_{el}\psi_{2\beta};$$
$$M_{dv} = P_{\text{п}} L_{12}\left(i_{1\beta} i_{2\beta} - i_{1\alpha} i_{1\alpha}\right);$$
$$J\frac{d\omega}{dt} = M_{dv} - M_g - M_t;$$
$$H_{\text{н}} = H_g + \Delta H + H_{\text{п}} + H_{in};$$
$$Q_p = Q_{ak} + Q_{\text{п}} + Q_i$$

где: $u_{1\alpha}, i_{1\alpha}$ -voltage and current of stator windings in axes α;

$u_{1\beta}, i_{1\beta}$ - voltage and current of stator windings in axes β;
ψ - flux linkage of the corresponding winding indices;
R_1 - active resistance of one stator phase;
R_2 - resistance of the rotor chain brought to the stator;
$i_{2\alpha}, i_{2\beta}$ - rotor circuit currents brought to the stator;
$P_п$ - the number of pairs of poles of the machine;
ω_{el} - electric angle of rotation, rotor relative to the stator;
L_{12} -mutual inductance;
$H_н$ - manometric pump head;
H_g - geometric head;
ΔH - the increment of pressure when changing the filling of the pipeline;
$H_п$ - hydraulic losses in the pump leak path;
H_{in} - inertial head of water mass in the flow path of the pumping station;
$Q_p, Q_{ak}, Q_п, Q_i$ - respectively, the pump flow, the cost of accumulation, overflow through the valve and outflow from under the shutter.

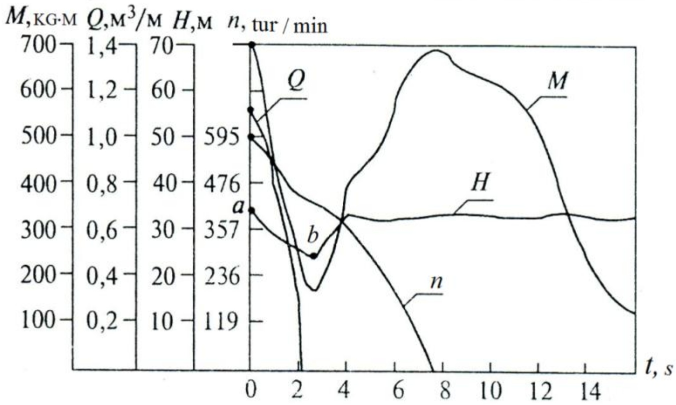

Fig.2. Turning off the electric drive pumping unit, power 630 kW

In connection with the rapid flow of electromagnetic transients in the calculation of self-starting, we neglect the dynamic characteristic of the electric drive. In view of the foregoing, we consider the calculation on the computer of shutting down the pump unit when the drive is disconnected and the locking device fails to operate or is absent (Figure 2). When an overrun mode of a pump installation occurs, the rotational speed decreases and the pressure decreases accordingly, then the rotational speed decreases so much that the flow becomes zero at the minimum headpressure H, although the impeller rotates in the same direction. The moment on the pump shaft also falls and has a minimum value at Q = 0 and at Hmin. Then begins the change in the direction of water flow (countercurrent mode), the pressure H also begins to grow, although the direction of rotation of the shaft of the pump unit remains the same. The speed of movement of water in the opposite direction increases rapidly. When changing the direction of water flow, it is undesirable to carry out the self-starting of the pump unit, since at the moment of switching on a large moment on the motor shaft is required.

V. EXPERIMENTALRESULTS

Below are some results of the experimental characteristics of the self-start. The engine was turned off and at $t_{shutdown}$ = 2.7 s it turned on and self-started (Fig. 3.). During the power interruption, the engine speed decreased to n = 333 rpm, the self-starting process was completed in 0.7 s, after which the pumping unit began to work in normal mode.

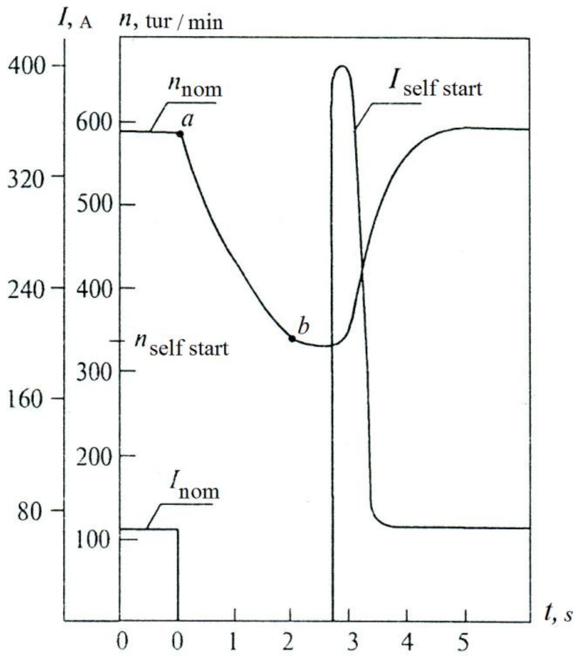

Fig. 3. Oscillogram of self-starting at t = 2,7 s

Optimally, it is possible to perform a self-start within the limits of the section a and b of the

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pump discharge characteristic; The value of excess torque is within the acceptable range, then the moment on the pump shaft grows. In the general case, it is proposed to perform self-starting at any time when the pump unit is still in the zone of the first quadrant of the overrun mode and when the pump flow changes from the nominal value to zero, which corresponds to the minimum head value.

Experiments show that the time of self-starting of a pump unit increases with decreasing rotational speed at coasting and has a maximum at n = 0, while the value of current and torque of the electric motor strongly increases.

VI. CONCLUSIONANDFUTUREWORK

Self-starting will be successful if the engine accelerates after the voltage is restored to the rated speed and the following conditions are met:

1) normal voltage in the pump impeller;
2) heating the motor windings in the normal level;
3) engine torque provides engine acceleration to rated speed;
4) the permissible value of pressure in the pipelines.

Mathematically modeling the process of self-starting and setting the duration of the power interruption with a different interval of time, we determine the maximum duration at which self-starting is impossible. In this case, one of the conditions for a successful self-start fails. Knowing this time, you can properly configure the mode of operation of the automation when the voltage is restored. To determine the exact time limit of the break, it is necessary to simulate the simulation of self-starting, taking into account all the accepted conditions.

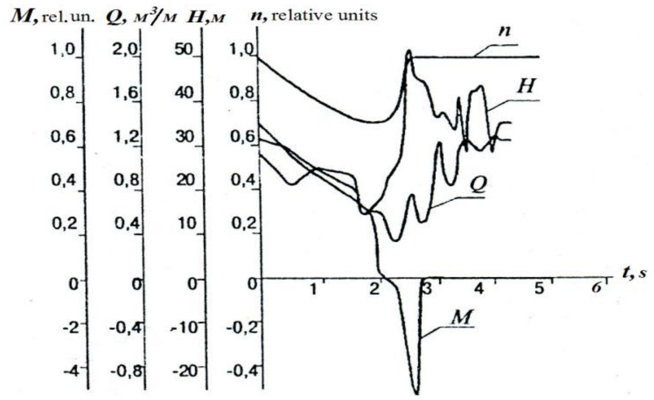

Fig.4. The results of the calculation of self-start t = 2 s

On the basis of the equations and instructions [4-5], an algorithm and a computer program for calculating the problem under consideration have been developed. This program calculates the criteria for assessing the success of the self-start of the pump unit when it is restarted after a short power interruption. The calculation consists of two stages.

The first is when the motor is turned off and the unit has run out to a specified speed, which is determined by the power interruption time.

The second is the moment the engine is turned on and accelerated to the rated speed. At each stage of changing the head, flow rate and speed of rotation of the pump in time are determined by the selection of parameters.

Figure 4 shows the characteristic of the process with an interruption interval tth = 2 s, constructed from the calculated data *Hf(t),Q=f(t), n= (t),M= f(t)* for an asynchronous ДАЗО-15-59-10У1, U_H = 6 кВ, P_H=630 кВт, n=595 об/мин, I_H=80 A and a centrifugal pump of the type 24НДС [6]. When the engine is switched off, M_{el} instantly drops to zero. The hydraulic moment of resistance of the pumping unit *M* and the frictional moment M_T, shown as *M* in the time diagram, are preserved. This leads to a decrease in the frequency of rotation of the pump n and the developed head *H*, because of which the flow rate *Q* decreases. Although the parameters *n*, *H*, *Q* decrease, the mode of the unit is kept “pumping”. In this time interval, when the motor is turned on, the second stage, self-start, begins. Under the action of the torque of the motor M_{el}, the pumping unit is accelerated to steady state. The results of field studies and computer simulations for speed parameters *n* are the same.

Findings

1. The response time of the auto-reclosing system of the electrical network for self-starting is determined from the overrun mode of a particular pumping unit, and the control of the restoring voltage is necessary to a value that ensures successful self-starting.

2. The system of self-starting electric motors must take into account technological limitations,

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actions of technological protections and automation of restoring the operation of auxiliary mechanisms. When designing and determining their operating conditions, it is necessary to take into account the effect of various types of transient processes, especially caused by load sheddings and switching off the drive.

3. An algorithm has been compiled for calculating the self-starting mode of a pumping unit with an asynchronous electric drive.

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Name	E-Mail	Affiliation	Country
Abidov Kudrat	abidoff@rambler.ru	DcS	Uzbekistan 
Zaripov Odiljon			
Narzullayeva Ozoda		Magistr