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On the matters of increasing the dependability of first stage pumping stations power supply

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Abstract. *First stage pumping stations are first category power consumers that usually have back-up power supply. Additionally, the engine room of the pumping station is equipped with synchronous or asynchronous high-voltage motors that in transient states may create unforeseen problems in the power supply system not only within the station, but beyond. The dependability of plant and equipment is defined by many factors, e.g. start-up procedures, stopping-down, operational changes, equipment shutdown. [6]. The primary factors that reflect the impact of the transient states are mechanical overload, voltage slumps in load centers, voltage slumps in switchgear busbars, etc. The value of voltage slump associated with start-up of high-voltage synchronous motors that does not last more than 30 seconds is neglected, though the impact of start-up voltage slump is a negative factor that affects adjacent consumers on the grid [7]. The dependability of the power supply system has an effect not only on pump station operation, but also on the service life of the facility's electrical equipment. An undependable power supply system can also contribute to higher electric loss and deterioration of power quality. Improving the dependability of power supply systems of the considered facilities requires first and foremost specific tasks to be solved. To that effect, this article specifies and analyzes primary causes of faults in first stage irrigation pumping plants. The authors clarify the dynamic stability of high-voltage synchronous motors and its dependence on short interruptions of power supply. They also analyze the impact of start-up currents of synchronous motors on the operation of pumping units and electrical equipment in general. The article substantiates the efficiency of soft starters (SSs) in start-up procedures of high-voltage synchronous motors of pumping units of irrigation pumping stations. The article also establishes the inefficiency of frequency converters in pumping units of irrigation pumping stations using specific examples. It was found that automatic transfer equipment in the considered facility does not ensure the speed of operation required for fault recovery and negation of water hammers in pumping units. The article sets forth the tasks and possible solutions related to improving the dependability of power supply systems of first stage irrigation pumping plants.*

Keywords: *pumping station, soft starter, frequency converters, automatic reserve input, synchronous motor, water hammer, dynamic stability, inrush current, short circuit.*

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High-voltage synchronous motors are the primary power consumers of first stage irrigation pumping plants. This machinery has high capacity factor and inrush current. Among the causes of pumping station failures are loss of dynamic stability of synchronous motors that in turn may be caused by unreliable performance of power supply systems and standby infeed automatics [5]. Another failure-causing factor is inrush current of large synchronous motors causing kinetic force in stator winding which can weaken the end-winding and induce unacceptable local heating in the rotor [4]. In powerful vertical synchronous machines with large active length, the start-up procedure causes uneven heating of bars that causes thermodynamic force and subsequently the destruction of starting winding. Additionally, at start-up busbar voltage may slump. The quality of power delivered to consumers connected to substations that feed pumping stations currently only defined by the provisions of GOST 13109-97 [7]. In the Russian Federation, voltage slumps shorter than 30 seconds are disregarded, whilst high-voltage synchronous motor start-up usually does not exceed 10 to 15 seconds. This problem, as well as the problem of start-up thermodynamic force is partially mitigated by starting-up large synchronous motors with partial voltage. In this case the start-up voltage is lower and the start-up time is longer. Therefore, in each particular case the start-up procedure for large synchronous motors varies [2, 3]. For example, when a powerful synchronous motor is started-up using

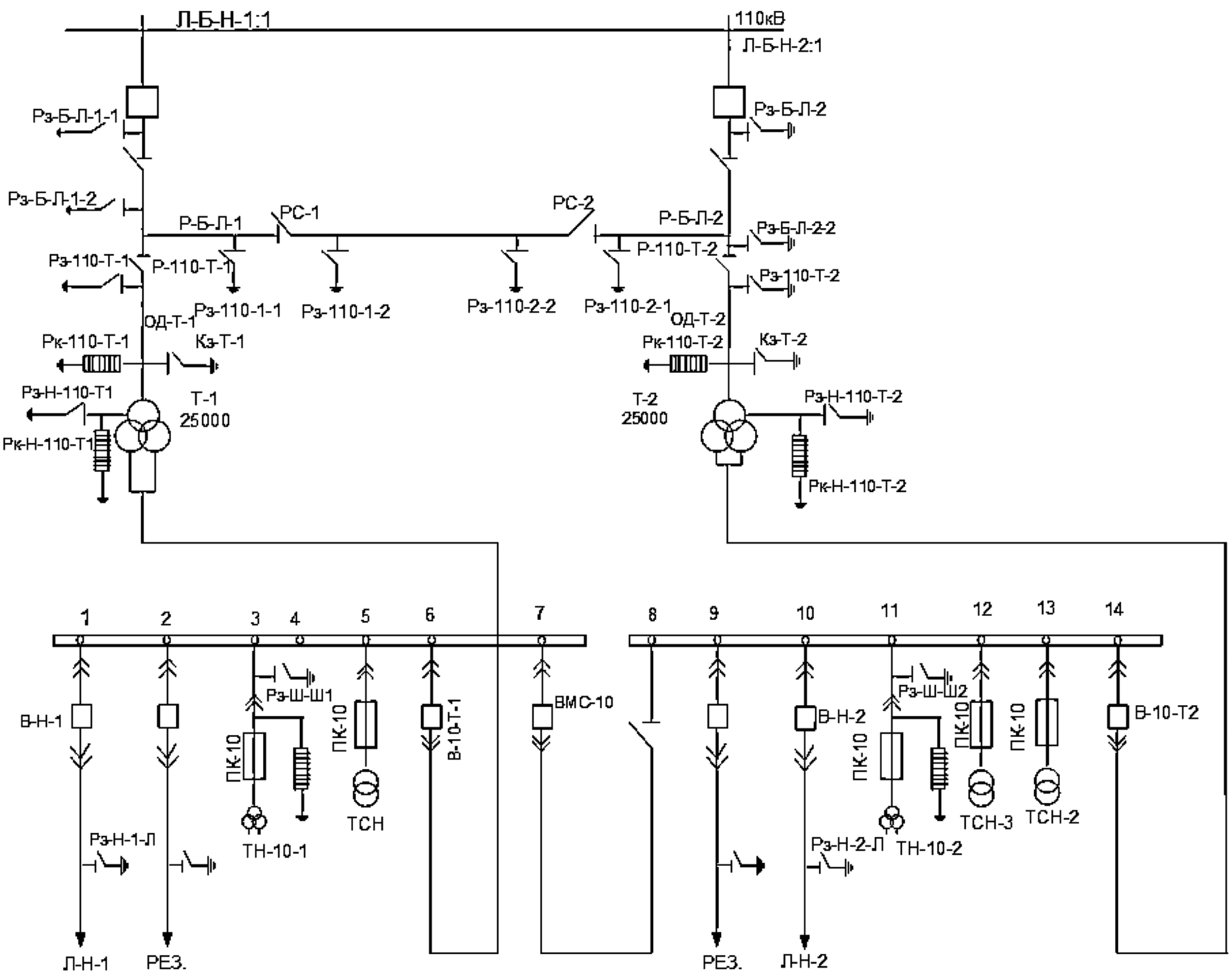

Fig. 1. First stage pumping station (ANS-1) power supply diagram

insufficiently powerful voltage source, a significant voltage slump may occur at motor output.

In this article the research object is the Asht pumping station cascade, namely ANS-1 situated in the Asht District of the Republic of Tajikistan. The design pumping power of the ANS-1 station is 1,7712 mil m^3 of water a day. As of today, only two pumping units of ANS-1 with total output of 0,88 mil m^3 of water a day are operational. Figure 1 shows the ANS-1 power supply diagram [1].

The ANS-1 pumping station is a first category power consumer, thus it is powered by two independent substations [1]. Power to ANS-1 is supplied from the Bulok-2 central power distribution station with the power of 2Ч63 MVA. Via two 110 kV power lines voltage from Bulok-2 is delivered to the power substation of ANS-1. The power substation of ANS-1 is equipped with two 25000 kVA 110/10 kV TRDN-type transformers.

Main and auxiliary pumping units are fed with 10 kV voltage. The station's control and lighting system is fed with 0.4 kV voltage.

The primary power consumers in ANS-1 are:

- 4 main pumping units with total power of 32 MW,
- 3 auxiliary pumps with total power of 4.8 MW,
- two TM 400 10/0,4 type transformers for internal requirements that power a 0,4 kV power network [1].

ANS-1 pumps stations consume around 250000 kWh a day. Water feed is 0,88 mil m^3 a day. In maximum feed mode, ANS-1 simultaneously runs four pumping units. As it was mentioned above, ANS-1 has 4 pumping units with synchronous drives. The pumping units are powered by vertical synchronous motors of the VDS-325/69-16 UKhL4 series of which the technical features are given in table 1.

Disruptions in pump station power supply cause significant water hammers in pipelines and, consequently, failures and breakdowns of pump station equipment. As the research shows, short interruptions of power supply are one of the primary causes of water hammers [5]. In order to prevent major water hammers it is required to reduce the action time of power supply recovery automatics. Previously conducted research has demonstrated that if the duration of power supply disruption is below 0,3 sec, the effect of static to total pressure ratio is in-

Table 1. Technical features of VDS-325/69-16 UKhL4 series of vertical synchronous motors

№	Type of motor	VDS-325/69-16 UKhL4
1	Power, MW	8
2	Stator current, A	540
3	Rotor current, A	400
4	Stator voltage, kV	10
5	Rotor voltage, kV	0,16
6	Speed, rev/min	375
7	Efficiency, %	0,959
8	cos, ц	0,9
9	I_{start}/I_{nom}	4-4,8
10	M_{start}/M_{nom}	0,32
11	$M_{0,05}/M_{nom}$	1,2
12	M_{max}/M_{nom}	1,8
13	Rotor moment of inertia, $t{\cdot}m^2$	24,5
14	Step bearing load, tnf	125
15	Number of pairs of poles	8

significant, and as the power supply interruption time decreases this effect declines, while the conditions for maintaining dynamic stability of synchronous motors improve [5].

For the purpose of synchronous motor start-up current reduction and thereby improvement of the voltage slump situation, as well as reduction of water hammer in pipelines, a number of technical measures have been developed, e.g. soft starters, frequency converters. Frequency transformers have a number of advantages over other startup systems, the main one being the adjustment of the motor speed and thus power-saving. But frequency transformers are only efficient if the range of speed adjustment is significant. If the range is narrow they do not provide any positive effect, while being very costly. In the context of the considered ANS-1 facility, frequency converters are not efficient, therefore the authors suggest using soft starters. Those devices are simple voltage regulators based on power semiconductors, i.e. thyristors and symistors. Soft starters are only used in the start-up procedures, after which they are shut down or used to start-up another motor. If a soft starter is used up to 3 to 4 times, the start-up current can be limited with insignificant voltage slump. Another advantage of soft starters over the frequency transformers consists in the fact that they are several times cheaper and have a simpler design.

Another factor that affects the operation of pumping station power equipment is the fault conditions, i.e. short circuit conditions. Corresponding research has shown that in case of three-phase short circuits the allowable time of power supply interruption is 0,09 – 0,11 sec for the pumping units in question under condition of short circuit duration of 0,07 – 0,08 sec [5]. During this time dynamic stability of synchronous motors is maintained. But the problem is that existing standby infeed automatics cannot provide required response time.

Therefore the problem of ensuring dynamic stability of high-voltage synchronous motors in the context of improving the dependability of pump station power supply system is relevant and in order to solve it, a number of tasks must be set and carried out:

- using soft starters in start-up procedures of high-voltage synchronous motors with low control ranges,
- developing fast-acting microprocessor-based standby infeed automatics,
- researching the application efficiency of soft starters in order to improve the dependability of power supply systems of first stage irrigation pumping plants,
- in order to reduce the equipment costs, researching less expensive methods of improving the dynamic stability of high-voltage synchronous motors, e.g. inclusion of a resistor in the exciting circuit, cyclic superexcitation, etc.,
- performing feasibility studies of deployment and application of intelligent power supply system supervision and monitoring solutions in first stage pumping stations.

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