# Energy-efficient asynchronous electric drive as a means of increasing the reliability and energy efficiency of pumping plants in the urban water supply system

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**Abstract.** The article discusses the issues of improving energy efficiency and reliability of the pumping plant for buildings and structures' water supply. An example of the operation of a pumping plant energy-efficient asynchronous electric drive is given. The optimal pump control algorithms are considered.

## 1 Introduction

The current pace of urban infrastructure development, the construction of multi-storey buildings in the city center, various business centers, hotel complexes and skyscrapers leads to the need to solve the problems of their electrification and water supply. New modern buildings put into operation require continuous supply of water and electricity. For this distribution substations and pumping plants for water supply are being built in the immediate vicinity of the facility. The inclusion of these additional capacities in the existing electricity and water supply networks is a significant load on the existing electricity and water supply systems. This leads to the quality deterioration of power supply and drinkable water supply hitches at the new facility. In this regard, an integral part of the design and construction of new buildings are the issues of improving the reliability, quality and efficiency of resource use.

## 2 Results and discussion

Consumers will not be able to receive water in the required volume using the existing water supply system for urban buildings and structures. In this regard, modern systems of booster pumping plants are selected to provide the required volume and pressure of water. The pressure boosting pumping plant allows the facility to be supplied with water of the required pressure from the city water supply. As a rule, such a pumping plant consists of two or three (in some cases up to six) pumps and a control cabinet. The presence of a frequency converter ensures soft regulation of the pumps rotation speed and maintaining the required pressure

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value depending on the current water demand. Consider the operation of a pressure boosting pumping plant using the Tashkent city residential complex as an example. The pumping plant consists of three high-pressure centrifugal multistage pumps connected in one pipeline and a pump control cabinet. Pump model is GRUNDFOS PN-SN A96501910 type CR15-7 A-A-A-E-HQQE. Pressure $H/H_{max}$ – 77.9/98.5m. Consumption – 17m$^3$/h. Drive motor power – 5.5kW, 3000rpm, 50Hz. The control cabinet is designed to control the pumps pressure by means of the pumps rotation speed frequency control. Provides stable maintenance of the set pressure and energy-efficient regulation of pumps when the water flow changes. The control cabinet contains a DANFOSS frequency converter, as well as additional protective and switching equipment. The operation of the pumping plant occurs automatically with pressure feedback on the pressure pipeline. If, during the operation, one pump is not enough, a special controller will give a command to connect an additional (next) pump. In this case, an additional pump is connected directly to the network. Thus, the pumps are switched on one by one in order to ensure the required pressure in the pipeline network. Figure 1 shows a general view of the control cabinet. Figure 2 shows a single-line scheme of an existing pumping station before modernization, where FC is a frequency converter; M1, M2, M3 – asynchronous pump drive motors; QF1-QF3 – circuit breakers; KM1, KM2 – contactors.

**Fig. 1.** General view of the pumping plant control cabinet.

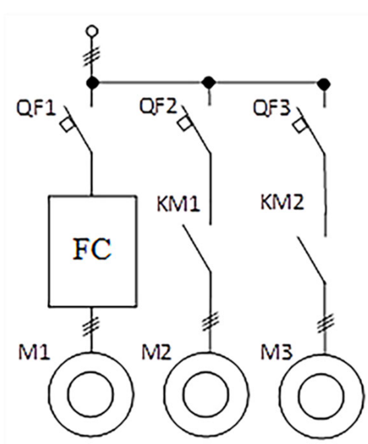


**Fig. 2**. Scheme of the pumping plant power part.

Pumps that are connected directly to the network experience starting current inrush during pressure regulation, the value of which reaches 58-65A. In this case, the duration of the start is 0.5-0.8 seconds. In addition, there are sharp pressure drops that are felt by the consumer in the form of a change in water pressure at a level of 10-18 meters for 10-20 seconds, strong vibration of the pipeline network, frequent leaks and water breakthroughs.

To avoid these disadvantages, it was proposed to introduce an energy-efficient asynchronous soft starter and water supply pumps control when designing water supply for houses, and replace the existing scheme of pumps start control directly from the network with an energy-efficient soft start and control system for the pumping unit. The UMP-2 energy-efficient soft start and control devices were additionally included in the power supply scheme for the pumps. The operation algorithms of these devices were developed and improved by the authors [2]. Figure 3 shows the general view of an energy-efficient soft starter and control device, Figure 4 – the modernized pumping plant power unit. Here, instead of the contactor group KM1, KM2, energy-efficient UMP-2 soft start and control devices, manufactured in Uzbekistan, are installed, which act as switching, protective and control equipment.

**Fig. 3.** General view of the energy efficient soft start device.

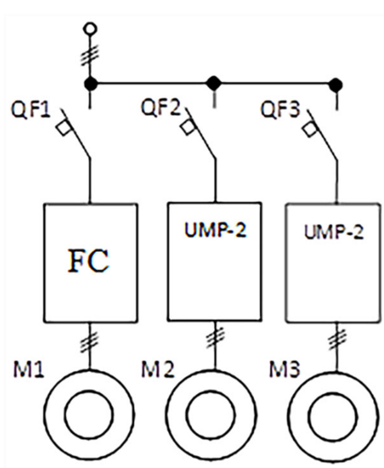


**Fig. 4.** Modernized scheme of the pumping plant.

The operation of the automatic pressure and water supply control system did not fundamentally change the operation algorithm as a whole. The pumps are also switched, according to the inherent algorithm of the GRUNDFOS controller, but some features have appeared. The need for cold and hot water during the day is different, and varies widely. Three pumps operate during the maximum water flow period. The main tasks of the introduction of the energy-efficient soft start and pump control devices:

- Ensuring soft start of the pumping unit. According to the scheme in Figure 2 additional pumps are connected directly to the network. This contributes to the appearance of hydraulic shocks, high starting currents, etc. But, in the modernized pump control scheme (Figure 4.), due to the optimal algorithm for changing the output voltage supplied to the input of the pump unit drive, UMP-2 devices make it possible to reduce starting currents by 2-3 times, to ensure soft acceleration of the asynchronous pump motor without jerks, and, in fact, without water hammer. During soft start, the pumping unit working blades do not experience the mechanical forces that are observed when starting directly from the network, and, accordingly, bearing assemblies and glands will last a longer period.
- After the asynchronous motor acceleration and reaching the operating point by the pumping unit, the system starts to work in the operating mode, and with excess pressure in the pipeline, it reduces the rotational speed of the first pump unit using a frequency converter. In steady state, the UMP-2 system allows you to bring the asynchronous electric motor operation into a power saving mode by regulating the output voltage supplied to the electric motor.

The physical meaning of ensuring the asynchronous electric motor operation mode in an energy efficient mode is to ensure its operation under the condition:

$$\frac{\partial i}{\partial \varphi} = 0, \quad (1)$$

where $i = \frac{I}{I_{nom}}$ – relative value of stator current, $I$ and $I_{nom}$ – present value and nominal value of stator current, respectively, $\varphi = \frac{F}{F_{nom}}$ – relative value of the magnetic field in the asynchronous electric motor air gap, $F$ and $F_{nom}$ – present value and nominal value of magnetic flux, respectively.

At the same time, taking into account that, $\Phi = f(U) = \sim kU$, we can represent the expression (1) in the form:

$$\frac{\partial i}{\partial u} = 0, \quad (2)$$

where $u = \frac{U}{U_{nom}}$ – relative value of the motor stator voltage, $U$ and $U_{nom}$ – present value and nominal value of motor stator voltage, respectively.

Thus, we can ensure a minimum stator current of an induction motor with any load on the shaft.

## 3 Conclusion

A number of changes were made to the operation of the existing pumping plant for water supply of the Tashkent city residential complex, after the introduction of an energy-efficient soft start and asynchronous motor control device. In fact, the task of providing water was carried out according to the old scheme, but it had the disadvantages described above. After the modernization, all the disadvantages were eliminated and the operation of the water supply pumping plant control system became more efficient and reliable in terms of energy efficiency and resource saving.

The following results were obtained:

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- starting currents reduction of the second and third pumps;
- pressure drop reduction from 10-18 meters to the level of 6-8 meters, which significantly reduced hydraulic impacts on the pipeline network;
- operating current reduction of the asynchronous motor.

The work results are summarized in Table 1.

**Table 1.** The work results.

| Scheme | Pressure differential, m | Starting current, A | Motor voltage, V | Operating current, A | cosφ |
|---|---|---|---|---|---|
| Direct start | 16-18 | 58-65 | 388 | 9.5-9.7 | 0.82-0.84 |
| With energy-saving soft start device | 6-8 | 25-33 | 372 | 9.1-9.3 | 0.86-0.89 |

The energy-efficient asynchronous electric drive systems proposed by the authors can be used not only in the field of water supply, but can also be used in other areas of industry. The presence of a modern microprocessor base in the control system of energy-efficient soft start and control device, as well as a flexible control algorithm, allow them to be integrated into almost any complex of automatic control and regulation systems of technological processes.

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