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Method for determining reactive power compensation with smooth control of pumping unit performance

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ABSTRACT: The issues of reactive power compensation at pumping stations of machine irrigation systems with low-voltage and high-voltage asynchronous and synchronous motors are considered, taking into account the location of pumping stations as a dead-end consumer of electricity with extended power lines. The peculiarity of pumping stations as a consumer of reactive energy is revealed. Additional losses of voltage, active and reactive power and their influence on losses of power, electricity and transmission capacity of electrical networks are described, methods for choosing devices for compensating reactive loads with smooth regulation of pumping units in machine irrigation systems are developed. The results obtained are the basis for the structure in the system of pumping stations for machine irrigation with smooth regulation of the electric drive of the pumps.

KEYWORDS*:* reactive power compensation, pumping station of mechanical irrigation systems, asynchronous motor, synchronous motor, frequency converter, compensating devices, techniques, higher harmonics, efficiency, power factor, pumped water volume, pool levels.

I. RELATED WORK

Reactive power does not produce any work, but without it, active power cannot be transmitted through power lines (TL), between the primary and secondary windings of the transformer and through the gaps between the stator and rotor of electric motors. Consumers of reactive power necessary to create magnetic (electrostatic) fields are both individual power transmission links and such power receivers that convert electricity into another type of energy that, according to the principle of its operation, uses a magnetic field (asynchronous motors (IM), converters, electric lighting installations with gas-discharge lamps). [1-4].

II. INTRODUCTION

The main advantages from the use of reactive power compensation devices can be distinguished:

- Energy savings

The introduction of reactive power compensating devices gives a significant economic effect. Reducing the level of energy consumption can be up to 40-50% of the total. With such volumes, the payback period for power compensation systems will be no more than one year.

- Extended equipment life

Compensation tools increase the service life of power transformers, since their use reduces the load on the equipment. The use of compensation settings also reduces the load on the transmission lines and the heating of the wires, which allows the use of smaller conductors.

- Cost savings for the installation of supply networks

At the stage of design and construction of new buildings, the installation of a reactive power compensation system can significantly save on the arrangement of the distribution network.

- Improving the quality of energy supply

The use of reactive power compensation means makes it possible to suppress network interference, avoid deep voltage drop and minimize phase unbalance. In addition, compensation systems as part of passive filters can reduce the level of higher harmonics.

- No fines

Measures taken to compensate for reactive power can be divided into those associated with a decrease in the consumption of reactive power of pumping units and requiring the installation of compensating devices (CD) at the appropriate points in the system.

The choice of ways to control the output parameters of the central pump should be carried out taking into account the features of the operating modes, control parameters (range, speed) characteristic of each of the considered groups of pumps and an assessment of the energy consumption for their implementation.

As shown in the previous section, when choosing one or another type of controlled electric drive for pumping units, along with generally accepted criteria (weight and size, cost, reliability, etc.), the following features should be taken into account:

- the operating range of speed control in the vast majority of cases is small;
- prevalence, significant installed capacities and long-term operation of pumping units determine the increased requirements for the energy performance of the electric drive;
- NPS pumps do not require extreme accuracy and high speed when adjusting the capacity.

Therefore, DC motors, which are inferior to AC machines in terms of reliability, cost, and weight and size indicators, should be excluded from possible control options. Next, we will consider ways to control pumping units based on asynchronous and synchronous motors.

The rotor speed of an AC motor can be determined as

$$\omega = \frac{2\pi f}{p_n}(1 - s)$$

there f - supply voltage frequency;
pn - number of pole pairs;
s - slip.

By changing one or more of the parameters included in the variants of the control system, it is possible to control the speed of the electric motor and, consequently, the pump. Figure 1. shows the possible systems of adjustable electric drive of pumping units.

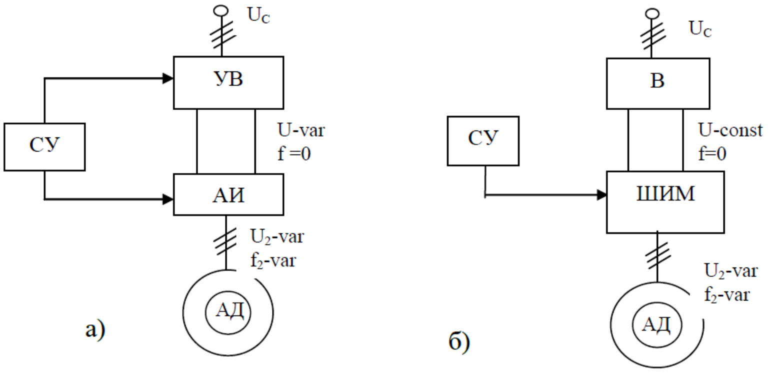

Figure 1. - Options for controlled electric drive systems for pumping units.

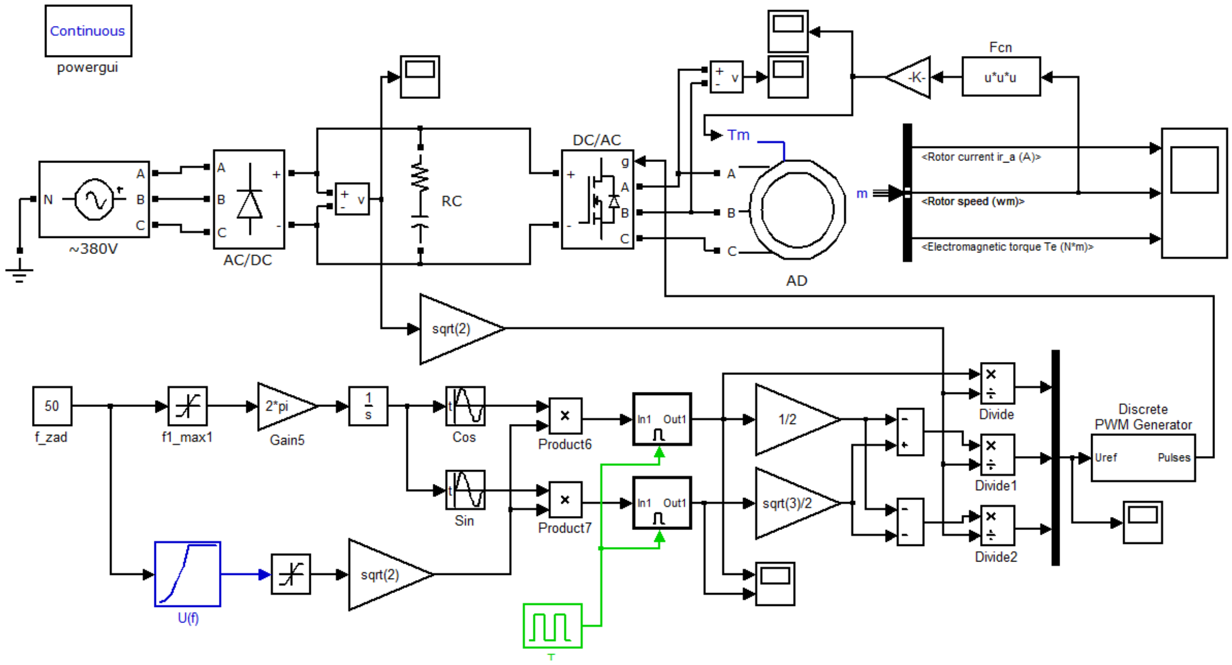

Figure 2. Power section of inverter with static frequency control with fan load

The power consumed by the pump, kW, is determined by the formula:

$$N = 9{,}81\frac{QH}{\eta_{н}} \quad (1)$$

there Q — innings, м^3/c; H — head, m; $\eta_{н}$— pump efficiency.

Power consumed by the pumping unit, kW,

$$P = \frac{N}{\eta_{ЭД}\eta_{np}} \quad (2)$$

there $\eta_{ЭД}$ — motor efficiency; η_{np}— Efficiency of the converting device (frequency converter, transmission, etc.).

The capacity of units at modern water supply and sewage pumping stations reaches 3.5-5 MW, and in large irrigation systems 12 MW.

The amount of electricity consumed by the unit during time t, when operating with a constant supply and constant pressure, is determined by the formula

$$W = Pt \quad (3)$$

there t — working time, hours

In real installations, pumping units usually operate with a variable supply and, accordingly, with a variable pressure. As a result, the power consumed by the unit for some time changes. Therefore, the use of formula (3) is limited to those cases when the pumping unit operates in a uniform mode for a long time. The following is a simplified methodology for predicting energy consumption.:

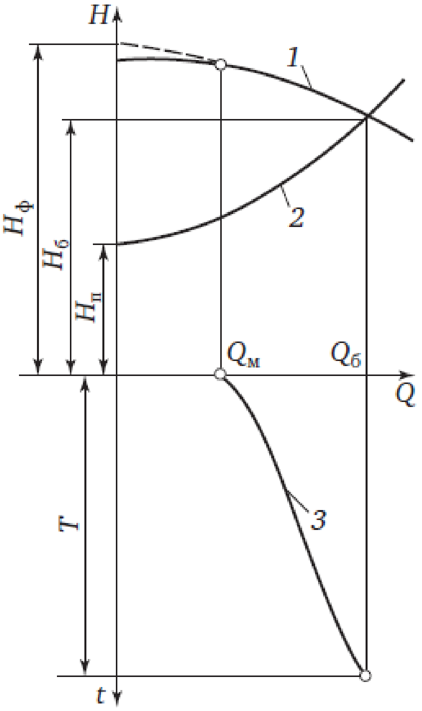

Figure. 3. An ordered diagram of the pump flow and a schedule for its joint operation with the pipeline:
1 - pressure-flow characteristic of the pump; 2 - characteristic of the pipeline; 3 is an ordered pump delivery diagram.

On fig. 3 shows a graph of the joint operation of the pump and the pipeline, as well as an ordered diagram (distribution curve) of the liquid supply. An ordered diagram (the concept is borrowed from [1]) of the fluid supply is understood as a curve connecting the ordinates of the fluid supply graphs in ascending or descending order. The diagram is built for a long estimated period of time, for example, a year.

An ordered diagram (in whole or in part) can be approximated by a straight line equation:

$$Q = Q_{\delta}\left[(1-\lambda)\frac{t}{T}+\lambda\right] \quad (4)$$

there Q_{δ} — the largest flow for a given pumping unit for the billing period; λ — relative minimum flow for a given installation:

$$\lambda = Q_M/Q_{\delta}\ ;(5)$$

T — duration of the billing period.

there Q_M— the smallest flow for this installation for the billing period.

A long period of time is taken as the calculation period, for example, a technical year, i.e. T = 8760 hours.

After integrating this dependence in the range from 0 to T and some other transformations, an expression was obtained to determine the amount of energy consumed in the estimated period of time.

$$W = \frac{N_{\delta}T}{\eta_{эд}}\frac{(1+\lambda)}{4}\left[(1+H_{П}^{*})+\lambda^{2}(1-H_{П}^{*})\right]\ (6)$$

there N_{δ} — power consumed by the pump at the highest flow, kW; $H_{П}^{*} = H_{П}/N_{\delta}$ - relative backpressure.

III.CONCLUSION

Since, the correct choice of the pump, the operating point on the combined graph of the water supply system will be located in the zone of maximum efficiency. To ensure the economical operation of the pumping unit, it is recommended to use those units that have a higher efficiency. Regulation of the parameters of the pumping unit by changing the speed of the pump is achieved by using an adjustable electric drive. This method increases the cost and complicates the maintenance of the installation, but allows, with a change in the speed of the pump impeller, to maintain a similarity of pumping characteristics and reduce the consumption of electrical energy.

A huge number of electricity consumers constantly load the network with the reactive component of the consumed power, and this load is constantly increasing. The introduction of reactive power compensating devices makes it possible to increase the reliability of power supply networks and increase the throughput of the power system.

REFERENCES

[1] N.S. Bakshieva "Reactive power compensation in power supply systems of forestry enterprises", Abstract, Kirov 1999.
[2] Saenko Yu.L. "Optimization of reactive power compensation in networks by valve converters", Bulletin of the Azov State Technical University, Issue No. 11, 2001.
[3] Lischenko S.A. Regulation of pumps at water pumping stations. – Moscow: Stroyizdat, 1949. – 84 p.
[4] Herman L. A. Regulated installations of capacitive compensation in traction power supply systems of railways: Monograph/L. A. Herman, A. S. Serebryakov; Moscow State University of Railways. M., 2011. 164 p.