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Frequency converter power reduction for controlling the hydraulic parameters of the pumping station

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Abstract. The article discusses the issue of power reduction for oil and gas equipment. It studies the method for reducing power of a frequency converter to control the hydraulic parameters of a pipeline by replacing a single centrifugal pumping unit with a pumping station consisted of series-installed pumps. The frequency converter is installed on the first stage pump. The method was tested in the water supply system for irrigation of high-temperature aerosol of technical carbon.

1. Introduction

In various technological processes of the oil and gas and petrochemical industries, liquids are supplied under excessive pressure of above 0.5 MPa. The main units for creating this pressure are multistage centrifugal pumps of various designs. For a smooth control of the hydraulic parameters of the network, the optimal way is to control the frequency of rotation of one of the units using a frequency-controlled electric drive [1].

2. Materials and methods

The purpose of these studies is to reduce the power of frequency converters by replacing a single pump unit with a pump station from several series-installed centrifugal pumps with lower pressure than a replaceable unit. The frequency converter is installed only on the first-stage pump. Its power may be lower than that of the frequency converter having a single pump unit.

It is known that under series installation of identical centrifugal pumps, their pressures are added up, and the flow remains unchanged, as shown in Figure 1.

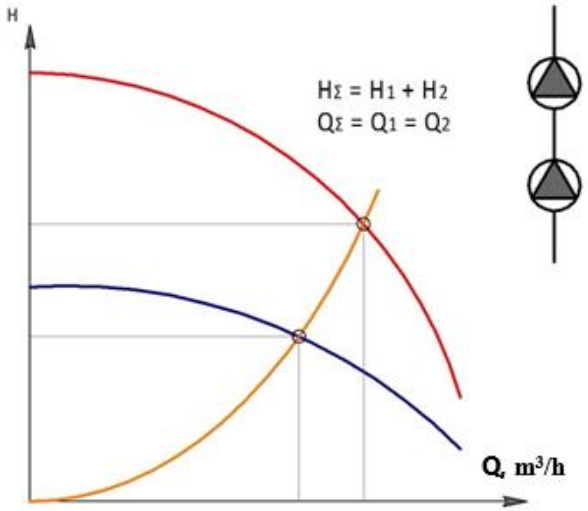

Figure 1. Hydraulic characteristics of the combined work of two rotary pumps.

To control the hydraulic parameters when using centrifugal pumps, the most economical and convenient way is to change the rotational speed of the impellers. The flow rate is proportional to the rotational speed of the impeller of the centrifugal pump:

$$Q \sim n \quad (1)$$

Pressure is proportional to the square of rotation frequency:

$$H \sim n^2 \quad (2)$$

Power consumption is proportional to the cube of rotation frequency:

$$P \sim n^3 \quad (3)$$

where *Q* is fluid supply; *H* is pressure; *P* is power consumed by the pump; *n* is pump shaft rotation frequency.

When changing the rotational speed of a single pump unit, it is necessary to install a maximum power frequency converter corresponding to pump power. Power consumption and supply change accordingly [2]. For a pump station, the operating mode changes as follows: one or several pumps operate at a constant shaft rotation frequency, ensuring the supply of the main volume of fluid at low pressure. One of the units changes the frequency of rotation of the impellers depending on the pressure sensor readings.

Thus, it is possible to use a low-power frequency converter and achieve accurate and timely pressure regulation depending on changes in the volume of fluid consumed by the technological units.

For experimental studies of pumping stations, a unit consisting of two vertical multistage pumps (DPVF-15-7, DPVF-15-11) was assembled and the hydraulic characteristics of the pumping station and the multistage centrifugal pump TsNS-38-220 were compared [3, 10]. The hydraulic characteristics of the pumps are presented in Table 1 and in Figures 2 and 3.

Table 1. Main characteristics of the pumps.

Name	Nominal power, kW	Maximum consumption, m^3/h	Maximum pressure, m
DPVF 15/7	7.5	22.5	102
DPVF 15/11	11	22.5	161
TsNS-38-220	45	38	220

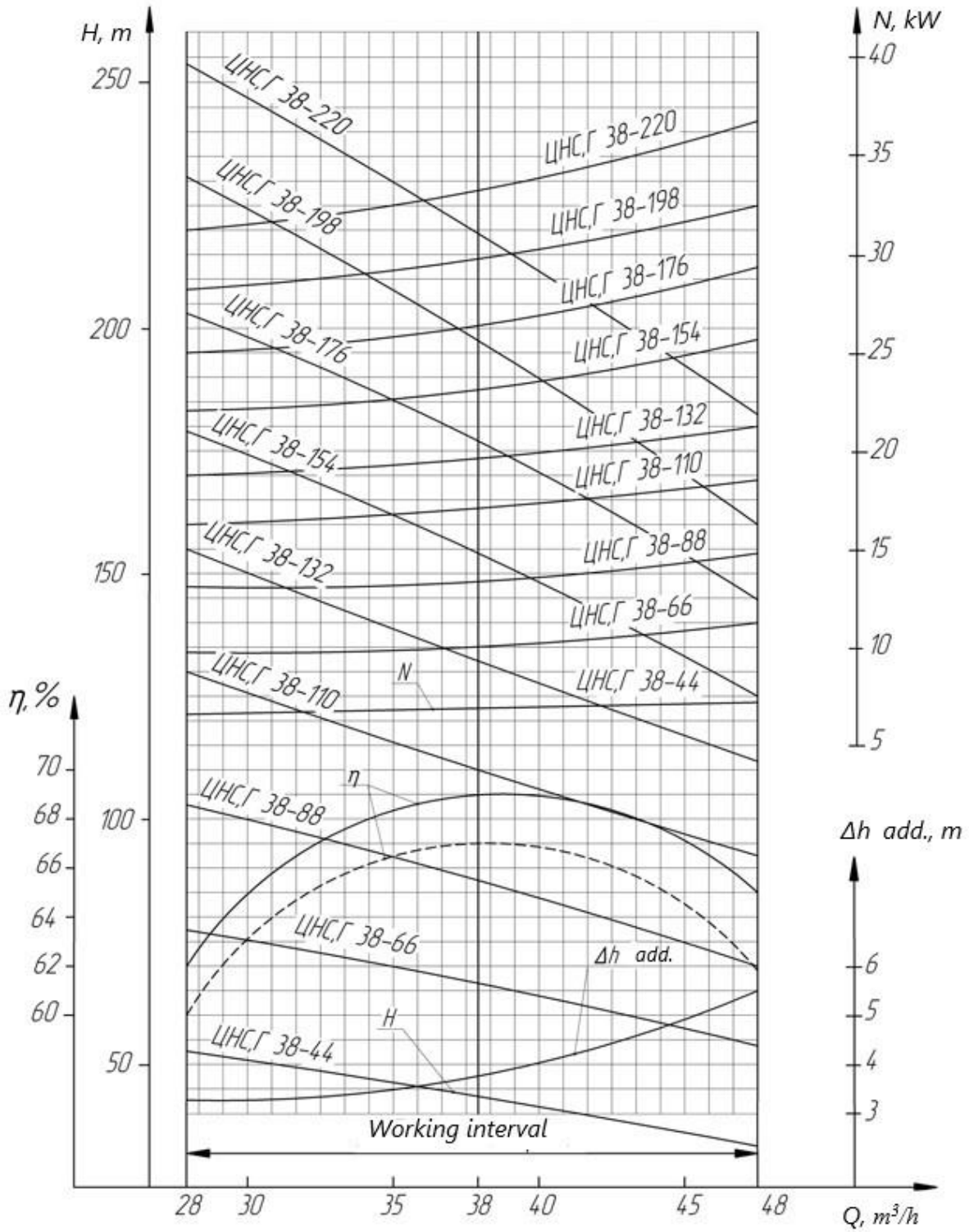

Figure 2. Hydraulic characteristics of TsNS-38 (ЦНС-38) pumps.

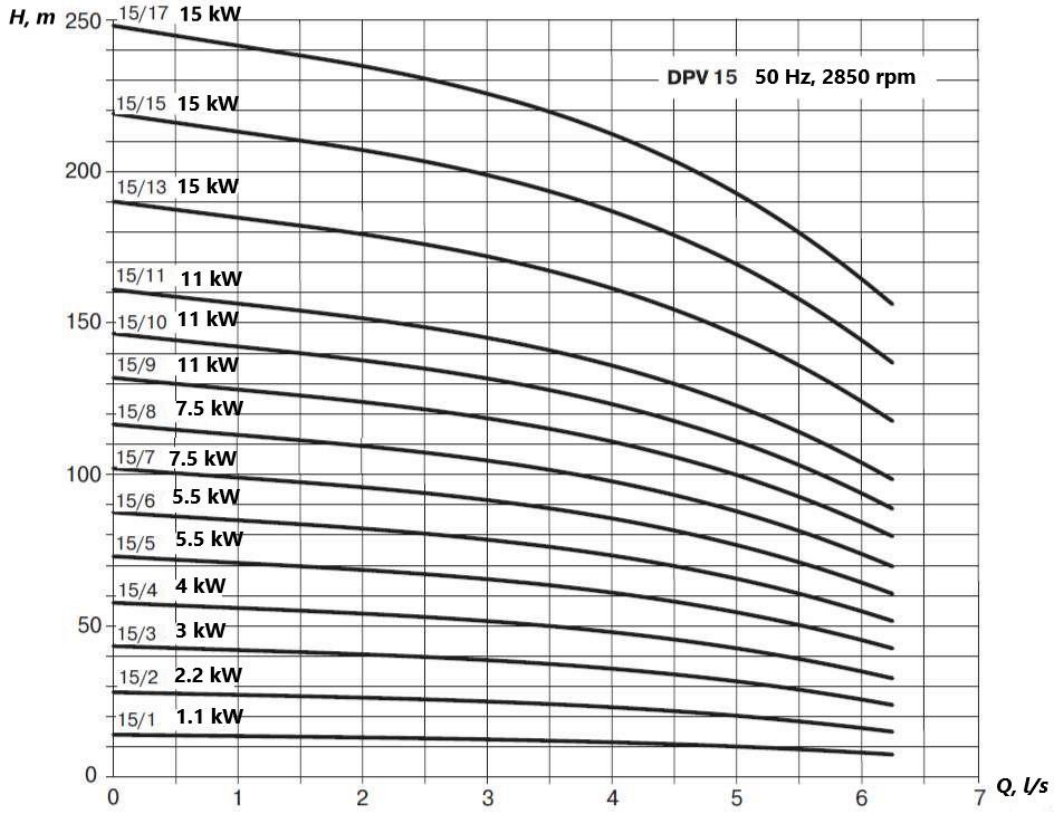

Figure 3. Hydraulic characteristics of DPV15 pumps.

The studies were carried out in plant conditions [4]. The pumps supplied water to spray nozzles of refrigerators-sprinklers at a rate of up to 6 tons per hour per sprinkler.

The pumping station had vertical pumps to reduce the pressure loss in the pipeline section between the units. Vertical pumps have flange connections of the suction and discharge parts, located in the lower part of the housing on opposite sides, which facilitates installation of the unit and reduces the number of local hydraulic resistances. There is a short straight section of the pipeline with a minimum number of valves between the pumps of the first and second stages [5, 6].

The electric drive of the first-stage pump (DPVF 15/7) with power of 7.5 kW was controlled by a frequency converter E2-8300-010H which operated in the automatic PID control mode based on a signal from the Metran-150 pressure sensor installed on the main water supply collector in front of the water-consuming units.

The required pressure was set by the personnel from the control room according to the readings of the remote recording devices.

Frequency converters increase the motor shaft rotational speed up to 3600 revolutions per minute by increasing the frequency of the alternating current to 60 Hz, which creates an additional reserve of pressure, controls power consumed by the pump and promptly signals its unacceptable excess.

The experiments identified that with a change in the rotational speed of the adjustable electric drive in the range from 10 to 60 Hz, pressure changes from 180 to 300 m when supplying the liquid up to 18 m^3/h which ensures stable operation of the three irrigation refrigerators. At the same time, power consumption reduced more than twice compared with the use of a single pump unit TsNSG-38-220 [7–9].

Thus, it was proved that it is necessary to replace single pumps with series-connected centrifugal pumps. It is sufficient to install a variable frequency drive on one of the connected pumps to reduce the cost of purchasing equipment [10].

3. Conclusion

The result of the research are as follows:

1. Series connection of pumps of the pumping station helps achieve stable hydraulic parameters of the pipeline (high pressure and a relatively small supply rate).
2. It is necessary to replace pumping units with pumping stations to reduce specific energy consumption.
3. Experimental studies showed that a change in the frequency of rotation of an adjustable electric drive from 10 to 60 Hz ensures the required operation mode of the pipeline.
4. The use of a frequency converter ensures pressure control and reduces energy consumption and financial costs.

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