ASPECTS RELATED TO VARIABLE SPEED DRIVE FOR PUMPS OPERATING WITHIN THE CHIRIŢA PUMPING STATION

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ABSTRACT: *In the operation of centralized water supply systems, approximately 90% of used energy is electricity, out of which a significant share, of over 80%, is consumed by water distribution in networks equipped with pumping stations.*
In the last decades, in order to adapt systems to the variable requirements of users, the water systems are provided with pumps driven by variable speed controlled motors.
In order to reduce the power consumption when water is delivered to consumers according to their demands, it is necessary to improve the pumps operating efficiency.
The paper presents a series of aspects regarding the defining of the opportunity for retrofitting and rehabilitate the pumps within the Chiri a pumping station.
Keywords: *pumping station; efficiency; power consumption; variable speed.*

1. Introduction

Pumps installed in water supply systems are serving networks of which demands may vary in time, between the minimum flow and the designed flow. Therefore there is need to adjust pumps in a manner that ables the conveying of the various flows demanded by users, in conditions of maximum energy and economical efficiency.

The variation of a pumped flow can be provided by means of different methods [1]:

- by modifying the system's head characteristic, reduced at delivery's origin by:
  - modifying of head loss characteristic $(h_{rcp}{\sim}Q)$ on pumps communications;
  - modifying of pumps' own head characteristic $(H{\sim}Q)_P^R$;
  - modifying of the resulting characteristic of a pumping group equipped with parallel coupled pumps;
- by an intermittent pumping and flow compensation, by providing the head demanded by network.

2. Theoretical aspects

2.1. Adjustments achieved by changing the pumps head characteristic

These adjustments are carried out by modifying the pump's head characteristics $(H{\sim}Q)_P^R$, while constantly maintaining both the pumps communication line characteristics $(h_{rcp}{\sim}Q)$, and the network characteristics $(H{\sim}Q)_R$.

By applying this adjustment method, the desired operating mode is always located within the network characteristic, and therefore the network demands and the pump operational regime become harmonized, both in terms of flow and head. In the case of networks having significant static head, this clear advantage can be altered by placing the operating point in other area of the operating diagram where the pump's efficiency is significantly reduced.

The adaptation to variable running regimes by modifying the pump's head characteristic is achieved by complex means (adjustable pump drives, adjustable mechanisms etc.) that, when correctly applied, will manage to decrease energy losses and, consequently, considerably increase the pumping system's overall efficiency.

The adjustment of pumping systems based on the modification of pumping characteristic is achieved by:

- the variation of pump's rotor speed;
- the variation of rotor blades pitch angle (for axial pumps).

2.2. Adjustments achieved via pump motor variable speed drives

a. General considerations

In the pumping installations that serve hydraulic systems, this adjustment is obtained by changing the pump's rotor speed. It requires the use of adjustable electric drives, that is, electric variable speed driving systems for asynchronous motors, using for this purpose static frequency converters featuring an adequate power.

By varying the pump rotor speed, the pump's head characteristic $(H\sim Q)_P^R$ is changed and, therefore, the head may be adjusted to values that correspond exactly to the pumping network's characteristics $(H\sim Q)_R$. The pump variable speed drive is of interest when there is need to pump, under the head actually required by the network, certain flow rates lower than the flow rate provided by a non-adjustable drive at a nominal speed no, in which case the pump's actual speed must be *n<no*.

b. The operational and energy characteristics of variable speed driven pumps

The operational and energy characteristics of the pump will vary, by reducing the speed, according to the transposition laws (1) [2]:

$$\begin{cases} Q_x = Q_o\left(\dfrac{n_x}{n_o}\right) \\ H_x = H_o\left(\dfrac{n_x}{n_o}\right)^2 \\ P_x = P_o\left(\dfrac{n_x}{n_o}\right)^3 \end{cases} \qquad (1)$$

where the factors marked with an "*x*" index correspond to the desired speed, and those marked with a "*o*" index correspond to a constant speed (see Fig. 1).

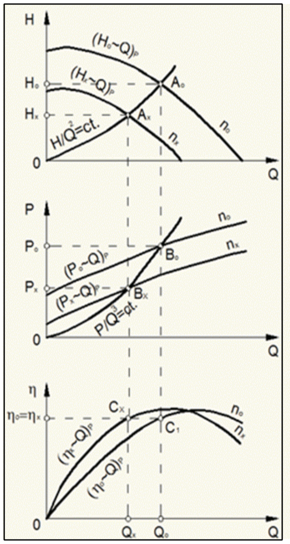

Fig. 1. Variation of pumps characteristic with rotor's speed variation

The next elements will be obtained in plan (Q,H) (see Fig. 2) [3]:

- a family of parallel head curves, of which ordinates get lower when sped gets lower. The head curves can be analytically expressed by a parabolic function (2):

$$H = A_0 n^2 + A_1 nQ + A_2 Q^2 \qquad (2)$$

- an efficiency isolines network, representing parabola arcs that pass through origin, and on which are located the operating regimes obtained with the same efficiency, at different speeds. These iso-lines have a quadratic form (3)

$$H = k_{\eta x} Q^2 \qquad (3)$$

where $k_{\eta x}$ is a parameter determined by values (Q_x, H_x) which are typical for a regime that, on a head curve corresponding to speed nx, is achieved at indicated efficiency ηx:

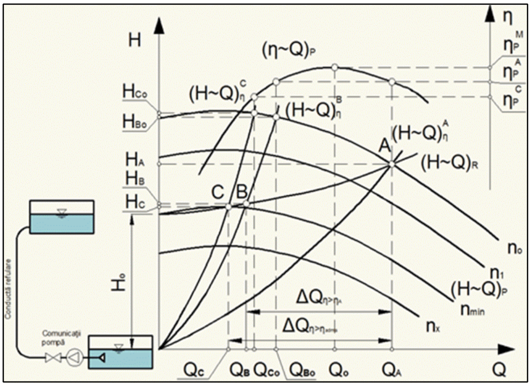

Fig. 2. Calculation diagram for speed adjustment coefficient

$$k_{\eta x} = \frac{H_x}{Q_x^2} = \frac{H_o}{Q_o^2} \qquad (4)$$

In order to provide a normal working condition to the pump, the minimum flow that this pump can provide is Q_C (see Fig. 2). The total pumping head HC under which a Q_C is to be supplied is corresponding to the network characteristic *(H~Q)*$_R$. The pump's efficiency, in such an operating regime, corresponds to the $k_{\eta C}$ parameter iso-line, this being given by equation (5):

$$k_{\eta C} = \frac{H_C}{Q_C^2} \qquad (5)$$

The value kηC is computed on the efficiency characteristic (η~Q)P:

$$\eta_p = R_0 + R_1 Q + R_2 Q^2 \qquad (6)$$

That corresponds to a flow Q_{Co}, provided by normal speed no within the similar working regime – located on the same iso-line, at the intersection of this one with the load characteristic $(H\sim Q)_P{}^R$ at n_0.

Taking into account the issues described above, the values that are defining the operational regime for the system made by pump and network are resulting as a solution of system (7) that includes the equations (2) and (3) with kηx=kηC from (5):

$$\begin{cases} H_{C_o} = A_0 n_o^2 + A_1 n_o Q_{C_o} + A_2 Q_{C_o}^2 \\ H_{C_o} = k_{\eta C} Q_{C_o}^2 \end{cases} \qquad (7)$$

The resulting flow is given by (8):

$$Q_{C_o} = \frac{-A_1 n_o + \sqrt{(-A_1 n_o)^2 - 4A_0 n_o^2 \left(A_2 - \frac{H_C}{Q_C^2}\right)}}{2\left(A_2 - \frac{H_C}{Q_C^2}\right)} \qquad (8)$$

which will correspond to the efficiency resulted from (9):

$$\eta_P^C = \eta_P^{C_o} = R_0 + R_1 Q_{C_o} + R_2 Q_{C_o}^2 \qquad (9)$$

3. Case study: the Chiriţa Pumping Station

The Chiriţa Water Treatment Plant is located in the east-southeastern area of Iaşi city (see Fig. 3) [4].

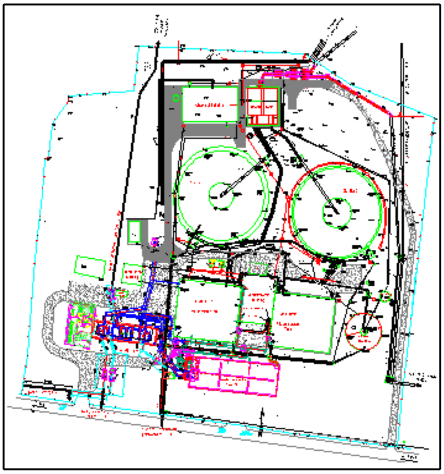

Fig. 3. Chiriţa Water Plant – general layout

The ”Chiriţa” pumping station is equipped with three pumping plants (see Fig. 4), called by their serviced area, as it follows [2]:

- the “City” pumping plant - pumps water from the filter station towards Iasi City distribution network (see Fig. 5);

- the “Şorogari” pumping plant - pumps water from the filter station towards Sorogari water storage complex (see Fig. 6);

- the “Industry” pumping plant - pumps raw water drawn from Lake Chiriţa towards Iasi City’s industrial area (see Fig. 7).

The “Industry” pumping plant includes (2 + 1) ASPV250B-110/4-T4-C1-EO-FC- ACH pumps that feature the following characteristics: Q = 250 l/s and H = 30 mWC. The pumps are coupled in parallel and are driven at constant or variable speed via a frequency converter.

Figure 8 shows the Chirita PS pumping process flow chart.

The Chiriţa pumping station is an automated facility (see Fig. 8). The data collection and transmission is carried out through a SCADA system (Supervisory

Fig. 4. The Chiriţa pumping station

Fig. 5. The “City” pumping plant

Fig. 6. The “Şorogari” pumping plant

Fig. 7. The “Industry” pumping plant

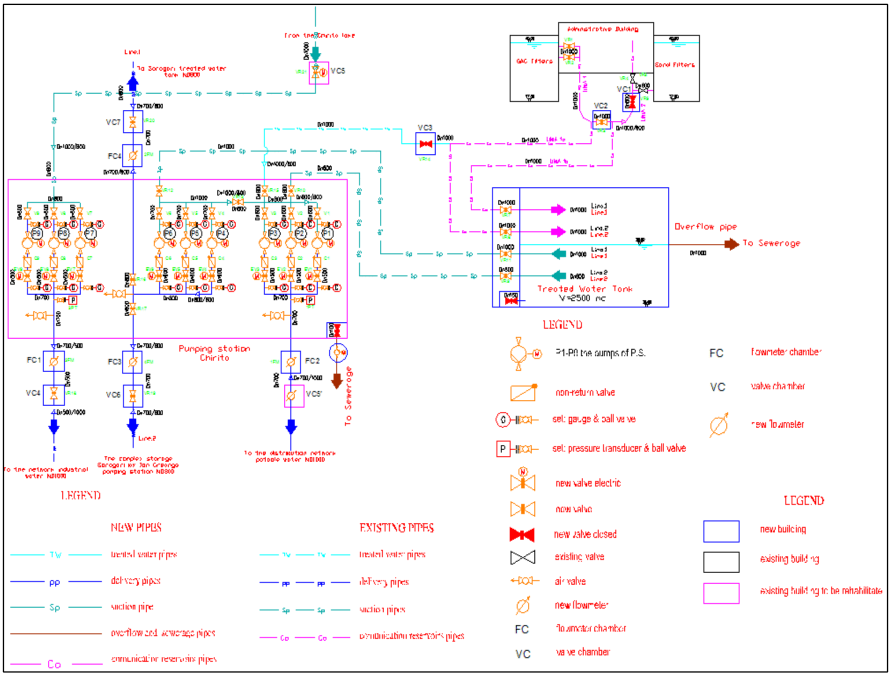

Fig. 8. Chiriţa Pumping Plant: operational diagram

Control and Data Aquisition).

Within the station, the installation for which the monitoring and control system is implemented comprises: WILO pumps, AUMA electro-actuated valves, hydraulic parameters measuring devices (flow, pressure) and electrical parameters measuring devices.

Out of the two pumping units that should operate simultaneously, since many years, only one unit is operational, this pump being operated at a much lower speed than the nominal speed n_o = 1450 rpm (this being due to the current much lower flows that are required to be pumped towards the industrial water network).

A speed much lower than nominal speed implies a decrease in efficiency well below its nominal value η_o = 83 %, this having serious implications on the pump's energy and economic efficiency. Thus, the specific energy consumption increases (i. e. more energy is consumed in order to pump 1 m3 of water); as well, the specific unit energy consumption increases.

It can be noticed that at a speed nx = 1130 rpm, in the case of a pumped flow Q_x = 155.86 l/s (see Fig. 9), the operating regime obtained with the same efficiency on the head curve corresponding to a nominal speed no = 1450 rpm corresponds to a flow Q_o = 200 l/s. The efficiency in this case is ηx = 80 % (see Fig. 10).

If we have the same speed n_x = 1130 rpm, in the case of a pumped flow Q_x = 93.52 l/s (see Fig. 9), the operating speed obtained with the same efficiency on the head curve corresponding to the nominal speed will correspond to flow Q_o = 120 l/s. The efficiency in this case is η_x = 59 %, a figure much lower than the nominal efficiency η_o = 83 % (see Fig. 10).

4. Conclusions

The operating personnel must strictly observe the prescribed operating regimes.

By applying adjustments achieved via pump motor variable speed drives, the desired operating mode is always located within the

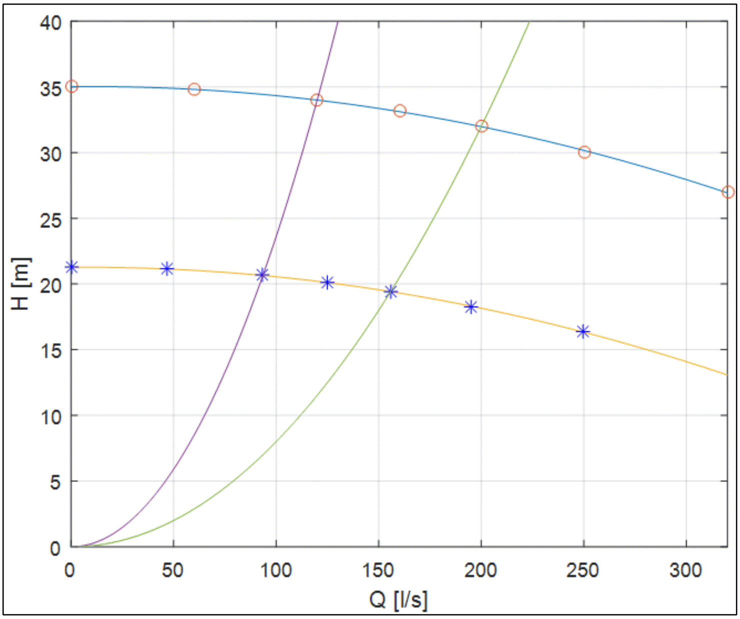

Fig. 9. WILO pump head characteristics
(at nominal speed n_o = 1450 rpm and at speed n_x = 1130 rpm)

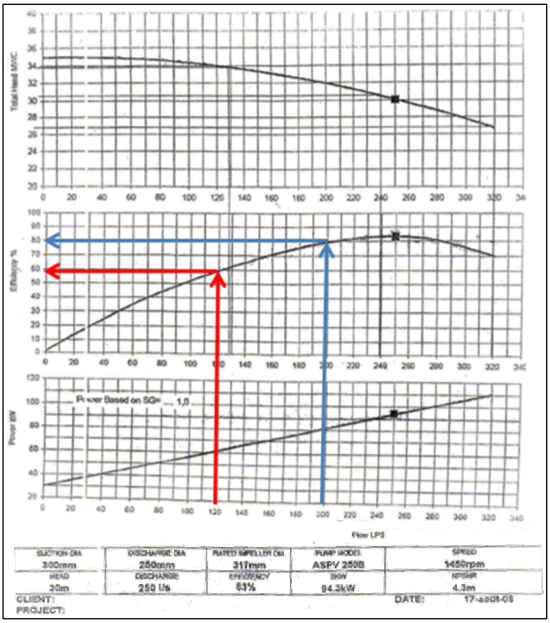

Fig. 10. WILO pump: operational and energy characteristics

network characteristic, and therefore the network demands and the pump operational regime become harmonized, both in terms of flow and head.

However, if the speed drops much more than the nominal speed, the efficiency decreases and the specific energy consumption increases.

In case of significant deviations from these regimes, due to fact that the nominal parameters of existing pumps are incompatible with the requirements of the serviced system, the rehabilitation of pumping installations must be considered.

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