INCREASE OF ENERGETIC EFFICIENCY AT CENTRIFUGAL PUMP

Dr Zoran Petrovic[1], Branko Radicevic[2], Miso Bjelic[3]

Summary: *In this papers it were showed how to determinate coefficient of specific power consumption for different types of regulation. It is also showed that using frequency regulation can be achieve biggest energy saving (11.5%), and at some specific areas of network pressure and flow rate, bypass system can be most effective. De-emphasis regulation system is always system of pure energy loss. Energy saving level can be higher if frequency regulator works at area of economic and stable pump operating considering well richness.*

Key word: *regulation, frequency regulator, bypass, de-emphasis, pump regulation graphic*

1. BRIEFLY REPORT

Increasing of the energetic efficiency is very important at all areas of industry. Optimization of the city's water supply systems takes important place at energetic efficiency area because there is a lot of space for decreasing of energy consumption which is one of the most important resources. From aspect of energy consumption and use of control system in water supply of our cities, we use technology from 1980.

Experimental results from this paper are connected to one of the Kraljevo pump stations. At the structure of the water production costs, electric energy has most important place. In theory there are a lot of solutions for control of asynchronous motors, but they were very expensive. Today's level of production technologies makes possible production of equipment for frequency regulations at low price.
In this paper is shown how specific consumption parameters can be calculated for different types of regulation. It is also shown that use of frequency regulator produce the biggest energetic savings (11.5%), and at some specific levels of pressure and flow rate, bypass system can be the most efficient. De-emphasis regulation system is always system of pure energy loss. Percent of energy saving can be higher if frequency regulator does regulation of revolution number at area of economic and stabile pump operating and if the pump operating is optimized with respect of well richness. Area of economic pump operating can be up to 80-90% relatively to pump efficiency at the nominal duty. Using the suggested methods, energetic efficiency energy consumption for one pump station for different types of pressure regulation can be raised up to 15%. At the basis of research, when it is economic reasons in question, investment in frequency regulation equipment is very reasonable.

2. INTRODUCTION

Water consumption at production and distribution systems fluctuates significantly during the 24 hours. It is very small by night, but during the day is much significant.

Wells can be sorted in two different types. First type is corresponding to those who have one well from which water is directly pumped to water supply network. Second type of wells corresponds to those who have system of wells and from where is water pumped to storage tank.

Subject of this analysis is selection of type of regulation for motors control at pump stations with tendency to improve energetic efficiency.

Centrifugal pumps and related equipment are two systems with serial link. Regulation of flow rate can be achieved at one of two next ways:

- using de-emphasis equipment
- using bypass control
- control the pump speed rotation

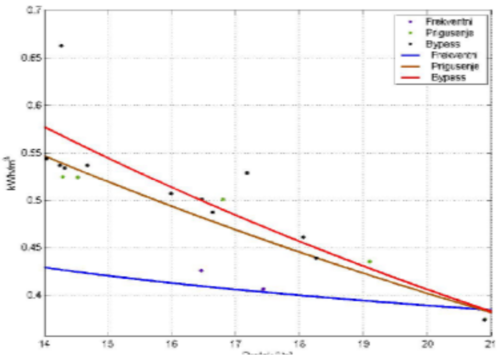
Upon the choose of new systems for motors control, it should attend to possibilities of using them at extreme conditions. At first part of this paper it is shown specific

3.SPECIFIC CONSUMTION OF ENERGY

Considering percent participation of individual flow rate vs. maximal flow rate during the total number of working hours for some relevant period of time and using the coefficient of specific consumption of energy (fig 1.b) for system with applied frequency regulator, efficiency percent can be calculated for any flow rate.
In case of de-emphasis systems, specific consumption of energy is always at maximum flow rate. If we use smaller flow rate, specific consumption is increasing,

[1] PhD Zoran Petrovic mech. eng., Faculty of Mechanical Engineering in Kraljevo, petrovic.z@maskv.edu.yu
[2]BSc Branko Radicevic mech. eng., Faculty of Mechanical Engineering in Kraljevo, radicevic.b@maskv.edu.yu
[3]BSc Miso Bjelic mech. eng., Faculty of Mechanical Engineering in Kraljevo, bjelic.m@maskv.edu.yu

rapidly. In case of systems with speed regulation, specific consumption of energy is not only decreasing with decrease of flow rate, but also gain minimal work point and works at maximal percent of efficiency.



a) Energy consumption vs flow rate

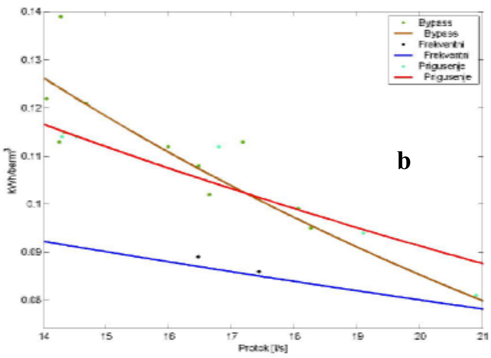


Fig.1. b) Coefficients of specific consumption of energy vs. flow rate

4. ENERGETIC EFFICIENCY

In matter of work time consideration for de-emphasis work regime, it is necessary to observe flow rate, pressure, number of working motors for a long period of time. If we add product of relative flow rate quotient comparing to maximal flow rate to product of relative quotient for specific consumption of energy, we will get a cumulative percent of system efficiency for system with applied frequency regulator vs. de-emphasis system.

Table 1. Cumulative efficiency coefficient for de-emphasis and frequency regulation systems

Flow rate [l/s]	Q/Qmax [%]	Relative quotation[%]	Percent of participation [%]
21	32	100	32
19	45	86.3	38.84
17	9	83.5	7.51
15	1	80.4	0.80
13	5	76	3.8
11	8	73	4.38
< 11	2	60	1.2
		∑	**88.53**

5. REGULATION DIAGRAM

Affirmation coefficient of specific consumption of energy is the best way for determination of best system for flow rate regulation at centrifugal pumps.

The most economic way for flow rate regulation is regulation by changing the number of revolution of pump, with limitation that pump must work at defined regulation area.

5.1 Pump characteristics at different number of revolutions. Regulation diagram

If we use following marks: Q for flow rate, H for effort and η for efficiency, then the work characteristics are functions of flow rate H(Q), N(Q) and η(Q) calculated at constant number of revolutions (fig. 2.)

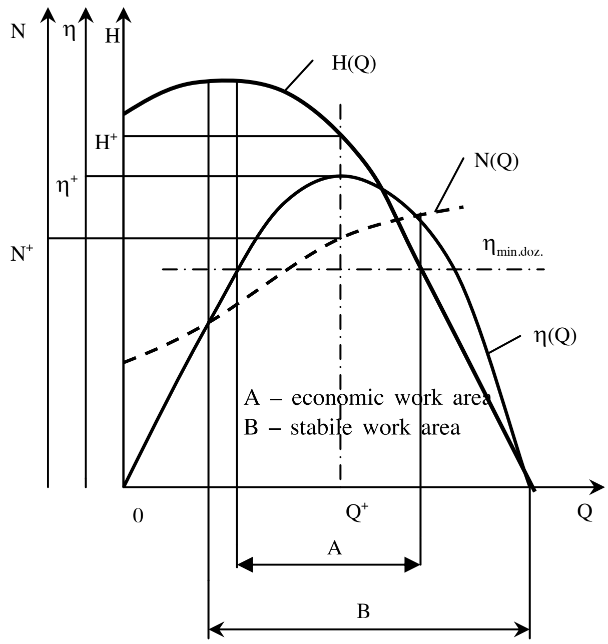


Fig. 2.

The most efficient regime of pump functioning is called nominal work regime, and parameters at this regime are shown at fig. 2. like Q^+, H^+, N^+, and $\eta^+=\eta_{max}$. Area of economic pump functioning is restricted by smallest acceptable efficiency percent. This area is usually restricted with following restriction, $\eta \geq (0.8\text{-}0.9)\eta^+$, where bigger value corresponds to bigger pump. Area of stabile regimes is at monotonously decreasing part of H(Q) characteristic ($dH/dQ<0$).

Left flow rate at economic work area for centrifugal pump is usually bigger than flow rate at stabile work area border, so the regulation area is economic work area.

If we use following marks: $Q(n_0)$ and $Q(n)$ for flow rates at revolution numbers n and n_0 and $H(Q(n))$, $N(Q(n))$, $\eta(Q(n))$ for work characteristics at $n \neq n_0$ then from analogy theory for flow in turbo-machinery follow:

$$\frac{Q(n)}{Q(n_0)} = \frac{n}{n_0}, \frac{H(Q(n))}{H(Q(n_0))} = \left(\frac{n}{n_0}\right)^2, \tag{1}$$
$$\frac{N(Q(n))}{N(Q(n_0))} = \left(\frac{n}{n_0}\right)^3, \eta(Q(n)) = \eta(Q(n_0))$$

Automodel flow at Reynolds number are called flows which has coefficients of flow resistance that not depend of Re. Flows that can be called automodel has following characteristics: $Re \cdot u = 5 \cdot 10^5$, $Re \cdot u = uD/\nu$, where D is diameter of pump's rotor, u-circumference speed, ν - coefficient of kinematical viscosity.

Equation (1) can be used at following condition:

$$n \geq \frac{3 \cdot 10^7 \cdot \nu}{D^2 \pi} \left[o / \min \right] \quad (2)$$

Where for clean water at 20°C, $\nu = 10^{-6}$ m^2/s

Work characteristics are affirmed at n_0, using equations (1) and (2) and can be copied for other number of revolutions (fig. 3.)

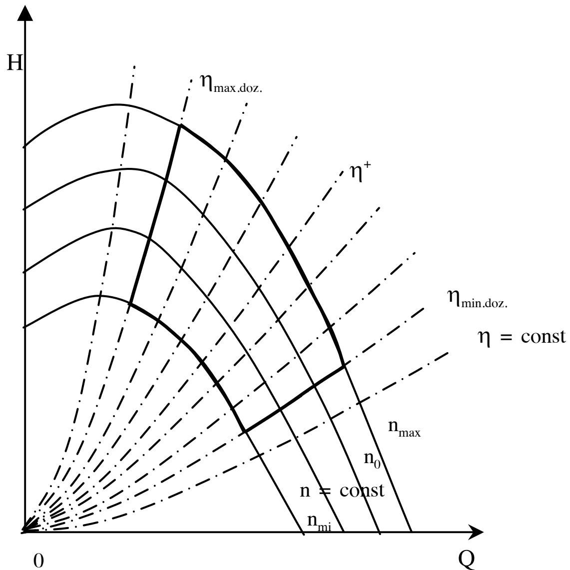


Fig. 3.

If we eliminate n/n_0 from (1), we will get:

$$H(Q(n)) = k_p (Q(n))^2, \text{ for } \eta = \text{const.} \quad (3)$$

$$k_p = \frac{H(Q(n_0))}{(Q(n_0))^2}$$

Conclusion is that similar work regimes lie at parabola (3) apropos these are parabolas of constant efficiency percents (fig. 3.)
At stabile work area, characteristic $H(Q(n_0))$ can be interpolated by following polinom:

$$H(Q(n_0)) = a_0 - b_0 Q(n) - c_0 Q(n)^2 \quad (4)$$

Coefficients a_0, b_0, c_0 can be determinate using the least square method. Using this method, error value is smaller than 1%.
With respect to (1) and (4), characteristic H(Q) at different revolution number can be interpolated by following function:

$$H(Q) = a_0 \left(\frac{n}{n_0}\right)^2 - b_0 \left(\frac{n}{n_0}\right) Q - c_0 Q^2 \quad (5)$$

The biggest number of revolutions at which pump can work is restricted with respect to strength of work elements.
At water supply systems pumps are driven by low power electro motors, so modern regulations of these pumps can be done using frequency regulation. Frequency regulation can not just decrease but also increase number of revolutions. Number of revolutions can't be increased more than 20% beyond nominal number. The smallest number is defined by (2). At lower numbers of revolution, efficiency is decreasing.

With respect to smallest and the biggest number (n_{min}, n_{max}), the smallest allowable efficiency and restriction that pump can't be in unstable area at diagram (3) we can isolate regulation diagram (bordered area at fig. 3)

6. CONCLUSION

Increasing of energetic efficiency for centrifugal pumps at water supply systems is very important because it can be saved up to 11.5-20% of electric energy which has the most significant part at drinking water price. Except that, electric energy is one of the most important resources, so its rational use can achieve multiple benefits. Economic reasons for investing in frequency regulation an equipment for work optimizations are obvious.

7. LITERATURE

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