

Energy saving of pumps in water supply pump station

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Abstract: This paper introduces some kinds of methodologies for the energy saving of the pump of water supply system. It also tries to find out ways to combine these methods and apply them into realities, get the simple and convenient way for quickly judge of energy saving effect.

Keywords: pump; impellers cutting; frequency-change pump; energy saving

1. Introduction

Basing on the statistic data, electricity costs of the whole operating costs in water plant separately is 24 %, 18 %, 21 % in 1999, 1998 and 1997. Pumps count for most of electricity consumption. Only a little part of electricity is depleted because of transformer, and electromotor of pumps use 97 % of it in water supply project. [1] The benefit of project is the life of project, so how to save electrical power, is very important to water supply project. Many cities in China has executed police of high electric energy cost for peak hours, so saving electricity of pump become more important for water supply project. But some projects do not adopt scientific methods yet. That cause many problems, such as energy waste badly, cavitation erosion, security trouble, pumps inefficiently working.

At present, there are three methods for the pump saving energy: 1) For new projects, optimize selection and combination of big and small pumps. For old one, select pumps again to replace the inefficient ones. 2) cut impellers of pump to enable it work in high efficient situation. 3) apply frequency-change pump. We can adopt one or more than one of these three methods correspond to deferent situation.

2. Optimize selection and combination of pump to save energy

2.1 Optimize selection

For new projects, optimize selection and combination of big and small pumps. When we select pumps, we should select high-efficiency pumps as possible as we can. Base on the volume and head of water supply system to choose pumps renewedly for old projects. Usually, pump of which efficiency lower

than 60 % should be replaced. Optimize selection can be like thereinafter. At first we should give a standard for roughly choose. The standard can be get like this:

$$Q = (0.9 \sim 1.20)Q_0$$

$$H = (0.9 \sim 1.20)(H_0 + \Delta H)$$

And Q is pump rating volume, H is pump rating lift that's to say they are the data when pump with highest efficiency, Q_0 , H_0 are volume and head of the water supply system; Δh is the loss from pump output to reference point of system; 0.9~1.20 is a coefficient range and it can be changed based on how many types of pumps will be in project.

Then we can reasonably select pumps roughly under this standard and pump selected must work with high-efficiency under this standard too. If work point can keep in right(left) high-efficiency segment of the pump curve only when the volume of pump is very big(small), we should replace pump with bigger(smaller) pump. If the pump work curve go much beyond the high-efficiency segment of pump curve or the efficiency of pump is lower than 60% frequently, we should combine deferent kind pump or apply frequency-change pump.

2.2 Optimize combination

In situation of paralleling operating, we can apply pumps with same lift but deferent volume and it is convenient for adjusting volume in this way. It is not good to parallel one type of pumps on occasion. Paralleling deferent types of pumps is perfectly fit when system has these character: volume does not change frequently or only changes around two figures (volume of winter and summer), and one of these two figures is not multiple of the other. In this kind of system, combination of pumps with same lift and deferent volume is convenient for flow adjusting. In

big system, because there are many pumps and types of pumps, it is complicated to select pumps. We can set up mathematical model, compel computer program to calculate optimum selection and combination of pumps.

Parallel pumps characteristic curve and system curve and get work point of each pump can be draw out. Every pump should be in they own high-efficiency segment.

The pumps selected should satisfy volume and head of the system in fixed number of year. Pump equipment can keep high average efficiency and low average current drain in fixed number of year. Pump station investment for mechanical and electrical equipment and capital construction is small. Pump station is convenient to operate and manage.

3. Cut impellers of pump to save energy

When the volume and head system needed is lower than the volume and head of pump.

We can adopt the method impellers of pump cutting to save energy.

As we know, the impellers cutting law of pump can be expressed like this:

$$Q'/Q = D_2'/D_2,$$

$$H'/H = (D_2'/D_2)^2.$$

$$N'/N = (D_2'/D_2)^3,$$

$$\text{cutting rate } \sigma = 100\% \times (D_2 - D_2')/D_2 [3].$$

Choose some points from characteristic curve of the pump we have had, we will get some groups of data (H_i, Q_i) . Substitute these groups of data into previous equation of pump impellers cutting law, we will get corresponding groups of solution (H_i', Q_i') . (H_i', Q_i') are points of pump after impellers cutting. Point these (H_i', Q_i') points, we can get characteristic curve of new pump.

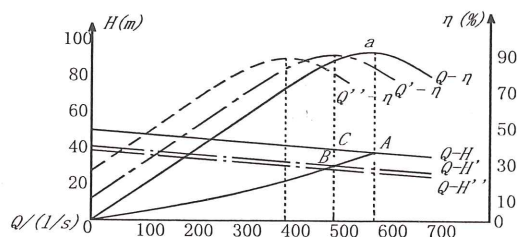


Fig. 1 the previous and new curve of pump with α 10%.

The head of system H' is 20m and the head of system is 500L/s. But data of pump is 31m and 580 L/s, so we have to cut impellers of pump to enable it suit to system. The lift is 25m and volume is 530 L/s after cut. C is working point when volume is 530 L/s. Substitute

H, D and Q of point C into $P = HQ/102 \eta$, we will get that shaft power are 187kw and 142kw separately. So power deference $\Delta P = 45$ KW. The energy saving rate is 24 % and it is considerable. We can get solution as shaft power 133 KW and energy saving rate 29 % when α is 15 % with same process. We can conclude that bigger α will lead to bigger energy saving rate. The reason is that bigger α will bring less rated lift, less rated volume and less rated power under the condition that volume and head of system have been satisfied. Furthermore, nearer data of pump and system is, less energy will be wasted. At the same, as α increased, the efficiency of pump will decrease. We can't allow lift and volume of pump less than system, even though we can get a high energy saving rate because pump work beyond rated condition is not permitted. The other reason we must limit maximal α is we regard the efficiency of pump as a constant when α less than some certain value. The limitation of α under deferent specific rotation rate has been listed in Table 1 [3].

Table 1 Maximal permission $\alpha/\%$

Specific rotation rate	maximal permission $\alpha/\%$
60	20
120	15
200	11
300	9
350	7
>350	0

Sometimes we can take off one stage from stage pump to satisfied actual need.

4. Timing operate to save energy

4.1 characteristic of timing operation

Frequency-change pump is one kind of pump adopted frequently at present. This kind of pump is the pump that adjust rotation of engine according to change of system volume. This method can save more energy compare with traditional method close valve. Because we can almost supply same amount of water as system need by this way, it is no need to build perch pool for balance and avoid water polluted again in poor at the same time. We can fuzzy control Frequency-change pump to achieve intelligentized water supply because of high automatization of frequency-change pump. So pump system become easier to operate, more convenient for management and can be combined with min air chamber. When the flow of system is too little for even one pump, we use air chamber to supply water

and turn off pump to reduce noise and electrical consume. By this way ,pump can operate well when switch. Frequency-change pump make pump system can be soft switch. The pump will have longer operating life. This pump system still some other advantage such as occupy less space, less investment and convenient for installation [2].

4.2 Means of timing operation

For big pump, we install hydrodynamic clutch between pump and engine. Characteristic of this means is that the rotation speed is constant. Hydrodynamic clutch transfers the energy of electromotor to pump, enable pump stepless decelerating operation. For small pump, apply frequency-change operation. Frequency-change operation is the operation that rotation of engine change with change of power supply frequency. Energy saving of timing operation.

Timing operation has great energy saving effect and timing operation can save more than half of energy than throttle operation for same pump. Based on correspondence theorem, the relationship among flow, lift, power and rotation rate of pump can be expressed like this: $Q_1/Q_2=n_1/n_2$, $H_1/H_2=(n_1/n_2)^2$, $N_1/N_2=(n_1/n_2)^3$

Pick points from previous curve, use correspondence theorem , can figure out corresponding flow, lift and power of pump after rotation rate change . Point these points ,we can get the curve $Q-H'$ of pump after rotation rate change.

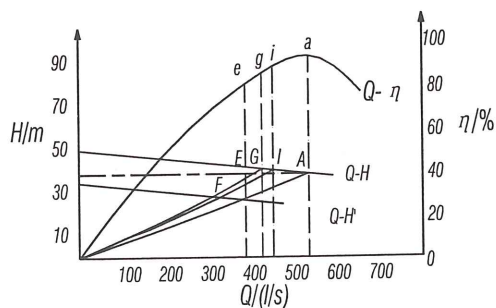


Fig. 2 the previous and new curve of pump.

Common project apply timing operation with constant press. A is design operating point, rotation rate here is rating rotation rate. Flow $Q_A=550$ L/s, lift $H_A=35$ m, efficiency $\eta_a=88\%$, put these data into expression

$P=HQ/102\eta$, we will get $P=214$ kW. When flow reduce to 80 % of Q_A , that is $Q=80\%$, $Q_A=440$ L/s. The operating point will move to E, here lift $H_E=39$ m,

efficiency $\eta_E=82\%$. Put them data into expression, we will get $P_E=205$ kW. Lift keeps constant, so operating point will move to f when Q is 80 % Q_A . from the point F that $Q_F=Q_E$, $H_F=H_A$ we can draw a equivalent efficiency curve to join $Q-H$ curve at point G and corresponding η_G is 84 %. Put η_G expression $P=HQ/102\eta$, we will get $P_G=179$ kW . Comparison between G and E show power saving is $\Delta P=36$ kW, energy saving rate is 12.6 %. We can get energy saving rates of different flow by this way. Table 2 has listed energy saving rates.

Table 2. Energy saving rates

Flow	Energy saving rates /%
80% Q_A	12.6
70% Q_A	18.9
60% Q_A	23.2
50% Q_A	28.4
40% Q_A	31.0
30% Q_A	35.2

Actual energy saving rates own to rotation rate control equipment and especially to application condition .We should draw conclusion based on not only energy saving rates bat also actual operation of pump. When actual flow is changing in range of 90 % rating flow to 100 % rating flow, it is not suitably to adopt rotation rate change equipment. Pump efficiency is about 90 % , so rotation rate control equipment can not bring great energy saving.

4.3 Rotation rate control equipment

It is commonly to adopt tow frequency-change pumps when flow with wide change range. The reason is: ensure frequency-change pumps always work in the high efficiency situation; we can narrow adjust dead area range too; require equipment adjust range less.

Rotation rate control equipment is installed with the biggest pump in the system. Better adjust range is 0.5 to 0.7 and the best adjust range is 0.7 to 1.0. If frequency-change pump is the only type pump in system, we should set the pump based on the biggest flow and head. When the range of change is too wide for frequency-change pumps in system, add pump to system. If system needs higher pump lift ,the lift we add to system is $H=0.25H_0$. Under the condition of there is frequency-change pump but ordinary pump, we can get the flow of pump we need by this $Q_f=Q_{\min}/0.5$, $Q_d=(Q_{\max}-Q_e)/n$. Q_f is the flow of frequency-change pump, Q_d is the flow of ordinary pump, $Q_{\max}$ and $Q_{\min}$ separately is the maximum and minimum flow of

system; n is the number of ordinary pump. There are something should be paid attention during operating frequency-change pump: 1) the pump should always work with high efficiency, otherwise there is no use to saving energy; 2) the rotation rate of pump should not lower than 50 % of rating rate to avoid pump mechanical breakage of pump; 3) combination of frequency-change pump and ordinary pump will cause ordinary pump operating power beyond rating power. Less flow the pump is, more serious the problem becomes. Pump operate with high power than rating power will lead to pump electromotor heat and combination efficiency will descend. Less flow the frequency-change pump is, less efficiency of combination drop to. If this problem becomes too serious to operate, we should adopt parallel frequency-change pump. 4) energy saving rating is lower as the pump water outlet invariable pressure is higher. So pump water outlet invariable minimum should be kept low as possible and near minimum lift of the high-efficiency segment, when head of system has been satisfied.

5. Combine three methods for saving energy

The relationships among flow, lift and power is $Q_1/Q_2=n_1/n_2$, $H_1/H_2=(n_1/n_2)^2$, $N_1/N_2=(n_1/n_2)^3$

Order $n_1/n_2=\gamma$, then relationships can be expressed like this

$$Q_1/Q_2=\gamma, H_1/H_2=(\gamma)^2, N_1/N_2=(\gamma)^3 \quad (1)$$

As we know the impellers cutting law of pump can be expressed like this: $Q'/Q=D_2'/D_2$; $H'/H=(D_2'/D_2)^2$; $N'/N=(D_2'/D_2)^3$. Order $D_2'/D_2=\beta$, we will get formula as

$$Q'/Q=\beta; H'/H=(\beta)^2; N'/N=(\beta)^3 \quad (2)$$

When these tow methods are used in one system, Q' , H' , N' in formula (2) equal Q_2 , H_2 , N_2 in formula (1). Formula (1) multiplied by formula (2), then eliminate the same term, we will get $Q_1/Q=\gamma\beta$; $H_1/H=(\gamma\beta)^2$; $N_1/N=(\gamma\beta)^3$. order $\gamma\beta=A$, We will get

$$Q_1/Q=A; H_1/H=(A)^2; N_1/N=(A)^3 \quad (3)$$

$D-G$, $K-I$ is equivalent efficiency curve. Order the energy saving $=1-W$, base on expressions $P=HQ/102\eta$, we can get the power quotient of pump after impellers cut and frequency-change. We can get the power quotient of previous pump at the same time. The quotient is $W=(H_K Q_K/102\eta_K)/(H_E Q_E/102\eta_E)$, for $Q_K=Q_E$, we can predigest the quotient as $W=(H_K \eta_E)/(H_E \eta_K)$, the energy saving ratio $=1-$

$(H_K \eta_E)/(H_E \eta_K)$ and $\eta_K=\eta_l$. Put actual flow and lift into formula (3), we will get the efficiency of correspond similar point η_{ed} . For $Q_E=Q_K$, we can get H_E and η_E , η_E is approximate efficiency.

6. Summary

To new small project, we usually use only one frequency-change pump and try our best to make the situation with biggest appearance probability be consisted in pump high-efficiency segment. To new middle project, if the change range of system volume is not wide and system volume only change around two data for many years, we adopt ordinary pump. If difference between these two system data is too much, we should cut pump impellers or take off one stage. If the change range of system volume is wide, we should install one or two frequency-change pumps except select ordinary pump according to volume change. For big new project, we should combine three methods for optimization of supply and need.

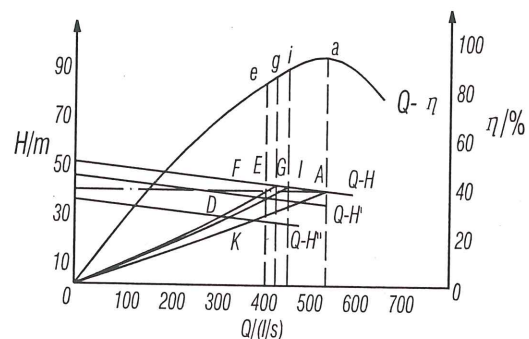


Fig.3. specific curve after impellers cut and frequency-change.

All methods must aim at saving energy during and we can't adhere to use frequency-change pump blindly. We should consider the early investment of rate change installation firstly as we select little pump of which power is less than 150KW. The reason is electricity saving is little relatively. Reclaim period will be too long because of high early investment. It is perfect to reclaim early investment by saving electricity in 2-5 years; otherwise other methods have to be apply.

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