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Discussion on energy saving technology of circulating water pump in heat supply network

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Abstract: Firstly, the frequency conversion operation mode of water pump is analyzed. By analyzing the specific speed of water pump and the characteristic curve of pipe network, it is found that before and after the passive frequency conversion, the pump efficiency is reduced and there is throttling loss. Then, the operation method of water pump is deeply studied, and a reasonable operation mode is selected by analyzing the operation characteristics and energy consumption of various operation modes. In the analysis of pump operation, the pump characteristic curve formula is combined with the law of proportion, and the pump head and efficiency curve formula under variable working conditions are derived. At the same time, combined with a heating project, after the analysis and calculation of different operation modes of the actual project under the temperature difference of fixed supply and return water, the conclusion that initiative frequency conversion can save power consumption compared with passive frequency conversion is obtained. In the future, the use of circulating water pump initiative frequency conversion technology in heating engineering will be more energy-saving.

Keywords: Operation method; Similarity law; Pump characteristic curve; Pump efficiency; Economic analysis

1. Introduction

The heat medium of concentrated heating system belongs to viscous fluid, which constantly produces friction resistance in the process of transportation. In order to ensure the continuity of fluid transmission and distribution, it is necessary to provide continuous transmission power. Circulating water pump is the equipment that provides power for heat medium transportation. The working principle is that the kinetic energy of the impeller is driven by the centrifugal force from the impeller to the outer part by the centrifugal drive[1]; In the diffusion tube, part of the kinetic energy of the heat medium is converted into pressure energy, and then discharged from the outlet; At the same time, due to a certain vacuum suction effect in the concentrated of the impeller, the fluid in the inlet pipe section of the circulating water pump is sucked into the pump under the pressure difference between the pump inlet and the impeller center[2]-[3]. Due to the continuous rotation of the impeller, the heat medium is continuously flowing in and out, thus continuously providing power for the heat medium transportation. Therefore, the circulating water pump is an important part of the concentrated heating system. The investigation found that in different actual operation of central heating system, the power consumption index of circulating water pump per unit heating capacity is very different[4]-[5], some less than 1kW. H, some systems up to 10kW. H; thus greatly reducing the economic benefits of heating enterprises and increasing the economic burden of heat users.

The operation energy consumption of circulating water pump is affected by many factors, such as the resistance characteristics of heating system, the type of circulating water pump, the operation regulation mode of

circulating water pump and so on. On the basis of these factors, this paper puts forward corresponding technical measures for energy-saving operation of circulating water pump for discussion.

2. Passive frequency conversion operation technology of circulating pump

The working principle of the passive frequency conversion technology of circulating water pump is that the frequency conversion pump and frequency conversion control system are set in the heat exchange station, the pressure difference setting, measuring, signal conversion and transmission devices are set at the beginning or end of the main water supply and return pipe, and the flow control valves are set at the user side. Set the pressure difference at the beginning or end of the main water supply and return pipe to a certain constant value. When the pressure difference increases and the deviation from the set value increases to the upper limit of a certain artificially set interval, the circulating water pump will operate at a reduced frequency under the action of the frequency conversion control system until the pressure difference is stable near the set value; on the contrary, when the pressure difference increases and the deviation from the set value decreases to a certain artificially set interval When the lower limit is reached, the circulating water pump will operate at a higher frequency under the action of the frequency conversion control system until the pressure difference is stable near the set value.

Whether the pump is similar before and after frequency conversion should be judged from three similarities: geometric similarity, motion similarity and dynamic similarity. Geometric similarity means that the ratio of pump size is a constant. Motion similarity means velocity triangle similarity. Dynamic similarity is a necessary and sufficient condition for motion similarity under the condition of geometric similarity. When the liquid flow in the channel is in the self mold area, if the pump meets the geometric similarity and motion similarity, then the pump can be judged to be a similar condition.

Before and after the frequency conversion, the physical characteristics of the pump do not change, so the geometric similarity meets the requirements. At this time, the concept of specific speed is introduced to judge whether the pump is under similar working condition after frequency conversion. The formula of pump specific speed is : $N_S = \frac{n\sqrt{G}}{H^{3/4}}$, According to the relationship between pump head and pipe network flow: $H = SG^2$, The formula of pump specific speed can be expressed as： $N_S = \frac{n}{S^{3/4}G}$ 。After the passive frequency conversion, the impedance value of the pipeline changes, and the specific speed derived from the above formula changes. Because the pump specific speed must be equal under similar conditions, the passive frequency conversion is not a similar condition. Before and after the initiativefrequency conversion, the impedance value of the pipeline does not change, and the specific speed is equal. Because the pump geometry before and after the initiative frequency conversion is similar, under the condition that the specific speed does not change, it can be concluded that the pump initiative frequency conversion is similar.

Passive frequency conversion has the following two characteristics: firstly, the operating conditions of circulating water pump before and after frequency conversion operation are not similar, and the parameter changes of circulating water pump before and after frequency conversion operation do not meet the similarity law; Secondly, when the circulating water pump deviates from the maximum efficiency condition (generally the design condition), the greater the deviation, the lower the operation efficiency and the greater the throttling loss of the user side[6].

The change of operating parameters of passive frequency conversion can be determined by the

following formula[7]:

$$H' = AG^2 + B\left(\frac{f'}{f_0}\right)G + \left(\frac{f'}{f_0}\right)^2 C \quad (1)$$

$$\eta' = A_1\left(\frac{f_0}{f'}\right)^2 G^2 + B_1\left(\frac{f_0}{f'}\right)G + C_1 \quad (2)$$

The performance curve and throttling loss of passive frequency conversion can be shown in the figure below.

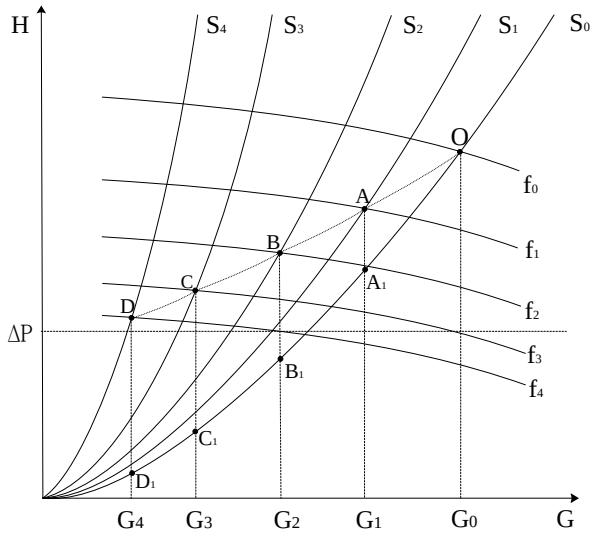

Figure 1: Initiative frequency conversion and passive frequency conversion

Data Description：

Constant pressure difference of user terminal in passive frequency conversion（The differential pressure at the user end is ΔP），After the pump frequency changes, the pump performance curve is O-A-B-C-D。In the process of initiative frequency conversion, the operating point is on the initial pipeline characteristic curve because the pipeline impedance value does not change. There is throttling loss in passive frequency conversion under the same flow rate, As shown in the picture AA_1(Throttling loss of water pump with passive frequency conversion under G_1flow),BB_1(Throttling loss of water pump with passive frequency conversion under G_1 flow).

3. Initiative frequency conversion operation technology of circulating pump

The change of user side heat load can be divided into two cases: the consistent change with all users of outdoor temperature and the non-uniform change depending on users' self-regulation behavior. When the outdoor temperature increases, the heat load of all users will decrease at the same time; otherwise, the heat load of all users will increase. With the consistent change of the heat load on the user side, the flow of each user and the total flow of the heating system will change according to a certain rule under the condition that the water temperature difference between the supply and return water is kept constant, resulting in the change of the pressure difference at the set point of the pressure difference according to a certain rule. Initiative frequency conversion technology is mainly aimed at the regular change of system differential pressure set point differential pressure caused by the consistent change of user side thermal load.

The working principle of initiative frequency conversion is to calculate the differential pressure of the set point of differential pressure according to the real-time outdoor temperature, and replace the current differential pressure setting value. If the newly set pressure difference is less than the current pressure difference setting value, the circulating water pump will operate at a reduced frequency until the pressure difference at the pressure difference setting point is reduced to the new setting value; otherwise, the circulating water pump will operate at a higher frequency.

In order to maintain the stable operation of the whole system and prevent the circulating water pump from frequent frequency modulation, the following settings are made in advance in the information processor: when the absolute value of the difference between the real-time collected outdoor temperature and the current differential pressure setting value is ≥1 ℃, the system will process the collected temperature information. When the absolute value of the difference between the collected outdoor temperature and the current set value of differential pressure is < 1 ℃, the computer does not process the collected outdoor temperature data, and the set value of differential pressure remains unchanged.

After using initiative frequency conversion, the resistance characteristic of circulating pipeline does not change, and the working point of circulating water pump will fall on the characteristic curve of circulating pipeline. As shown in figure (1)。Therefore, the working points of circulating water pump before and after frequency conversion are similar working points, and its performance parameters meet the similarity law. Namely:

$$\frac{G_2}{G_1}=\frac{n_2}{n_1},\frac{H_2}{H_1}=\left(\frac{n_2}{n_1}\right)^2,\frac{P_2}{P_1}=\left(\frac{n_2}{n_1}\right)^3 \quad (3)$$

（3）Technology of combining initiative frequency conversion with passive frequency conversion for circulating pump

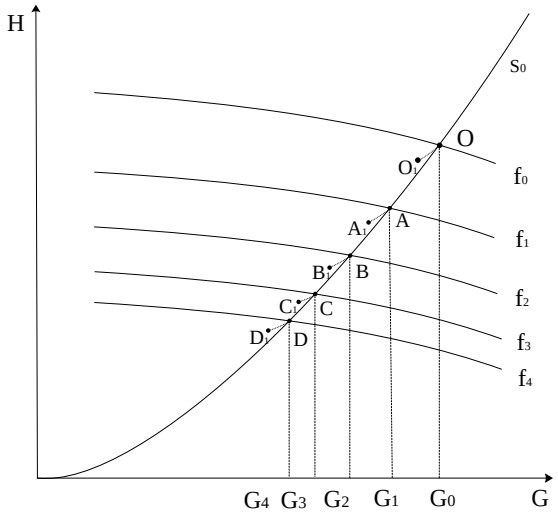

Figure 2: Combination of initiative and passive frequency conversion

On the basis of the completion of initiative frequency conversion, there are still the following two trends that will cause the measured value of pressure difference at the pressure measuring point to deviate from the current set value of pressure difference. First, when the outdoor measured temperature changes, but the absolute value of the difference between the outdoor temperature and the current differential pressure setting value is less than 1 ℃, the resulting change in the user's heat load will lead to the change in the opening of the

user's branch regulating valve controlled by the return water temperature, resulting in the change in the resistance characteristics of the pipe network and the deviation of the differential pressure at the pressure measuring point from the current differential pressure setting value. Second, the initiative adjustment of individual users, such as the artificial adjustment of the opening of the control valve and the artificial change of the set value of the return water temperature, leads to the change of the resistance characteristics of the pipe network and the deviation of the pressure difference at the pressure measuring point from the current set value of the pressure difference.

In the above two cases, if the measured value of the pressure difference at the pressure measuring point has the trend of increasing (greater than the current set value), the upper computer of the central control center will send the frequency reduction control command to the frequency converter, and the frequency conversion controller will automatically adjust the frequency conversion operation of the circulating water pump, so as to control the pressure difference at the measuring point of the pipe network to be stable near the set value corresponding to the outdoor temperature at this time. On the contrary, the upper computer of the central control center sends the frequency up control command to the frequency converter, and the frequency conversion controller automatically adjusts the frequency conversion operation of the circulating water pump, so as to control the pressure difference at the measuring point of the pipe network to be stable near the set value corresponding to the outdoor temperature at this time, so as to complete the passive frequency conversion adjustment process of the circulating water pump.

In the frequency control technology combining initiative frequency conversion and passive frequency conversion, the initiative frequency conversion regulates the initiative change of the set value of the medium voltage difference, so that the passive frequency conversion based on the initiative frequency conversion only deviates from the initiative frequency conversion working condition slightly, so its efficiency will not change greatly compared with the initiative frequency conversion working point. At the same time, compared with the passive frequency conversion process, it has smaller throttling loss. When the outdoor temperature change does not meet the conditions of initiative frequency conversion, but the pipe network flow has changed, the frequency conversion control technology combining initiative frequency conversion and passive frequency conversion can further realize energy saving on the basis of the last initiative frequency conversion.

4. Energy consumption analysis of initiative and passive variable frequency pumps

The heat load of a heating project is 29461.2kw. Under the rated condition, the head of the pump is 36m, the flow is 2533.7m3/h, and the heating area is 590000 square meters. The heating load time continuation diagram and the change of pipe network flow with time are shown in Figure 3.

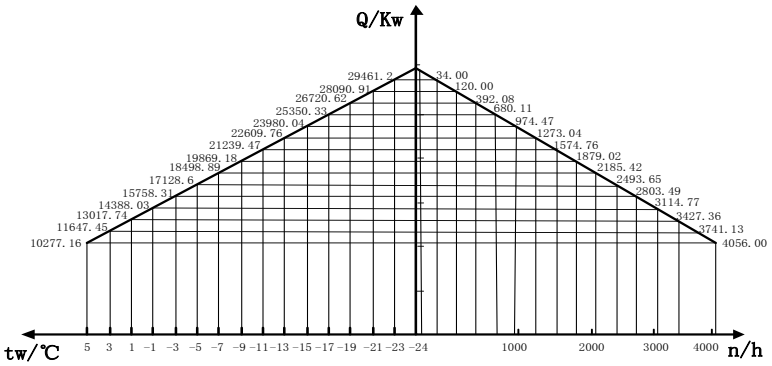

Figure 3: Heat load time continuation diagram

According to the performance curve of the circulating water pump, the curve equation of the performance parameters under the design condition can be obtained by using MATLAB software to fit the pump data:

$$H = -2.815*10^{-6}G^2 + 0.001747G + 49.645$$

$$\eta = -2.014*10^{-5}G^2 + 0.0883G - 2.93$$

According to the formulas (1) and (2), the curve equation of the performance parameters under the frequency conversion condition can be obtained:

$$H' = -2.815*10^{-6}G^2 + 0.001747G\frac{f'}{f_0} + 49.645(\frac{f'}{f_0})^2 \quad \eta' = -2.014*10^{-5}(\frac{f_0}{f'})^2G^2 + 0.0883(\frac{f_0}{f'})G - 2.93$$

Adopting the passive frequency conversion control mode of "each user branch is equipped with a valve to control the opening according to the return water temperature, the pressure difference of the main water supply and return pipe at the outlet of the heat exchange station is constant, and the circulating water pump takes the pressure difference as the frequency conversion signal", the calculation shows that the total power consumption of the water pump in the whole heating cycle of the heating project is 581647.8 kwh.

After transforming the passive frequency conversion into the initiative frequency conversion operation mode, since the operation conditions of the circulating water pump before and after the frequency conversion are similar, under the condition that the discrete value of the temperature change in the above heat load continuation diagram is taken as the initiative frequency conversion control signal, the power consumption of the water pump is 344346.9 kwh.

In practical engineering, in order to achieve further energy saving under the temperature between the discrete values of temperature change in the above heat load continuation diagram, the combination of initiative and passive frequency conversion is usually considered.

4. conclusion

（1）The reasonable parameters of pump selection are head, flow and power. Pump flow selection is the flow of heating system under the design condition, which is calculated according to the design heat load of the system. After calculating the design resistance of heating system, the head of circulating water pump can be determined according to this index. The rated efficiency and the rated head of the pump can be calculated by the formula.

（2）Under the condition of passive variable frequency operation, the operation condition of circulating water pump before and after variable frequency operation is not similar, and the parameter changes of circulating water pump before and after variable frequency operation do not meet the similarity law. When the circulating water pump deviates from the highest efficiency condition (generally the design condition), the greater the deviation, the lower the operation efficiency and the greater the throttling loss of the user side.

（3）Under the condition of initiative frequency conversion operation, the resistance characteristics of the circulating pipeline do not change, the working point of the circulating pump will fall on the characteristic curve of the circulating pipeline, and the efficiency of the pump is the same as that under the design condition. Therefore, the working points of circulating water pump before and after frequency conversion are similar working points, and its performance parameters meet the similarity law.

（4）Under the operation condition of combining initiative frequency conversion with passive

frequency conversion, the initiative frequency conversion regulates the initiative change of the set value of the medium voltage difference, so that the passive frequency conversion based on the initiative frequency conversion only deviates from the initiative frequency conversion condition slightly, so its efficiency will not change greatly compared with the initiative frequency conversion operation point; at the same time, it has less throttling loss compared with the simple passive frequency conversion process. When the outdoor temperature change does not meet the conditions of initiative frequency conversion, but the pipe network flow has changed, the frequency conversion control technology combining initiative frequency conversion and passive frequency conversion can further realize energy saving on the basis of the last initiative frequency conversion.

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