The Design of Constant Pressure Water Supply System Based on ABB Inverter

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Abstract

The inverter constant pressure water supply system is a more efficient, energy saving solution than traditional way, it is able to saving energy more than 50%. According to performance of head and pipe resistance in specific speed, and the relationship between motor speed and motor frequency, VVVF can realize constant pressure water supply. This paper introduces a constant pressure water supply system in which uses ABB’s ACS510 both as drive and controller. Practical operation shows, the designed system realized tracking to set pressure value, error within permitted. Thinking working 8000 hours one year, the system can reduce 54.4% energy consumption than valve throttling way. © 2011 Published by Elsevier Ltd. Open access under CC BY-NC-ND license.

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1. Introduction

Constant pressure water supply is widely used both in production and living. Compared with traditional water tower and high tank way, the new frequency conversion constant water supply system is more advantage in equipment investment, stability of the system, and the degree of automation [1]. The pump is a typical square torque class load. That means its torque is proportional to the square of the speed, the flow is proportional to the speed, and so power loss is proportional to the cubic of the speed. When using a throttle valve way, no matter valve working at any opening, the motor is always working as rated speed. Thinking water supply system is satisfied when valve opening is 80%, at this point the speed is \( n_1 \),

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and power is $p_1$. At the same situation, when it comes to frequency conversion way, only lower motor speed to 80% of rated speed while hold valve fully open could meet the same demand of water supply. And this point’s power loss $p_2$ has the following relation with $p_1$,

$$\frac{p_2}{p_1} = \left( \frac{n_2}{n_1} \right)^3 = \left( \frac{0.8n_1}{n_1} \right)^3 = 0.512$$

(1)

From formula (1), compare with traditional water supply way that valve opening is 80%, the frequency conversion way loss power is only 0.512. Usually, the motor capacity is greater than actual demand to left a certain margin, that is to say motor is not working at rated status and speed is less than rated even at water peak [2]. Frequency conversion constant water supply system has great potential in energy saving. The designed water supply system in this paper had running more than six months, and compared with traditional way it can saving energy 54.4%.

Currently, widespread frequency conversion constant water supply system is formed by PLC, SCM, other special controller plus inverter [3]. These additional controller increased not only the cost but also the failure rate of system. In this paper, we are going to design a constant pressure water supply system, and according to practical running result prove that abandoned special controller only use inverter can also realize stable constant water supply, achieve same energy saving.

2. Principle of Constant Pressure

2.1. Characteristic of water supply system

The characteristic of water supply system as shown in Fig1, the performance of head means, hold the valve opening unchanged, the relationship between head H and flow Q at a certain speed, it reflects the relationship between head and water consumption; the performance of pipe resistance means, hold motor speed unchanged, the relationship between head H and Q at a certain opening, it reflects the relationship between head and water supply. At the intersection of head and pipe resistance performance, system while meeting both of them, water consumption and supply reach a balance so that can stable running. The intersection is called working point of water supply system. Water consumption is time-varying according to the need of user. So the task of water supply system is achieves accurate control to water supply flow, make it dynamic balanced with water consumption flow, to ensure system stable running.
Fig. 1. Work point of water supply system H means the water supply system’s head, Q is the flow of system.

2.2. Principle of frequency conversion water supply system

From previous section, accurate control water supply flow can realize water supply system constant pressure stable running. When valve opening constant, change motor speed can change the flow. Motor speed \( n \) has following relationship with frequency \( f \), where \( p \) is pole pairs, \( s \) is slip ratio.

\[
n = \frac{60 f}{p} (1 - s)
\]  

According change motor power supply frequency change speed then change water supply flow, it is the principle of frequency conversion water supply system.

3. Design of Variable Frequency Constant Pressure Water Supply System

3.1. Water consumption calculation and analysis

Residential area water consumption is consist of mainly by the water for living, water for fire control, green water and other uncertain water to wait for a few parts. Life water consumption is the most important water demand analysis basis because of the highest percentage of total water consumption. According to the water supply flow calculation method which is shown as formula (3) in architectural water drainage standard, the highest time water flow could be calculated.

\[
Q_h = \frac{K_s Q_d}{T} \text{ m}^3/\text{h}
\]  

(3)
Where $Q_h$ is water flow in an hour when water consumption is maximum, it units is $m^3/h$. $Q_d$ is a day’s water flow, a residential area have residents 600, according to each have an average of 3.5 individuals. The total numbers of water population is 2100. According to city residential standards; the maximum water supply in daily life should not be less than 230 L for each person, in this system we thinking 300 L for each one, from formula (3), $Q_d$ is $630\ m^3$. $K_h$ is hours vary coefficient, it means the ratio of the maximum water consumption in the maximum day’s hour and that of average hour, in our city $K_h$ can selected as 2.5. $T$ is hours of use water in a day, select $T$ as 20. Then can calculate the $Q_h$ value is $78.75\ m^3/h$. Resident highest for 12 layers, according to 3.5 meters per layer, thinking pump head of 48 $m$ is enough. Comprehensive consideration of the pump and motor efficiency, and system allowance, choosing three 45KW pumps can satisfy the water supply demand.

3.2. System structure

Principle of variable frequency speed constant pressure water supply system as shown in Fig.2. System is consists of controller, actuators and detection link, form a closed loop control system. The inverter as a control core of whole system, according to the deviation between a given pressure and that of assessment change rev pump sets and pump rotation speed, realize the accurate control of pressure. Main circuit of the variable frequency speed constant pressure water supply system as shown in Fig.3.

![Fig.2. Schematic diagram of the variable frequency speed constant pressure water supply system. It is consist of inverter, pump motor and pressure gauge as a loop control system.](image-url)
According to the inverter output frequency the first pump start-up, when hydraulic is insufficient for industrial frequency, and cut frequency pump, if hydraulic still insufficient start the second insufficient, cut the second pump for industrial frequency, frequency conversion startup third pump, when the pump is going to stop order instead. Through adjusting the quantity and adjust into pumps water pump motor speed, realize the constant pressure water supply.

The system doesn't use a separate controller, but adoption inverters built-in PID adjustment function, So in hardware configuration, according to the actual water demands of a residential area, only by a inverter, three 45KW pump motors, 1 remote transmission gauges, 6 ac contactors, air circuit breaker and intermediate relays and indicator other auxiliary equipment composition.

The inverter choosing ABB’s acs510 series standard of acs510-01-088A-4, system I/O board of wiring as shown in Fig.4.

Fig.3 Main circuit of constant water supply system. ACS510 is the control core of the system, its output is directly to three motor, according to the actual pressure feedback decide which motor or motors should be start as variable frequency.

Fig.4 Wiring diagram of inverter’s I/O. The system can works as manual and auto ways. When it works as manual way, AI1 is the given speed of motors. AI2 is the actual pressure feedback from pressure gauge, it is the important basis of inverter output frequency.
4. System Running Test

4.1. Outlet pressure

System has been put into running more than half a year and still stable operation. That the constant pressure water supply system can satisfy the requirement. Fig.5 for the site observed one day different time record curve.

From Fig.5, the system realized to successfully tracking setting pressure that constantly change according actual demand. In order to protect the motor, reduce instantaneous current shock when motor speed up and slow. The rise and decline time of inverter parameters are set long as 60s. And at water flow changes moment, the pressure value fluctuates. Due to above two reasons, pressure of setting and actual has some deviation, but the deviation within the acceptable range.

4.2. Energy-saving effect

For more than half a year, about 50% of the time system working at 80% under the rated speed, and 30% in 70 percent rated speed time work, 20% in 60% of the rated speed time for work. According to the system 8,000HRS annual work, use the way valve control consumes electricity 359 MWH while using frequency control energy consumption as 164MWH, saving energy 54.4%. According to each production 1MWH 0.5t to emissions of carbon dioxide, 97t total could reducing emission per year.

5. Conclusion

System put into use, has been more than six months, still stable operation. And can meet the constant pressure water supply demand of one Residential area. Through the compared result of power consumption that before and after use frequency speed control, the designed system has obvious effect in energy-saving, is a kind of effective and feasible scheme of constant pressure water supply. And this design saves currently in widespread use PLC, and other special controller, but using inverter built-in PID
frequency adjustment function, for control system controller and actuators double tasks, due to not use PLC or other special controller, making the system cost reduced significantly, operating more simple and more easier to maintain and to reduce the system's failure.

References

