Automation Design of Water Supply System for Residential Area

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Abstract. Variable-frequency constant-pressure water supply system is gradually developed based on variable frequency speed regulation technology. In this paper, it is carried out of stepless speed regulation, constant pressure control and the soft starting of the water supply system by the combination of frequency converter and PLC. This control system is recommendable for its high stability, reliability and automation.

1. Introduction

Nowadays water supply system is of particular importance for the residential area, which has been the main living form in the city with the rapid urbanization. The economy, reliability and stability of the water supply system have direct impact on the normal life and work of the residents.

All the traditional water supply types, like high cistern or water tower and variable-frequency speed-regulation system based on single chip microcomputer, have some disadvantages and influence the normal water consumption of residents seriously. These include the waste of water and electricity, low efficiency, low reliability. So, several constant pressure water supply methods emerge as the times require. Among them, the controlling system composed by frequency converter and PLC is the most popular for its stable system and powerful functions [1].

2. Working principle and composition of the system

Variable-frequency constant-pressure water supply system is driven by three-phase asynchronous motor to rotate the pump so as to supply water. The speed of the asynchronous motor is adjusted by the change of the input AC frequency with the frequency converter. The flow rate of the pump changes with it and the pressure of the water supply system can be controlled. Thus, the essence of frequency conversion in water supply system is the frequency control of motor speed of three-phase asynchronous motor, which is achieved by changing the stator power supply frequency and changing the synchronous speed [2].

If the pressure of the pipeline networks is lower than the setting value during the operation, the pressure difference will be calculated and fed back to converter. And then the increment of output frequency from the converter can be calculated and send an order to the converter. The speed of the pump motor increases under the higher frequency and the pressure of the pipeline networks raises in real time. If the actual pressure is higher than the setting pressure, the adjustment process reverses. The output frequency of the converter will cut down while the flow rate of the pump is also decreasing.
This process repeats during operation and maintains the actual water supply pressure equal to the setting value [3]. The process of system control is shown in Figure 1.

![Figure 1. Schematic diagram of frequency conversion constant pressure water supply system](image)

The main purpose of the variable-frequency constant-pressure water supply system is to control the pressure of pipeline network. It is a closed-loop control system and is composed of PLC, frequency converter, pressure sensors and pump motors etc. Theoretically, only two pump motors can fully meet the water supply requirements, but the type and quantity of equipment in the system is determined by the scale of the residential area actually.

Working process of pump increasing: Assume the sequence of the pump increasing is Pump 1 and then Pump 2. At first, Pump 1 starts to work. When the water supply pressure is lower than the setting value, the output frequency of the converter increases and the speed of the motor also increases. When the output frequency of the frequency converter reaches the upper limit and runs steadily for some time, the AC contactor between pump 1 and converter disconnects and Pump 1 switches to power frequency condition. At the same time, the frequency converter will connect to Pump 2 and the motor of Pump 2 switch to work in variable frequency condition.

The working process of pump decreasing is reverse. By doing this, the water supply pipeline networks can work steadily within the setting range. This system is designed according to two pumps, while multiple pumps system is similar.

For the sake of system debugging or fault maintenance, manual mode is set. When the system runs in manual mode, automatic mode is invalid. Administrator can execute pump increasing or decreasing manually by inputting switching signal in PLC as needed.

3. Design of Hardware Circuit

3.1. Main circuit

The main circuit of the system is composed by power switch Q, fuse FU, AC contractor KM, and thermal relay FR. One frequency converter controls two pumps. Pump 1 and Pump 2 can switch between power frequency condition and variable frequency condition. The on-off of AC contactor is controlled by PLC [4].

KM1 is the AC contractor that controls Pump 1 and Pump 2 to run in automatic mode. KM2 and KM3 control Pump 1 to operate in power frequency condition or variable frequency condition. KM4 and KM5 control Pump 2 to operate in power frequency condition or variable frequency condition.

3.2. Control circuit

PLC and frequency converter make up the control unit of the water supply system. Pressure sensors work as the feedback element and realize the real-time control of the pumps by providing feedback of the real-time pressure in the pipeline networks. The components model is Siemens S7-200 PLC, Siemens frequency converter MM44 and several pressure sensors.
Connect K1, input PLC I0.1 as “1”, and then contractor KM1 is energized. The system operates in automatic operation mode.

Connect K2, input PLC I0.2 as “1”, and then contractor KM1 coil is cut. The system enters the manual operation mode.

Users can connect K3 or K4 to start Pump 1 or Pump 2 in power frequency condition. I0.5 and I0.6 are the input control interfaces of the converter.

4. Programming

4.1. PLC Programming

The PLC programming is shown in Figure 2.

Connect the main power switch Q and close the switch K1, the system will operate in automatic mode. The system will switch of the pumps according to the pressure of the pipeline networks.

When the water consumption increases and the pressure decreases, if the water pressure is still insufficient since the output frequency of the frequency converter has risen to the upper limit 50 Hz, Pump 1 will switch to power frequency condition after a short delay. At the same time, the output frequency of the frequency converter reduces gradually, Pump 2 will work in variable frequency condition to maintain the water pressure stable in the setting range. The “delay” in the process is to reduce the frequency of the frequency converter and soft start Pump 2 so as to decrease the starting current and avoid motor overburning.

![Flow chart of main program](image-url)

**Figure 2.** Flow chart of main program
When the water consumption decreases, the water pressure increases, and the output frequency of the converter is lower than the lower limit, the pumps will be switched in reverse sequence. The lower limit of the frequency converter can be set according to the demand of the water supply site. However, to avoid the idling of the motor, the lower limit can be set between 30 Hz and 35 Hz.

4.2. Parameter Setting of the Frequency Converter MM440

The frequency of the frequency converter is corresponding to the control voltage one by one. The highest frequency is 50 Hz while the lowest is 30 Hz [5] [6]. Parameter setting is shown in Table 1.

| Parameter numbers | Factory Default | Setting value | Explanation |
|-------------------|----------------|---------------|-------------|
| P0003             | 1              | 1             | Set user access level as standard |
| P0004             | 0              | 7             | Command and numeric I/O |
| P0700             | 2              | 2             | Choose the order source as “Input from terminal block” |
| P1000             | 2              | 2             | Choose the frequency setting as “analog input” |
| P1080             | 0              | 30            | Lowest frequency of the motor operation (Hz) |
| P1120             | 50             | 50            | Highest frequency of the motor operation (Hz) |
| P1121             | 10             | 5             | Slope ascent time (S) |
|                   | 10             | 3             | Slope descent time (S) |

5. Conclusion

It is carried out of stepless speed regulation, constant pressure control of the water supply system by the combination of the PID module of Siemens PLC (S7-200) and the frequency converter MM440, which are high efficiency, energy saving and strong anti-interference. Meanwhile the frequency converter is used to the soft starting of the motor so as to reduce the equipment loss and prolong the service life of pump and motor. The close-loop control for the pressure of water supply pipeline networks gains rapid response, high precision and stable operation. The test results illustrate that the variable-frequency constant-pressure water supply system based on PLC and frequency converter has strong practicability.

References

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