

Design of Multi-speed Motor Control System Based on S7-1200 PLC and Frequency Converter

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Abstract. In order to realize multi-speed control of motor, a control system based on S7-1200 PLC and Siemens MicroMaster420 frequency converter is designed. Through the analysis of the cooling fan control requirements, the hardware system and software programming of the whole control system are designed. The PLC control unit of the control system completes signal acquisition, logic control and communication, etc. The system sets the parameters of the converter by changing the on-off state of the converter digital input, and further realizes the steering change and speed adjustment of the motor. Through experimental comparison, it is concluded that the control system designed in this paper can save more than 30% of the electric energy. The load of the motor is greater, and the energy-saving effect is more obvious. The advantages of the control system are simple circuit structure and convenient operation. The designed control system is simple and effective to realize the multi-stage control of the motor and improve the reliability and stability of the motor.

1 Introduction

At present, resource consumption and waste per GNP in China are much higher than those in most other countries. Environmental protection and energy saving has been an increasing number of the factory to improve the quality and sustainable development as an important way. Energy conservation and environmental protection can effectively alleviate the resource and environmental constraints faced by social development and promote the upgrading of social industrial structure and the transformation of economic development mode[1]. Variable frequency speed control technology with excellent speed control performance, significant power saving effect is widely used in all fields. [2]. Variable frequency speed regulation is an important means of saving energy, reducing consumption and improving control performance. It also increases production and quality. Because the actual power consumption of pump, fan or other load is proportional to the cubic square of the speed, the pump or fan load inverter speed regulation can save 20%-60% of the electricity. Variable frequency speed regulation of frequency converter plays an important role in energy saving. In addition, frequency converter can also be used in intelligent control and improve the level of technology and product quality[3]. Based on the control system composed of PLC and frequency converter can improve the starting performance and energy-saving optimization of motor. In this paper, the multi-speed control of the motor is realized, which can improve the performance of the motor and prolong the service life and save energy[4].

This paper adopts S7-1200 PLC and Siemens MicroMaster420 to realize multi-speed control.

2 Design control requirements

Air cooler is generally used in cold storage, cold chain logistics refrigeration environment, which is driven by an electric motor. The energy consumption of the air cooler accounts for 40% of the whole refrigeration system, which is a very large proportion and has great energy saving potential. The control requirement is to use S7-1200 PLC, MM420 inverter to realize the three-speed adjustment of the motor[5]. Specific requirements are as follows: when the start button SB1 is pressed, the motor starts and rotates at 10HZ. After 10 seconds, the motor rotates at 20HZ, and after 20 seconds, the motor rotates at 40HZ. When the stop button SB2 is pressed, the motor stops running.

2.1 Design of control system

Design of the hardware. S7-1200 PLC is mainly used for the design of the control system, which is stable in operation, easy to use and can effectively replace the relay control circuit[6]. MM420 inverter has the following advantages, such as a wide speed range, strong communication ability, accurate control performance and high reliability, low speed high torque output, stable dynamic performance, super overload capacity and so on. With these advantages, MM420 inverter can be used in different applications. Three-phase asynchronous motors are widely used, mainly because of the mature manufacturing technology, easy maintenance and repair,

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high mechanical efficiency, simple regulation and other characteristics.

Motor parameter setting. Taking small three-phase AC asynchronous motor as an example for multi-stage speed control, the motor parameters are as follows: voltage 380v, current 0.18a, power 30w, frequency 50HZ, speed 1430r/min.

Inverter fixed frequency setting. Three methods are provided for selecting the fixed frequency of MM420 inverter. The first one is Direct selection (P0701--P0703=15). A numeric input selects a fixed frequency. If several fixed input connected at the same time, the selected frequency is the sum of them. The second one is Direct selection and ON(P0701-- P0703=16). With both the selected fixed frequency and the ON command, a numeric input selects a fixed frequency. Similarly, if several fixed inputs are switched on at the same time, the selected frequency is the sum of them. The last one is Binary code and ON (P0701-- P0703=17). DIN1 to DIN 3 three digital input terminal constitute binary code and a total of eight combinations can be formed. The system can set 8 different speeds, actually only 7, because one of them is 0. Each binary code corresponds to a fixed frequency, corresponding to the parameters P1001 ~ P1007. If the frequency is selected by Direct selection or Direct selection and ON command, the number of input terminals is not enough to set the speed of 7 segments. At this time, the selected frequency is the result of superposition. The frequency selection is limited and inconvenient, especially in the case that all switches are closed. Therefore, this paper adopts the binary code to select the Binary code and ON command. The relationship between fixed frequency values and corresponding parameters is shown in Table 1.

Table 1. Inverter fixed frequency setting

DIN3	DIN2	DIN1	Frequency
0	0	0	0 [OFF]
0	0	1	P1001
0	1	0	P1002
0	1	1	P1003
1	0	0	P1004
1	0	1	P1005
1	1	0	P1006
1	1	1	P1007

Circuit wiring diagram. Through the above analysis of the parameter, the designed circuit wiring diagram is shown in figure 1, mainly including Converter, PLC and Motor, which can achieve multi-speed regulation according to the control requirements. In this paper, only three speed is taken as an example to illustrate the working process. DIN3 ends as ON to switch ON, and OFF to stop the motor function. DIN1 and DIN2 realize motor speed adjustment according to binary code.

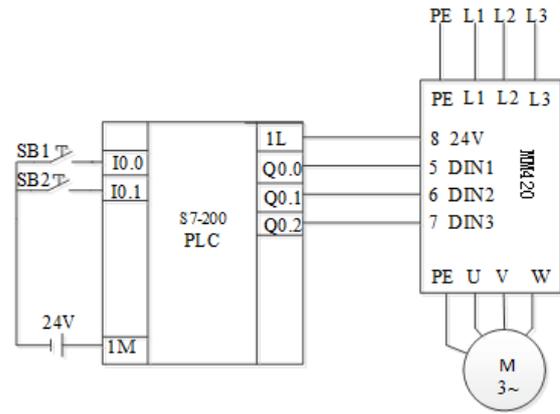


Figure 1. Circuit wiring diagram

The following is a detailed control illustration of Figure 1. When press the start button SB1, I0.0 is connected, Q0.0- and Q0.2 settings are pressed. the timer T37. starts: the electric timing. When the digital input port DIN1 of the frequency converter MM420 is "ON" and DIN3 is "ON", the motor rotates at the fixed frequency 1(10Hz) set by parameters P1001. When T37 reaches 10 seconds, Q0.0 is reset, Q0.1 is set, and Q0.2 is switched on. At this time, DIN2 is "ON", and the motor rotates at the fixed frequency 2(20Hz) set by parameter P1002. After another 10 seconds, DIN1 and DIN2 are "ON" and the motor rotates at the fixed frequency of 3 (40Hz) set by parameter P1003. When the stop button SB2 is pressed, I0.1. starts to generate power, and Q0.0, Q0.1 and Q0.2 start complex bits. DN1, DIN2 and DIN3 are IN the state of "OFF" and the motor stops running. The binary code form of DIN2 and DN1 is 01, 10, 11 when three speed rotation. The other multispeed forms are similar to this and not be repeated. The key of the system is the setting of inverter parameters. The I/O distribution table of PLC is shown in Table 2.

Table 2. I/O distribution table

Circuit symbol	Input		Output	
	Address	Function	Address	Function
SB1	I0.0	Start button	Q0.0	DIN1
SB2	I0.1	Stop button	Q0.1	DIN2
			Q0.2	DIN3

Design of software. The software design part includes PLC control program and frequency converter parameter setting.

Design of System control program. Figure 2 is part of PLC programming that realizes multi-speed function control.

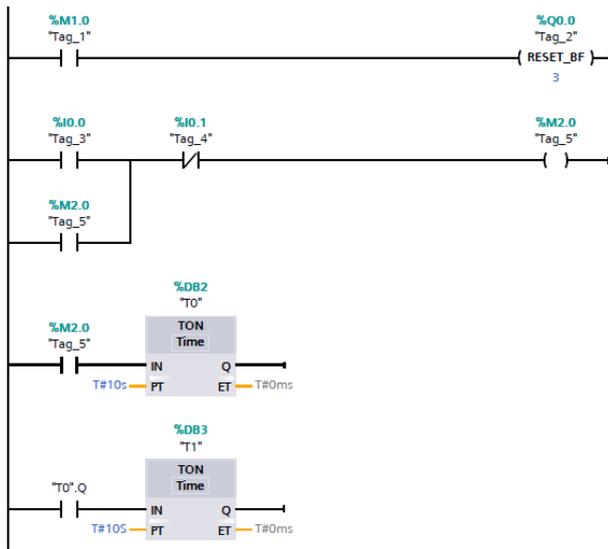


Figure 2. PLC control program

Design of frequency converter’s parameter. The parameter setting of converter is shown in table 3, and only the main parameter setting values are listed.

Table 3. Converter parameter setting

NO.	Converter Parameters	Factory Value	Setting Value
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1	P0304	230	380
2	P0305	3.25	0.18
3	P0307	0.37	0.03
4	P0310	50	50
5	P0311	0	1430
6	P0700	2	2
7	P0701	1	17
8	P0702	1	17
9	P0703	1	1
10	P1000	2	3
11	P1001	0	10
12	P1002	5	20
13	P1003	10	40

3 Experimental results and analysis

The design of multi-section speed control system is applied to the air cooler and the power consumption is tested experimentally, which is mainly compared with the power consumption without changing the speed regulation mode. The experimental condition is that the evaporation temperature of the cold storage is in the range of -30°C to 10°C respectively, and the air cooler is used for refrigeration. Figure 3 shows the relationship between power consumption and evaporation temperature.

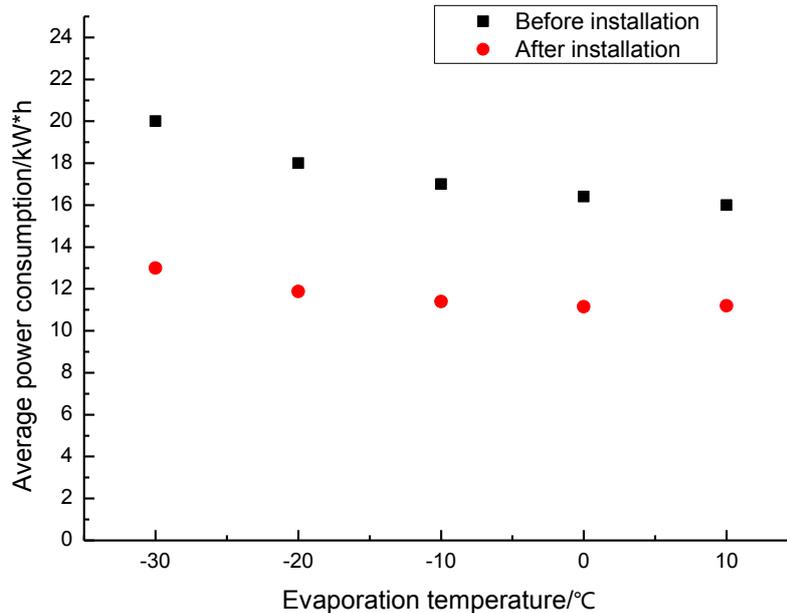


Figure 3. The relationship between power consumption and evaporation temperature

From the figure, it can be seen that after using the new control system, the power consumption is about 30% under the same experimental conditions. As the evaporation temperature of the cooling fan decreases, the power consumption of the cooling fan in both control modes will increase. However, with the new control system, the energy saving becomes more obvious as the evaporation temperature decreases, which can reach 35% when the evaporation temperature is -30°C . The experimental data show that the new control system has more advantages.

4 Summary

This paper designs a motor multi-speed control system based on S7-200 PLC and Siemens MicroMaster420 frequency converter, which mainly includes hardware design and software programming. After the design is completed, the scheme is used in the cold air machine for comparative experiment. The experimental data show that the electric energy consumption can be reduced by 30% after using this control system. The air cooler runs stably

and energy consumption is obviously reduced. The whole control system is simple, flexible and easy to operate. The scheme achieves the design purpose and can be extended to other motors used in aviation industry.

References

1. Qu. F: Advanced Process Control Applications for Industry Manufactory. Microcomputer information. Vol. 8(2003), p.1-3
2. Dong min hui: Nverter application technology(Tsinghua university Publications, China, 2017)
3. Yang li: Multistage Speed Control of Motor Based on PLC. Digital Technology &Application, Vol.37(2019), p. 28-31
4. Niu, y. b. Research on Three Phase Asynchronous Motor Control System based on PLC.Digital Technology &Application, Vol.36(2018) , p. 127-129
5. Yang Weiwei; Liang Jiejunyi; Yang Jue; Zhang Nong: Optimal control of a novel uninterrupted multi-speed transmission for hybrid electric mining trucks. Proceedings of the Institution of Mechanical Engineers, Vol(2019), p. 3235-3245
6. Wang.Z.G: M ultistage Speed Control Based on S7 - 200 an d MM440 Inverter On-Line. Electric switch.Vol.1(2014), p. 67-69