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Design and Implementation of a Centralized Air Conditioning Energy Saving System based on Intelligent Control System

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Abstract: ***This paper introduces a programmable logic controller and frequency converter in the central air-conditioning energy saving system in new applications, based on the water cooling, cooling, air conditioning cooling tower fan system intelligent transformation, realize the conversion of energy, as the basic ideas and goals, through the optimization of the traditional fuzzy PID technology. The refrigeration system, the new system in adjusting parameters and frequency temperature more convenient, and analyzes the significance and value of the new system in the practical application through specific case.***

Keywords: centralized air conditioning; programming logic controller; fuzzy PID control

1. Introduction

There is a widespread the problem of high energy consumption of the centralized air conditioning for civil, public and commercial buildings in China, generally the energy consumption of centralized air conditioning accounts for about 50% of the total energy consumption of the whole building, while shopping malls and comprehensive building are more than 60% and above. While in most of existing centralized air conditioning, the compressor can implement self-control with a PLC, so the control of other parts of the centralized air conditioning g is the focus in our research. And other parts, the capacity of freezing circulating water system, cooling circulating water system and the cooling tower was selected by the maximum cooling and heating load demand of building, and reserved enough margin. No matter how season, day and night, and the user load changes, each motor is full-speed operation under power frequency for a long time, the waste of energy is obvious. So it has very important economic significance of saving power consumption of refrigerant circulating water system, circulating water system and cooling tower fan system when central air conditioning at low load. The traditional central air conditioning adopts P1D control more, because this control method has features of quick response and simple operating method, but it cannot effectively control the air conditioning with uncertain parameters. Following, it will take typical structure characteristics of centralized air conditioning system as an example, through the combination of PLC and frequency converter, using the fuzzy PID control process implemented by water pump and fan system of air conditioning system to make up for the shortage of the traditional PD.

2. The Composition and Working Principle of Central Air Conditioning System

Centralized air conditioning air conditioning system is shown in figure 1, it is mainly composed by several parts including refrigeration compressor, cooling water circulation system, frozen water cycle system, cooling towers, and cooling tower fan.

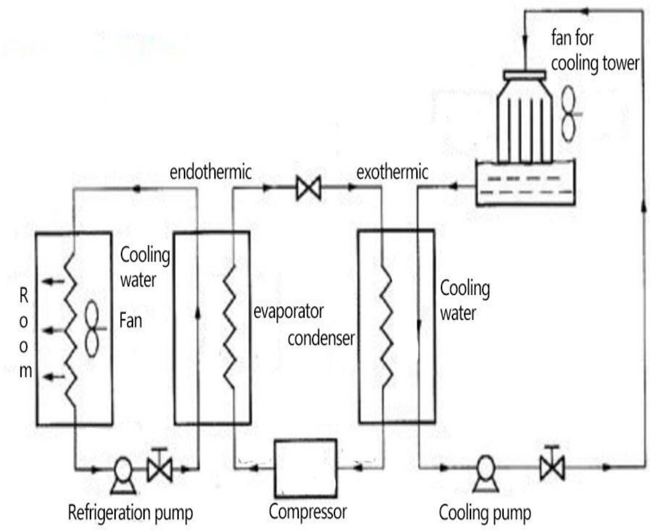

Figure 1: The composition of central air conditioning system

Its working principle is: the refrigerant absorbed heat in compressor is compressed into high temperature and high pressure gas through the compressor, and by heat transfer with cooling water changed into high temperature and high pressure liquid, then condensed into low temperature high pressure liquid, through closure it changed into low temperature low pressure liquid and evaporated back to compressor by absorbing the heat of freezing water of air conditioning, so the refrigerant circulating cycle is formed then. Chilled water flowed out of frozen host is sent into chilled water pipe by cooling pump pressing, through the coil pipe of the room to take away the heat inside the room, then cool down the room. The evaporated refrigerant released heat in the condenser, carried out heat exchange with cooling circulating water, and then the cooling pump brought the heated cooling water to the cooling tower for spray cooling, carried out heat exchange with air. Cooling tower provided cooling water for freezing host, cooling water circling through the freezing host, and it will take away the heat produced in the freezing host to cool down the freezing host. So the circulating process of chilled water and cooling water is formed.

3. Variable-frequency speed control system

Due to the capacity of water pump motor and the cooling tower fan is designed for the maximum heat exchange amount required by air conditioning, but in the actual condition, the heat exchange amount is far less than the design value. And due to the value of the heat exchange amount depends on the speed of water pump motor and cooling tower fan. So if the speed of water pump motor and cooling tower fan can be adjusted according to the actual heat exchange amount, then it can greatly reduce the power consumption, and saving electricity.

Fan and water pump loads belong to square torque load, namely torque T is directly proportional to the square of rotational speed n, Toc n, the output power of the motor shaft is proportional to the speed of the three party. Also by the speed of n=60f (1 - s) /P motor speed can be achieved by adjusting the input frequency. Therefore, the motor input frequency down tuning, motor power consumption will be greatly reduced, resulting in power consumption will decline. Motor using VVVF technology can realize stepless speed control in central air conditioning operation, adjusting the throttle valve opening in the operation process, the liquid flow smoothly, reduce the throttle loss, avoid mechanical shock and impact current, by reducing the frequency of operation, the system can avoid long full load at high speed, so the benefit of the unit maintenance, especially can effectively extend the service life of the motor and generator, and by changing the motor speed to change water flow speed and fan speed to meet the requirements of normal operation of air conditioner, so as to realize the purpose of energy saving.

4. System Model

Variable frequency control system of central air conditioning is mainly composed of programmable controller PLC, frequency converter, contactor, central air conditioning system, temperature detection and feedback device and they formed a closed-loop automatic control system. They are controlled by the PLC through frequency converter to control the cooling water pump, cooling pump and fan, with PLC inverter for switching control, realize the continuously adjustable of water pump and fan speed, make the fan motor of water pump can set the speed according to the value of the actual heat load, thus save energy, and reduce a large number of intermediate relay as compared with the traditional controller, and because the stability of the PL itself, can improve the running reliability of the system. Because the controlling principle of all water pumps of central air conditioning system and fan system are the same, so here only one kind of refrigeration pump fuzzy control system is introduced.

4.1 Fuzzy control system structure of freezing pump

Fig. 2 is structure chart of fuzzy PD control system of freezing pump, the given value of the controlled object is r the actual measured value is y then the closed-loop deviation is e, e = r - y deviation rate of change is Δe , Δe-y_n-y_{n-1},y_n is the deviation of current sampling time; y_{n-1} is the deviation of former sampling time. Big dotted box is the part can be completed by Siemens PLC. It based on the deviation e of input value r and feedback value y and deviation rate of change De calculated by fuzzy reasoning to get Kp、Ti and Td of PID algorithm, the obtained output U as the given value of frequency converter, through the inverter to control the speed of freezing pump, ultimately achieve the goal of control room temperature.

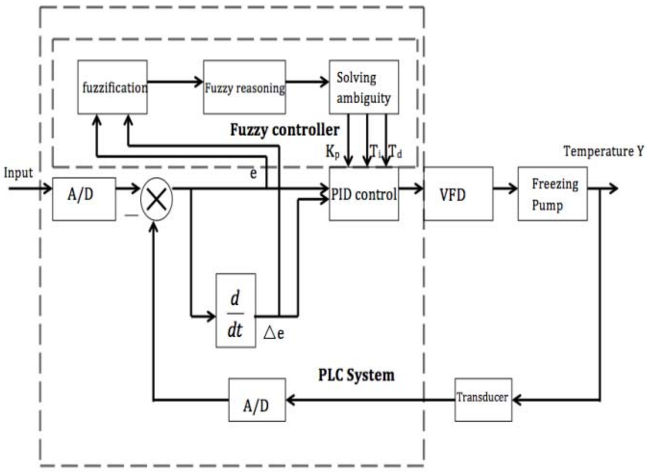

Figure 2: the structure of fuzzy PID control system for refrigeration pumpinput,

4.2 Fuzzy PID controller design

The form of number patterns of common PID algorithm is:

$$u(n)=K_P\left\{e(n)+\frac{T_s}{T_i}\sum_{m=0}^{n}e(m)+\frac{T_d}{T_s}\left[e(n)-e(n-1)\right]\right\}$$

Where: Kp is the proportionality coefficient; Ti is integral constants; Td is differential constant; U (n) is the output of the controller; e(n) is the deviation; Ts for the sampling period. The input variables Kp Ti and Td of PD controlling part are calculated by the fuzzy controller shown in the small dotted box in Fig. 2, it is calculated by fuzzy reasoning of temperature deviation e and temperature variation rate Δe. In order to convenient for PLC programming, it shall use the method of fuzzy control query table. Here it will first convert e Δe Kp Ti and Td into corresponding fuzzy language variables E EC KP TI and TD and can get fuzzy control query table of Kp by calculation.

As shown in Fig. 1. Fuzzy control query table of TITD can be obtained in a similar way.

PLC based on the actual input blurred after E and EC actual amount control is obtained by look-up table KP, T and TD after fuzzy PD controller KP, Ti and TD by controlling the frequency converter to control the speed of cooling pump.

Table 1: Fuzzy control query table of KP

KP		EC										
		—5	-4	-3	-2	-1	0	1	2	3	4	5
E	—5	—5	—5	-4	-4	-3	-3	-2	-2	-1	-1	0
	-4	—5	-4	-4	-3	-3	-2	-2	-1	-1	0	-1
	-3	-4	-4	-3	-3	-2	-2	-1	-1	0	1	1
	-2	-4	-3	-3	-2	-2	-1	-1	0	1	1	2
	-1	-3	-3	-2	-2	-1	-1	0	1	1	2	2
	0	-3	-2	-2	-1	-1	0	1	1	2	2	3
	1	-2	-2	-1	-1	0	1	2	2	2	3	3
	2	-2	-1	-1	0	1	1	2	2	3	3	4
	3	-1	-1	0	1	1	2	2	3	4	4	4
	4	-1	0	1	1	2	2	3	3	4	5	5
	5	0	1	1	2	2	3	3	4	4	5	5

4.3 Fuzzy PID control realized by PLC

MITSUBISHI PLC is selected, this machine has advantages of small volume, powerful hardware and software, and convenient system configuration. The flow chart of using PLC to realize fuzzy PD control algorithm is shown in figure 3.

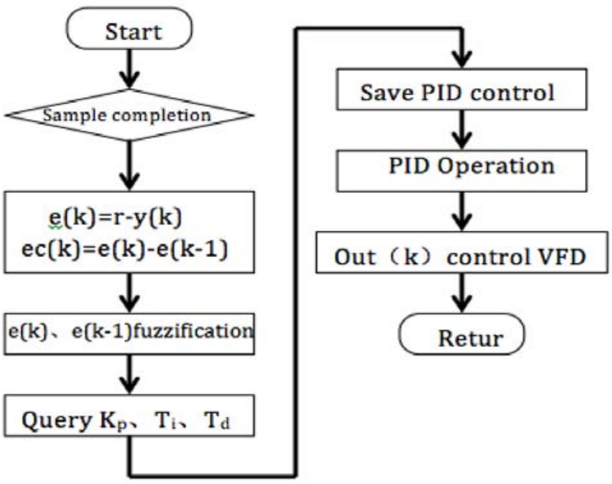

Figure 3: Fuzzy PD algorithm routine flowchart cooling pump

5. Conclusion

This article uses MITSUBISHI PLC, using fuzzy PID control method of central air conditioning of energy-saving upgrade, through a period of observation, the energy-saving effect is better than that of centralized air conditioning, achieved good energy saving effect, basically reached the expected goal of energy saving. The experiment of the fuzzy PID control technology and air conditioning technology, and the use of the programmable controller, the characteristics of simple operation, flexible and strong stability, make the system more stable, more intelligent, and reach the target of reducing energy consumption. The fuzzy PID control method used in central air conditioning, taking into account the advantages of the traditional control mode at the same time, optimizing the system response speed, reduce the output shocks, adjust the steady-state error and achieved good results, this is a good reference in the similar centralized air conditioning large time delay, nonlinear, high complexity the system.

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