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Enthalpy Control for Central Air-conditioning Systems

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Abstract. With the application of central air-conditioning systems increasing, the problems of its energy consumption and controlling environmental comfort attract more attention. Enthalpy control uses less energy than temperature control, and can meet the requirements of environmental comfort. This paper introduces the definition of enthalpy, enthalpy control principles and methods and so on, and describes the enthalpy control of central air-conditioning systems in detail. Fuzzy logic control method is proposed for the room temperature and three-dimensional fuzzy control structure is constructed. According to the errors in relative humidity, control rules are divided into three parts to achieve automatic control of room temperature. Simulation results show that the proposed controller has good robustness, and better static and dynamic characteristics than the traditional controller.

Keywords: Central air-conditioning systems, enthalpy, Fuzzy control, Energy saving;

1. Introduction

With the development of air conditioning technology and the improvement of people's requirement about environment, the central air-conditioning has become indispensable to modern buildings infrastructure. It should be noted that on the one hand, the central air-conditioning system consumes a lot of energy while providing comfortable living and working environment to people, on the other hand, the central air-conditioning system can't meet people's higher requirements for environment comfort through controlling the air temperature. The reason is that human comfortable level depends not only on the ambient air temperature but also on the relative humidity of the air. Using enthalpy control in the central air-conditioning systems will be more energy-efficient than using temperature control, at the same time it can implement the reasonable adjustment between the temperature and humidity, and then can meet the people's requirement for the comfortable environment. In the control process of central air-conditioning system, the controlled object' characteristic parameters or structure will be changed with the lode or interference factors. For central air-conditioning systems has a great hysteresis, nonlinear and time variability, it should be controlled by fuzzy logical control. The advantages of fuzzy logical control are stronger robustness, good dynamic response, fast rise time and small overshoot. In order to solve the coupling between the temperature control loop and humidity control loop, three-dimensional fuzzy controller is selected in the paper. And temperature control is used as an example to explain control method. The system is simulated by MATLAB. According to the simulation diagram, the control effect of the designed fuzzy controller is analyzed from the robustness and the stability.

2. Enthalpy Control Way

Application of central air conditioning system has been popular. It is a major problem in air conditioning design to ensure air conditioning system to meet the requirements in the temperature, humidity, fresh air and cleanliness, and the system can run in low power consumption at the same time. At present, air conditioning system of commercial buildings more generally adopt CAV air conditioning system with primary return air. Such system is relatively simple, easy to grasp and operate. Using the full new wind at transition season, it can meet the indoor health requirements with the installation of one or two level filter [1],[2].

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Air handling process of return air system in the summer is that air sent to the indoor in order to absorb the more heat and wet. After that, some air is carried out of the room, the other part back to mixing tank and mix the outdoor air, release heat through the surface cooling treatment, and then is given into air-conditioned room by fan to form a circle.

The task of central air-conditioning system is to provide a working and living environment which temperature and humidity are suitable to meet user requirements. Meanwhile, in the present requirements of saving society, it is to be taken into account how to run the central air-conditioning systems to consume less energy. Among them, the air conditioning process closely relates to the state of outdoor air and the ratio of new air and return air. In different weather conditions, using different return air ratio and running method can reduce the energy consumption of central air-conditioning.

The working of air-conditioning system usually divides into three seasons running [3]: summer cooling condition is from June to September; winter heating condition is from late November to mid or late the next year in March; the rest of time as transition season. Usually in transition season only ventilating devices are used, the cold and heat source are not started. In the following, enthalpy control way is explained.

The running essence of central air-conditioning system is that according to the outdoor air state, the indoor air state and the blast state, under the guidance of the principle of energy conservation the air handling process is determined. In the process, the energy conservation principles should be abided as follows.

1) The phenomenon of cold and hot offset should avoid when the indoor temperature and humidity are adjusted.

2) In the premise of meeting the sanitary conditions, fresh air is rationally used and its energy consumption should be reduced, meanwhile cooling capacity of new air is also full used.

3) Cold and heat source closed or are delayed to use as much as possible.

4) Make the most of the indoor temperature fluctuations range and extend the time without the energy consumption.

5) Need to take a different air handling measures in different climatic regions.

3. Fuzzy Control

In the control process of air-conditioning system, the characteristic parameters or structure of controlled object will change with the influence of load or interference factors. For central air-conditioning systems has a great hysteresis, nonlinear, and time variability, PID control won't get good control effect. Using fuzzy logical control can play a good role of strong robustness, good dynamic response, fast rise time, small overshoots [4],[5].

Actuators of air-conditioning systems include surface cooling, steam humidifier, heater. The controlled object of the system is the indoor temperature and humidity. To control these two variables, we construct two independent control loops. The actuators of temperature control loop consist of surface cooling and heater. The actuators of humidity control loop contain surface cooling and steam humidifier. The paper adopts the temperature control as an example to illustrate. In order to solve the problem of coupling between temperature control loop and humidity control loop, it selects three-dimensional fuzzy controller [6],[7]. Input variables of temperature fuzzy controller are the temperature error e, the temperature error rate ec and the relative humidity error ct. The output variable is u.

Membership functions of temperature error e, the change of temperature error ec and output variable u adopt symmetrical triangle function. All membership functions are defined as triangular partitions with seven segments from -3 to 3.Each domain interval divided into 7 equal regions, denoted by NB(negative big), NM(negative medium), NS(negative small), ZO(zero),PS(positive small), PM(positive medium) and PB(positive big) and assigns each region a fuzzy membership function. Relative humidity error ct takes three fuzzy sets, which domain is from -2 to 2 and membership function is denoted by N, ZO, P, and adopt triangle function with three segments. Fuzzy reasoning method adopts the minimum value method and deblurreingmethod adopts weighted average method [8],[9].

Three-dimensional fuzzy controller is constituted because of the introduction of relative humidity error. Based on the relative humidity errors the control rule-making is divided into three parts, so the changing process of the air is factually reflected. Here are fuzzy rules of the temperature fuzzy controller based on experience. Combined with the above analysis, three fuzzy control tables are obtained. When the relative humidity error ct is respectively N, ZO, P, the fuzzy rule tables of temperature fuzzy controller are shown in Table 1,2,3.

Table1. Fuzzy rule table of output u when ct is N

ct=N u		e						
		NB	NM	NS	ZO	PS	PM	PB
ec	NB	NB	NB	NB	NM	NS	NS	NS
	NM	NB	NB	NM	NM	NS	NS	NS
	NS	NB	NM	NS	NS	NS	ZO	ZO
	ZO	NS	NS	ZO	PS	PS	PS	PM
	PS	NS	ZO	PS	PS	PM	PM	PM
	PM	ZO	PS	PS	PM	PM	PB	PB
	PB	PS	PS	PM	PM	PB	PB	PB

Table 2. Fuzzy rule table of output u when ct is ZO

ct=ZO u		e						
		NB	NM	NS	ZO	PS	PM	PB
ec	NB	NB	NB	NB	NM	NM	NS	NS
	NM	NB	NB	NM	NM	NS	NS	NS
	NS	NB	NM	NS	NS	NS	ZO	ZO
	ZO	NM	NM	NS	ZO	ZO	PS	PS
	PS	NM	NS	ZO	PS	PS	PM	PM
	PM	NS	ZO	PS	PS	PM	PM	PB
	PB	PS	PS	PM	PM	PB	PB	PB

Table 3. Fuzzy rule table of output u when ct is P

ct=P u		e						
		NB	NM	NS	ZO	PS	PM	PB
ec	NB	NB	NB	NB	NM	NS	NS	NS
	NM	NB	NM	NM	NM	NS	ZO	NS
	NS	NB	NM	NS	NS	ZO	PS	ZO
	ZO	NB	NM	NS	ZO	PS	PS	PS
	PS	NM	NS	ZO	PS	PS	PM	PM
	PM	NS	ZO	PS	PM	PM	PM	PB
	PB	PS	PS	PS	PM	PB	PB	PB

The step response simulation result of the system is shown in Fig.1. It can be seen from the simulation figure that the controller has smaller overshoot and shorter adjustment time, and its dynamic response and steady-state characteristics are good. When the response of controller is near to the balance and has tended to deviate, the speed of curve's change becomes slower. The response of system becomes stable at the balance at last. The output of controller can be adjusted automatically according to the change of process. Thus, this kind of controller has better adaptive ability, self-adapting ability and good robustness.

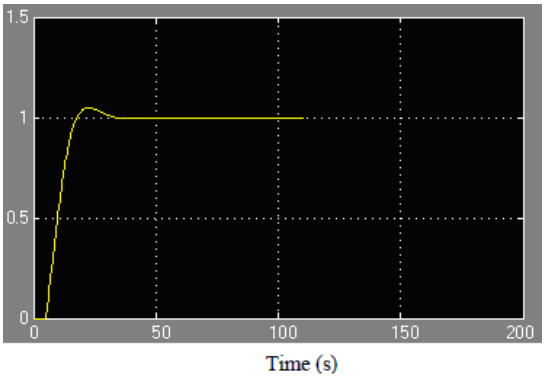

Fig.1. Temperature fuzzy control simulation

4. Conclusion

According to the fluctuation range of indoor air, enthalpy control makes full use of cooling and heating capacity of the new air. The control method is simple and practical. Using enthalpy control, central air-conditioning systems can not only adjust the temperature and humidity well to meet the environment comfort to people, but also achieve the energy saving purpose through the use of new and return air enthalpy to determine the operating condition of relatively fresh air ratio, which can reduce the use of artificial cold and

heat source farthest. It shows enthalpy control has broad prospect in the central air-conditioning systems. The fuzzy controller can effectively solve nonlinear, time-varying and the accurate control of non-mathematical model object. It is simple in design, convenient to implement, optimized in control, strong in robustness and good in real-time. The fuzzy controller can eliminate limit cycle oscillations to make the rest of error greatly decrease for servo system and the system with permanent disturbance. Simulation results show that using fuzzy controller to control air conditioning temperature can not only reduce the fluctuations of room temperature, but also enhance the reliability and its efficiency.

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