Simulation of the Air Conditioning System Using Fuzzy Logic Control

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Abstract: Fuzzy logic control has been widely implemented in air conditioning and ventilation systems which has uncertainty or high robust system. Since the dynamic behaviors of the systems contain complexity and uncertainty in its parameters , several fuzzy logic controllers had been implemented to control room temperature in the field of air conditioning system. In this paper, the fuzzy logic control has been developed to control room temperature and humidity in the precision air conditioning systems. The nonlinear mathematical model was formulated using energy and continuity equations. MATLAB was used to simulate the fuzzy logic control of the multi-variable air conditioning systems. The simulation results show that fuzzy logic controller can reduce the steady-state errors of the room temperature and relative humidity in multivariable air conditioning systems. The offset are less than 0.5 degree Celsius and 3 percent in relative humidity respectively under random step disturbance in heating load and moisture load respectively

Keywords: Fuzzy Logic Control, Multivariable Control System, Air Conditioning System, HVAC

1. INTRODUCTION

The consumption of energy in heating, ventilating, and air conditioning (HVAC) equipment in industrial and commercial buildings constitutes 50 % of the world energy consumption [1]. Therefore, an HVAC system is essential to a building in order to keep occupant comfortable. However , many HVAC systems do not maintain a uniform temperature and humidity throughout the interior areas of building. In a modern intelligent building a sophisticate control system should provide excellent environmental control.

Over the last few year, fuzzy logic control has been widely applied for handling the system which has uncertainty or high robust system. Since the dynamic behaviors of the systems contain complexity and uncertainty in its parameters, several fuzzy logic controllers have been implemented to control room temperature only in the field of air conditioning system. [3,4]

In this paper, the fuzzy logic control has been developed to control room temperature and humidity in the precision air conditioning systems. The output manipulating variable are flow rate of refrigerant and air supply flow rate. The nonlinear mathematical model was formulated using energy and continuity equations [2]. MATLAB was used to simulate the fuzzy logic control of the multivariable air conditioning systems.

2. PLANT MODEL

2.1 Description

We consider the single-zone air conditioning system shown in Fig. 1. It consists of the following components : air conditioner , a circulating air fan , the thermal space , ductwork , dampers and mixing air components. In our system, we assume the system is operating on the cooling mode.

The assumptions of the simulation of air conditioning system in cooling mode are as follows.

- First, 25 % of fresh air is allowed into the system and it gets mixed with 75 % of the circulated air (position 5) at the flow mixer.
- Second, air mixed at the flow mixer (position 1) enters the heat exchanger where it gets cooling.
- Third, the cooling air enter the fan coil into thermal space. It is called supply air (position 2)
- Fourth, the supply air enters the thermal space to offset the sensible (actual heat) and latent (humidity) heat thermal loads acting upon the system.
- Finally, the air in thermal space is drawn through a fan (position 4),75 % of this air returned and the rest is exhausted from the system.

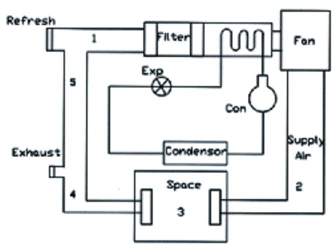


Fig. 1 HVAC plant

For design , the controller maintains temperature and relative humidity at set point 25 °C and 33 % RH (relative humidity) respectively. This controller input for system are the regulate speed of compressor which vary refrigerant from air conditioning system to cooling coil and the circulating air flow rate using the variable speed fan These set of control actions characterize the air conditioning system as :

- A variable air volume system (VAV) that results in the lowest energy.
- In regulated speed of compressor that can safe energy during starting the motor every time in operation.

Our objective is to design an air conditioning system aiming at maintaining comfort conditions within a thermal space, without energy waste. The need to achieve the proposed objective is justified by the drawbacks of current HVAC control methodologies. The importance of the problem at hand lies on the impact that energy efficient HVAC systems can have on industrial and commercial energy consumption.

2.2 Plant Model

The differential equations describing the dynamic behavior Of the air conditioning system as shown in Fig.1 can be derived from energy equation and mass conservation equation as :

$$\dot{T}_3 = \frac{f}{V_s}\left(T_2 - T_3\right) - \frac{f\times h_{fg}}{C_p V_s}\left(w_s - w_3\right) + \frac{1}{\rho V_s C_p}\left(Q_0 - h_{fg} M_o\right)$$

$$\dot{w}_3 = \frac{f}{V_s}\left(w_2 - w_3\right) + \frac{M_0}{\rho V_s}$$

$$\dot{T}_2 = \frac{f}{V_{he}}\left(T_3 - T_2\right) + 0.25\frac{f}{V_{he}}\left(T_0 - T_3\right)$$

$$-\frac{f\times h_{ref}}{C_p V_{he}}\left(\left(0.25w_0 - 0.75w_3\right) - w_s\right) - \frac{nVN\Delta h_{ref}}{C_p V_{he}} \qquad (1)$$

where T_o = Temperature of outdoor air

T_2 = Temperature of supply air

T_3 = Temperature of thermal space

f = Volumetric flow rate of air

h_{fg} = Enthalpy of water vapor

ρ = Air mass density

V_s = Volume of thermal space

C_p = Specific heat of air

w_s = Humidity ratio of supply air

w_3 = Humidity ratio of thermal space

M_o = Moisture load

V_{he} = Volume of heat exchanger

Δh_{ref} = Different Enthalpy of refrigerant

V = Volume space of compressor.

Assumptions

1.Ideal gas with perfect mixing

2.neglected wall and thermal loss between components

3.neglected infiltration and exfiltration effects

The numerical values used in the simulation are given in Table. 1

3. FUZZY CONTROLLER

The proposed fuzzy logic controller structure for air conditioning system is shown in Fig. 2 This scheme consists of a two input-two output fuzzy controller to make the overall system stable. The input variables of the fuzzy controller are temperature error , e_t and humidity ratio error , e_h which are defined as :

$$e_t = T_r - T_y$$

$$e_h = H_r - H_y \qquad (2)$$

where T_r = Set point room temperature

T_y = Actual room temperature

H_t = Set point room humidity ratio

H_y = Actual room relative humidity ratio

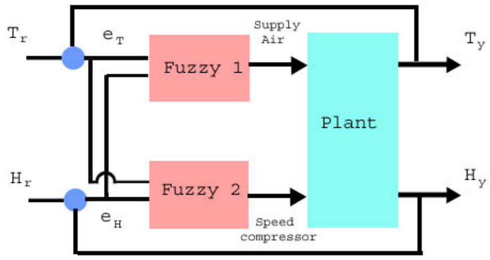
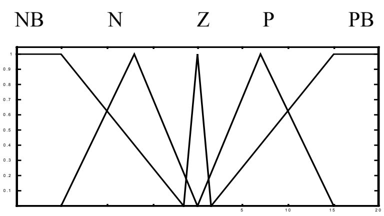


Fig.2 HVAC fuzzy control system

Table. 1 Numerical values for simulation

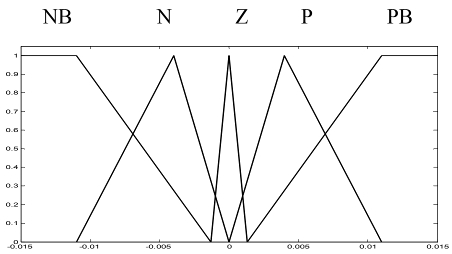
$\rho = 1.19Kg/m^3$
$C_p = 1.005kJ/Kg^\circ C$
$f_{ref} = 400\,cfm$, $f_{oref} = 100\,cfm$
$t_f = 24 hours$
$T_{2ref} = 12.7^\circ C$, $T_{3ref} = 25^\circ F$
$w_s = 0.0070kg/kg$, $w_{3ref} = 0.0092kg/kg$
$V_s = 8.0m^3$
$V_{he} = 0.9m^3$
$\Delta h_{ref} = 67.65kJ/kg$
$T_o = 35^\circ C$

In the fuzzy controller, the measured e_t and e_h values are scale to some real number in the interval of (-1,1) . The values of linguistic variable are composed of linguistic terms PB (Positive large) , P (Positive small), Z (Zero) , N (Negative small) and NB (Negative large) which are all fuzzy set. This set of linguistic terms forms a fuzzy partition of input and output spaces . The knowledge base of the fuzzy logic controller is composed of a database and rule base. The rule base represents fuzzy control rules. The membership function of the fuzzy sets and the fuzzy rules have significant effect on the control performance. Fig. 3 and Fig. 4 show the membership functions of the fuzzy set for temperature error and humidity ratio error and control inputs.



e_t (degree Celsius)

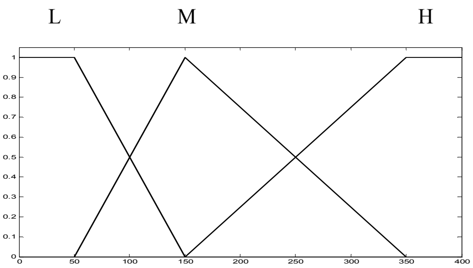
Fig. 3 Antecedent membership function of error temperature



e_h (humidity ratio)

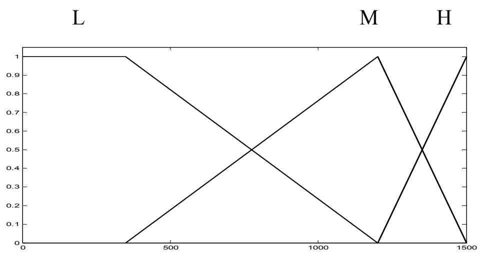
Fig. 4 Antecedent membership function of error humidity ratio

In the design of the fuzzy member the first control output signal is the flow rate of the cold supply air . There are three levels of supply air which are low , medium and high flow rate as shown in Fig. 5 . Similarly, The second control output signal is the compressor speed in the air conditioning system. There are also three levels of speed which are low , medium and high speeds as shown in Fig. 6



supply air (cfm)

Fig. 5 Consequent membership functions of supply air



speed compressor (rpm)

Fig. 6 Consequent membership function of compressor

The control law for this simulation on the air conditioning system are show in table 2.1 and table 2.2 as follows

Table 2.1 law of supply air

Supply air		e_h				
		NB	N	Z	P	PB
e_t	NB	H	H	M	M	L
	N	H	H	M	L	L
	Z	H	H	M	L	L
	P	H	H	M	L	L
	PB	H	M	M	L	L

Table 2.2 law of speed compressor

Speed of compressor		e_h				
		NB	N	Z	P	PB
e_t	NB	H	H	H	H	H
	N	H	H	H	H	H
	Z	H	H	M	M	M
	P	L	L	L	L	L
	PB	L	L	L	L	L

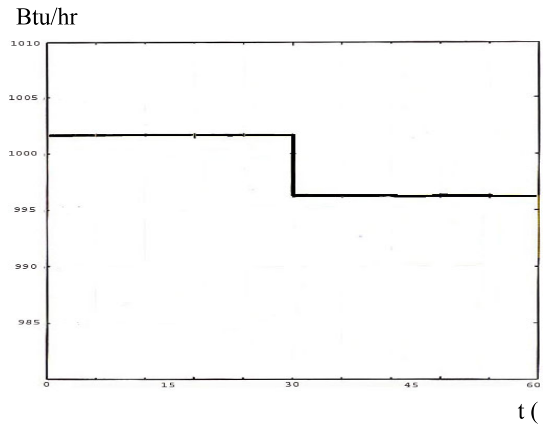


Fig. 7 Heat load disturbance

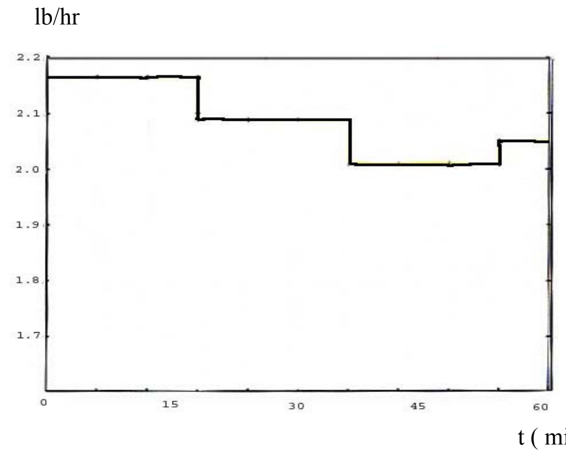
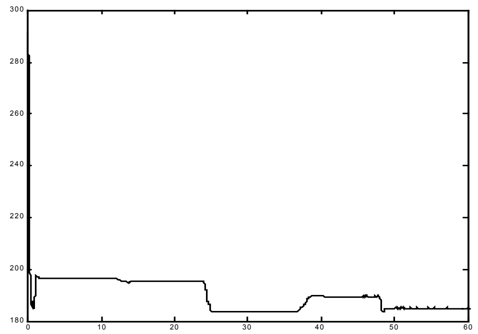


Fig. 8 Moisture load disturbance

4. SIMULATION RESULT

The HVAC system as shown in Fig. 1 has two input variables and two output variables which are the room temperature and room humidity ratio. The two manipulating variables are supply air flow rate and compressor speed or the refrigerant flow rate. The fuzzy logic control has been implemented to the multivariable. HVAC system by using the system parameter in table 1. Fig. 9 and Fig. 10 show the response of the manipulating variables which are supply air and compressor speed due to random heat loads at 1000 BTU per hour average and random moisture loads at 2 lbm per hour average. The HVAC can reach steady state within 2 minute. The supply air flow rate and speed of the compressor will be operated at the minimum level that save a lot of energy. The transient response of room temperature and relative humidity of the HVAC system under heat load and moisture load as shown in Fig. 7 and Fig. 8 respectively are show in Fig. 11 and Fig. 12 with the initial conditions at 25 ° C and 33 % relative humidity response show that fuzzy logic control can reduce the steady state error to the value of less than 0.5 degree Celsius in room temperature and 3 percent in relative humidity respectively.

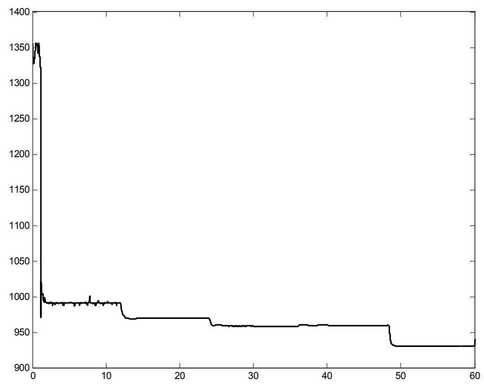
supply air (cfm)



t (min)

Fig. 9 The flow rate of supply air as control signal

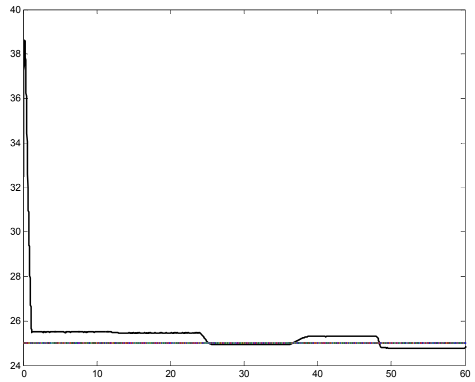
speed of compressor (rpm)



t (min)

Fig. 10 The compressor speed as control signal

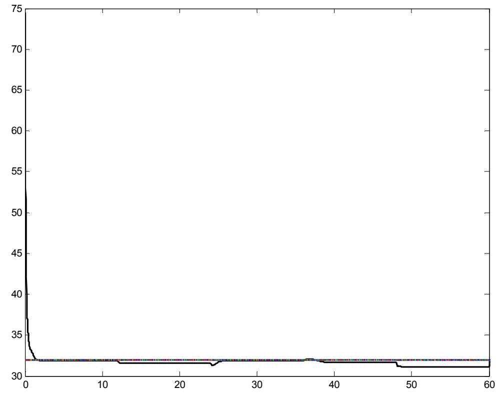
Degree Celsius (° C)



t (min)

Fig. 11 Transient response of room temperature in Air conditioning system under fuzzy logic control

Relative humidity (%)



t (min)

Fig. 12 Transient response of room humidity room humidity in air conditioning

5. CONCLUSION

The simulation of air conditioning system using fuzzy logic control can be concluded as

1. The fuzzy logic controller can reduce steady state error in the air conditioning system.
2. The offset of temperature and relative humidity are less than 0.5 degree Celsius and 3 percent in relative humidity respectively under random step disturbance of heat load and moisture load respectively

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