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FUZZY LOGIC CONTROL OF FAN COIL UNIT

Suriyon Chomdee[1] and Suttichai Premrudeepreechacharn[2]

[1] Department of Mechanical Engineering, [2] Department of Electrical Engineering

Faculty of Engineering, Chiang Mai University

Chiang Mai 50200, Thailand

Tel : 6653-896055-Ext1090 Email : energy_cmu@hotmail.com

ABSTRACT

This paper presents a new method of air flow control in fan coil unit using fuzzy logic control. Fuzzy logic control, which has gained popularity in recent year due to its simplicity in application to practical situation demanding a non - mathematical model based control strategy , is applied to the control of temperature in air conditioning area using rate of air velocity. A performance comparison between constant air velocity and derivative controls of the temperature is made with fuzzy control. It was shown that the fuzzy logic controller performed better in term faster settling time of the room temperature and increase comfort. The fuzzy control is able to give a more robust control of the temperature with respect to dynamic response during the pull down of room temperature.

1. INTRODUCTION

Modern control theory has been successfully applied to area where system behavior is well - defined. However, when the structure of the system is unknown or the parameter variation is excessive, or when there is a multiple objective to be achieved, the effectiveness of modern control theory diminishes. Furthermore goals and constraints in real-word control problem are not always quantifiable by a single numerical valve. In this situation, fuzzy set theory, introduced by Zadeh [1] can be an effective means of dealing with such " linguistically " specified objective.

Recent application in the heating , ventilation , and air conditioning (HVAC) industry have included fuzzy control of air temperature and humidity in air - conditioning system [2] and some simulations and experimental study on the HVAC components as seen in [3] - [4]. The primary aim of these HVAC studies was to develop a robust controller that could offer closer control of temperature and humidity to enhance human comfort and better system performance. This paper discusses the fuzzy logic control of fan coil unit. First, the mathematical model of air condition system considered in this paper is described. Next, the fuzzy knowledge based controller is described. Then, the simulation of air-condition system with fuzzy logic control is presented.

2. AIR CONDITIONING SYSTEM MODEL

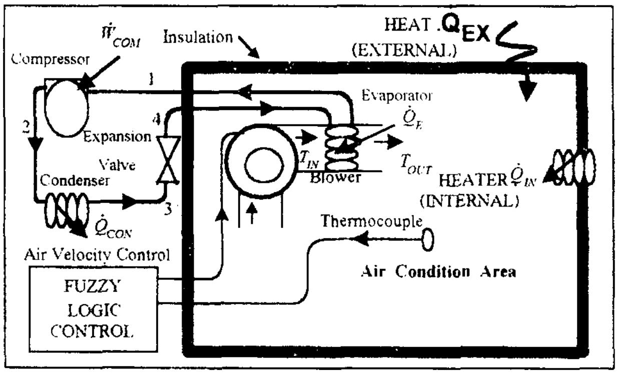
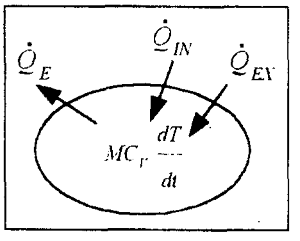


Figure 1: Model of Air conditioning System



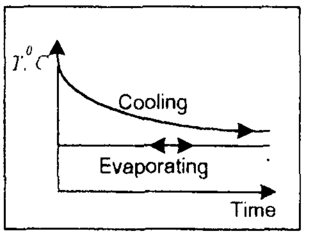


Figure 2:Energy balance Figure 3:One fluid Changing phase

From Fig.2 and energy balance equation, we have

$$\dot{Q}_{EX} + \dot{Q}_{IN} = \dot{Q}_E + MC_P \frac{dT}{dt} \qquad (1)$$

From Fig.1, at evaporator, the energy loss can define as

$$\dot{Q}_E = UA_{Tube}(LMTD) = UA_{Tube}\frac{\Delta T_1 - \Delta T_2}{\ln\frac{\Delta T_1}{\Delta T_2}} \qquad (2)$$

where

$$\Delta T = (T_{H.IN} - T_{C.IN}) = (T_{IN} - T_E)$$

$$\Delta T = (T_{H.OUT} - T_{C.OUT}) = (T_{OUT} - T_E)$$

$$A_{TUBE} = Surface \quad area \quad of \quad Evaporator$$

Hence, the equation for overall heat tranfer Coefficient can define as

$$\frac{1}{U} = (\frac{D_o}{D_I h_I}) + (D_o \frac{ln(\frac{D_o}{D_I})}{2k_{TUBE}}) + \frac{1}{h_o} \quad \_\_\_\_(3)$$

For approximate design purposes for heat exchanger, the first and second term is less than the last term, hence, for this reason, we have

$$U = h_o = B(\frac{\rho VD}{\mu})^m (\frac{k_{AIR}}{D_o}) \quad \_\_\_\_(4)$$

Considered Fig. 3, the hot side fluid is single - phase liquid or gas whose temperature decreases along the exchanger, causing the single component fluid on the other side to evaporate at an approximately constant temperature.

From Eq. (4) substitute into Eq. (2), we have

$$\dot{Q}_E = B(\frac{\rho VD}{\mu})^m (\frac{k_{AIR}}{D_0}) A_{TUBE} [\frac{\Delta T_1 - \Delta T_2}{ln \frac{\Delta T_1}{\Delta T_2}}] \quad \_(5)$$

The external heat is defined as

$$\dot{Q}_{EX} = (T_{Amb} - T_{Room})(\frac{k_{Ins}}{x_{Ins}}) A_{Wall} \quad . T_{room} = T(t)\_(6)$$

In addition, the energy storage is defined as

$$MC_V \frac{dT}{dt} = MC_V \frac{[T(t) - T(t-1)]}{\Delta t} \quad \_\_\_(7)$$

From Eq. (5), (6) and (7) are substituted in Eq. (1) and rearranged, we have

$$\Delta T = T(t) - T(t-1) = \frac{\Delta t}{MC_V} \{[T_{Amb} - T(t)](\frac{k_{Ins}}{x_{Ins}}) A_{Wall} + \dot{Q}_{IN} + B(\frac{\rho VD}{\mu})^m (\frac{k_{AIR}}{D_0}) A_{TUBE} [\frac{\Delta T_1 - \Delta T_2}{ln \frac{\Delta T_1}{\Delta T_2}}]\} \quad \_(8)$$

We will use Eq. (8) to control the fan coil unit and also use with fuzzy logic control as discussed in next section.

3. FUZZY KNOWLEDGE BASED CONTROL

Fuzzy control is a class of non - linear control which is equivalent to a variable gain PI control under certain inference conditions . Since the first attempts to apply fuzzy logic to control system, many different type of fuzzy knowledge based controller (FKBC) have been proposed. The principal structure of a FKBC considered in this paper is shown in Fig. 4.

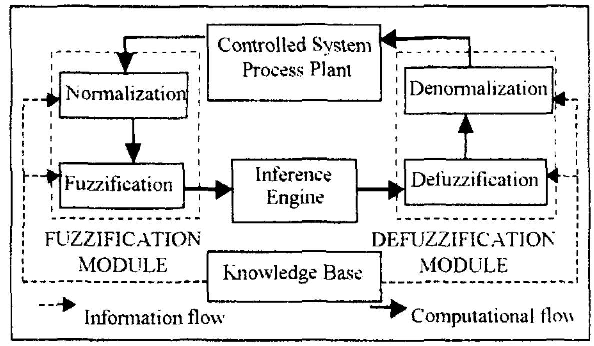


Figure 4: The structure of a FKBC

Fuzzy Logic Control in Matlab Programing

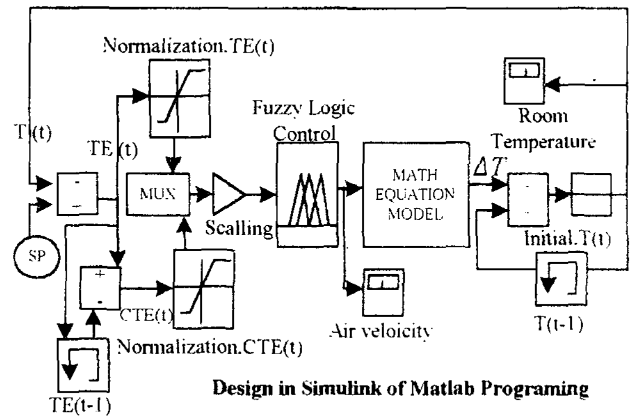


Figure 5: Block diagram for Simulation constant temperature control

Figure 5. shows a block diagram representing a two - input, one output fuzzy controller with an error (TE) of the temperature , and rate of change of the temperature error (DT = CTE) as the fuzzy input variables, and the fuzzy output variable being the Air Velocity(VEL). Math equation model instead real plant of air conditioning area.

The controller can be regarded as a fuzzy- PI controller because it is a fuzzy controller that accounts for error and the rate of rate of change of error of the variable to output an action.

Table 1 : Fuzzy Control Rule Table (49 rules)

TE \ CTE	NB	NM	NS	ZO	PS	PM	PB
NB	PB	PB	PB	PB	PM	PS	ZO
NM	PB	PB	PB	PM	PS	ZO	NS
NS	PB	PB	PM	PS	ZO	NS	NM
ZO	PB	PM	PS	ZO	NS	NM	NB
PS	PM	PS	ZO	NS	NM	NB	NB
PM	PS	ZO	NS	NM	NB	NB	NB
PB	ZO	NS	NM	NB	NB	NB	NB

Table 2 : Reduce of Rules to 22 rules

TE \ CTE	NB	NM	NS	ZO	PS	PM	PB
NB	PB	PB	PB	PB	PM	PS	ZO
NM	PB	PB	PB	PM	PS	ZO	
NS	PB	PB	PM	PS	ZO		
ZO	PB	PM	PS	ZO			
PS	PM	PS	ZO				
PM	PS	ZO					
PB	ZO						

Default rules have been used as a start in the controller design as show in Table1. After simulation,we can reduce the rule base to use only 22 rules as show in Table 2. The seven fuzzy subsets used tc characterize the input (TE,CTE) and output (VEL) linguistic variables : negative big (NB), negative medium (NM), negative small (NS), Zero(ZO),positive small (PS) ,positive medium (PM) and positive big(PB) are show in Fig 6a-6c. The control surface output of fuzzy logic controller is shown in Fig. 6d which used only 22 rules.

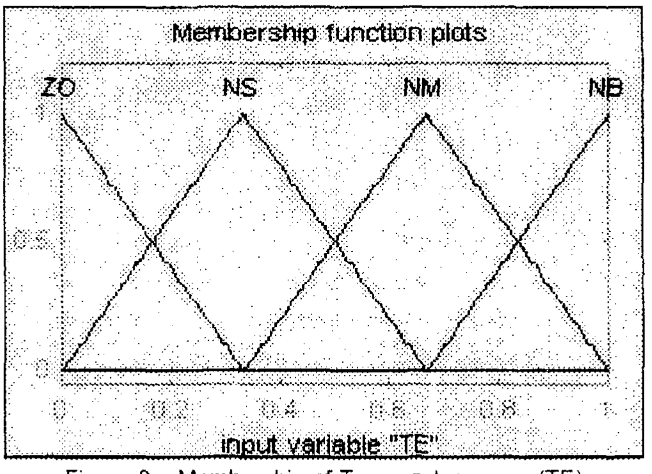


Figure 6a: Membership of Temperature error (TE)

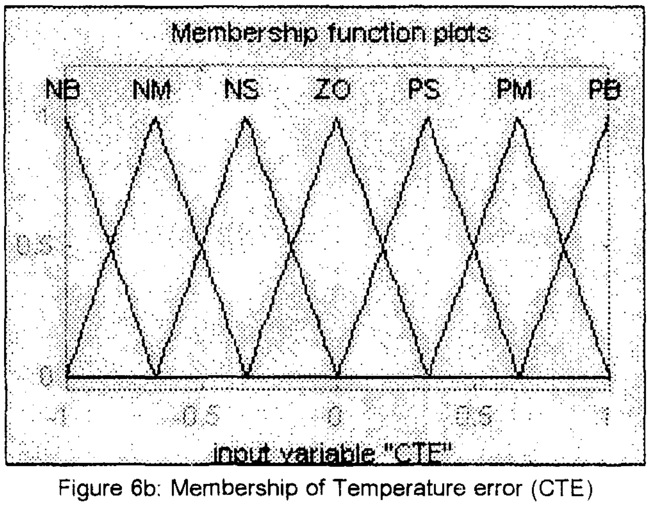


Figure 6b: Membership of Temperature error (CTE)

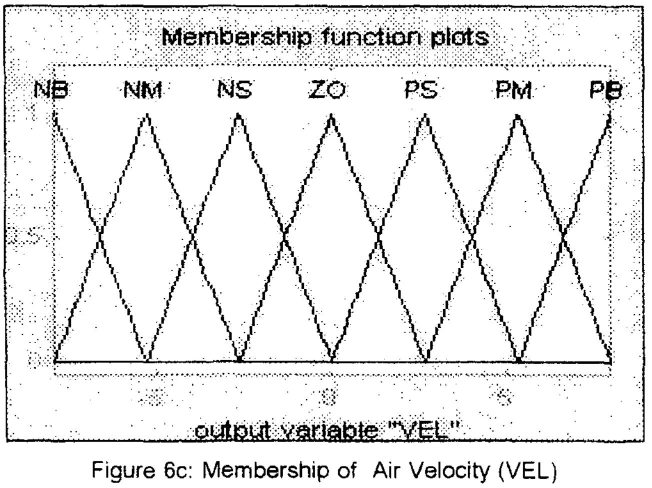


Figure 6c: Membership of Air Velocity (VEL)

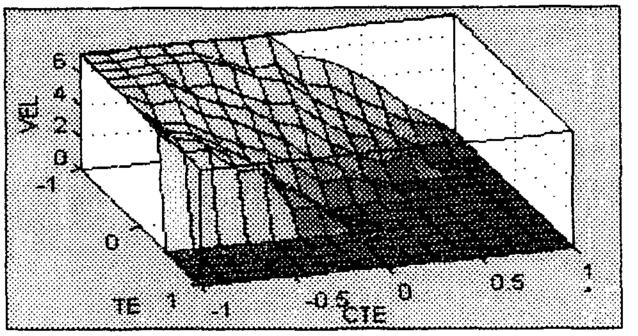


Figure 6d: Surface of FKBC (22 rules)

4. SIMULATION EXPERIMENTAL SETUP

The experimental setup consisted of a full – scale commercial refrigeration unit. It has a 3517 watt (1 tons of refrigeration) evaporator with copper coil consisting 1 circuit and a total air side surface area of 3.2 m^2 (Cross flow heat exchanger). The outer diameter of copper tube was 12.7 mm. with wall thickness of 0.41 mm .

[At average air temperature 300 ^{0}K from Physical properties ρ = 1.1 kg/m^3, C_P= 1000 J/kg ^{0}C, C_V= 718 J/kg ^{0}C , $\mu = 2 \times 10^{-5}$ kg /m.s , k_{AIR}= 0.026 W/m^{0}K]

[Reynolds number 40 – 4000 B = 0.615 . m = 0.466]

- Range of air velocity 0 - 7 m/s.
- Level of air velocity through evaporator HIGHT = 7 m/s , MEDIUM = 4 m/s , LOW = 2 m/s.
- Insulation used polyurethane thickness of 51 mm. k = 0.0000228 kW/ m ^{0}K.
- Volume of internal air conditioning area 4×5×3 = 60 m^3
- Initial Temperature T(0) = 36^{0}C,Set point Temperature = 25 ^{0}C ,Evaporator Temperature T_E = 10 ^{0}C.

An application software was used for data capturing and control calculation. It runs by using fuzzy logic toolbox and Simulink of MATLAB , *offering simulation capability for most control and mathematical modeling, as well as for real time data capturing and control functions.*

5. SIMULATION RESULTS

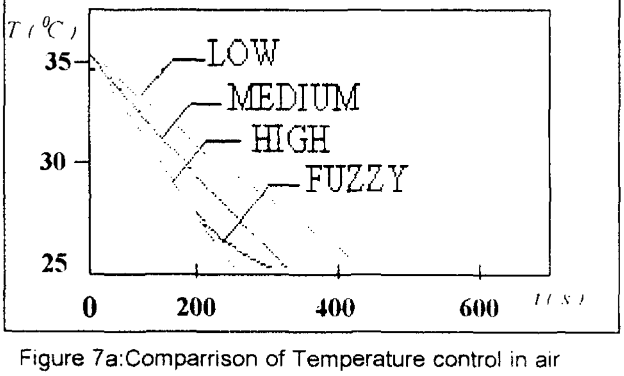


Figure 7a:Comparrison of Temperature control in air condition area

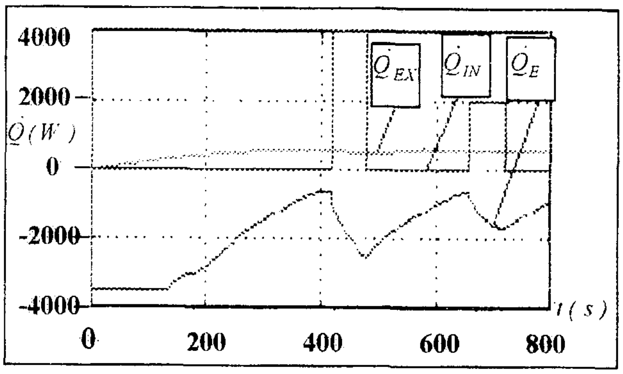


Figure 7b: Change of heat in air condition area

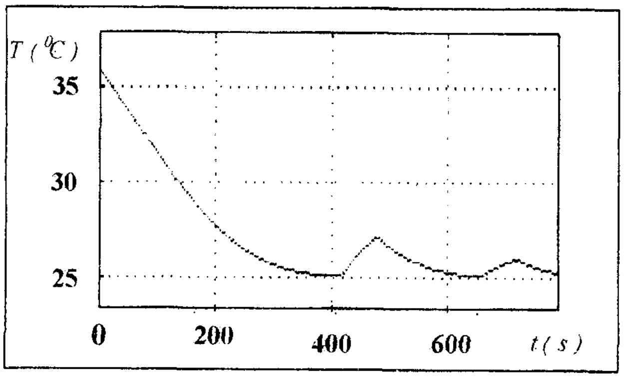


Figure 7c: Temperature control by Fuzzy Logic

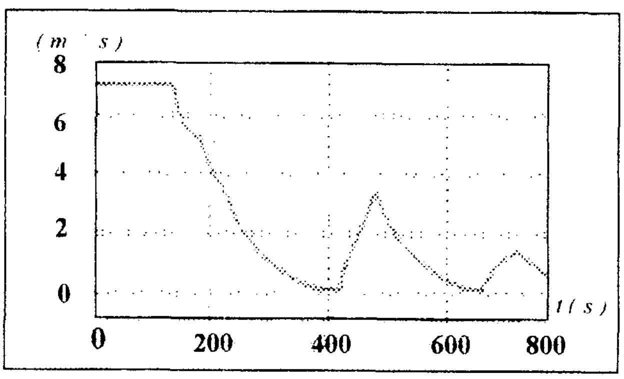


Figure 7d: Change of air velocity flow through evaporator

Figure 7a. shows the dynamic response of temperature control with the air velocity using fuzzy logic control or constant control. The temperature setpoint is 25 ^{0}C and the initial air condition area temperature was 36^{0}C , with no internal Cooling load. From the simulation , it was observed that the fuzzy logic control is able to give better initial temperature control in term faster dynamic response (Case level Low and Medium air velocity) . The temperature stabilized much faster under fuzzy control after the first 310 second , while the case low air velocity brought the super temperature to the set point after 495 second of simulation running time. [Line HIGHT = 255 second , MEDIUM = 325 second ,LOW = 490 second and FUZZY= 310 second]

Figure 7b. shows the system responds the dynamic response of heat from external ($\dot{Q}_{EX}$). The heater is turned on generate internal energy ($\dot{Q}_{IN}$) 4kW at 420 second and 2 kW at 660 second after the initial start of the simulation. The heater is turned on for 60 second each time. The simulation result also shown the evaporator absorbed heat ($\dot{Q}_{E}$), which was the response of a cooling load from internal and external.

Figure 7c. shows the dynamic response of room temperature control with air velocity under fuzzy logic control when the system change cooling load. Fuzzy control will correct problem by increate air velocity. Time of used in correct problem heat load internal 4 kW is170 second and 60 second for case 2 kW.

Figure 7d. shows dynamic response of air velocity flow through evaporator with fuzzy logic control, which was the effect from change cooling load in fig 7b.

6. CONCLUSION

This paper has discussed a new method of air flow control in fan coil unit using fuzzy logic control. The simulation of fuzzy control of room temperature using rate of air velocity through evaporator. The fuzzy control was able to give a robust of the temperature with respect to dynamic response during the pulldown of room temperature. Air velocity to be help to increase comfortable.

7. NOMENCLAURE

D_o	Outside diameter of copper tube , mm
T_{Amb}	Outside Temperature ,^{0}C
D_i	Inside diameter of copper tube , mm
V	Velocity , m/s
k_{AIR}	Thermal conductivity of air ,W/m.^{0}K
k_{Ins}	Thermal conductivity of insulation ,W/m.^{0}K
M	Mass of inside air , kg

8. REFERANCES

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