

Fuzzy Control Used in VAV System

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Abstract: Normal PID controller can't online adjust parameters, when object exists structure nonlinearity, parameter time-variation or model indeterminacy, it is more difficult in adjusting parameters, and optimal parameters are inclined to drift. This article uses VAV rooms as research objects, adopting fuzzy control and PID control to compose fuzzy self-adjustment PID controller, and makes use of parameters of PID controller with fuzzy controller online adjusting to process large numbers of emulate research, and further using in fact control.

Keywords: fuzzy control, fuzzy self-adjustment PID, simulating imitation

1. INTRODUCTION

Variable air volume (VAV) system makes up with chiller and hot unit, air handling unit, air damper and air duct, supply/return fans and air-conditioned rooms. Control system includes five parts:

- (1) Indoor temperature control, namely VAV terminal device;
- (2) Indoor positive pressure control, namely supply and return fans matching control;
- (3) Supply air static pressure control;
- (4) Supply air temperature control;
- (5) Amount of fresh air control.

Five parts are mutually independent and interactive again, every loop exist strong couple when one room's temperature drop, its air damper of terminal device will turn down followed. It will cause increase in supply air static pressure of main supply duct and other rooms' supply air rate. At this time, those rooms' air ducts of terminal device will turn down in order to hold their supply air rate. But this will cause increase in system static pressure once more. When value of system static pressure increase to one degree, static pressure controller will reduce rotate speed of supply air fan to fall air rate, and the air rate of return fan falls followed. So system static pressure goes back to primary degree, and every air damper of terminal device turns up again.

Because the change of system pressure certainly affect fresh air rate, supply air temperature will change, and controller has to adjust value lift of air fresh value, air exhaust value, air return value. Value position of the three values will bring about changing of system static pressure and flow rate. In this course, system is in the state of frequent adjusting. Air damper turn up at one time and turn down at the next time, and the same of air rate.^[1]

Therefore control requirement of VAV system is higher than constant air volume (CAV) system. It is difficult to build up one suitable project control maths model. Generally the systems' unable running or unable well running is by reason of uncomely control systems. VAV system is one strong disturb, high nonlinear complex system, so traditional PID control effect is not good. In the past a few years fuzzy logic control is applied to HVAC gradually, and gain more good effect than traditional PID control. This article discusses the fuzzy control applying to VAV terminal device.

2. FUZZY CONTROL THEORY

Fuzzy control is computer intellectual control basing with fuzzy set theory, fuzzy language variable and fuzzy logic consequence. Fuzzy maths is the base

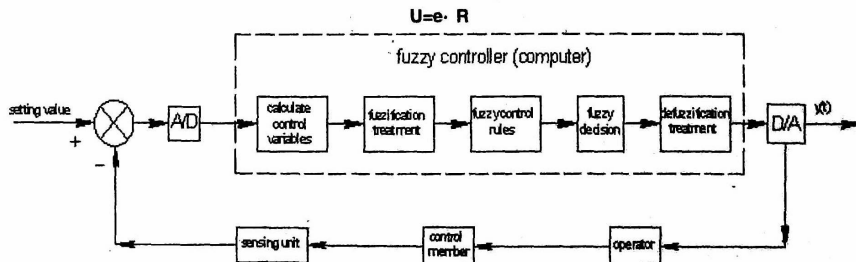


Figure 1: fundamental of fuzzy controller

of formula-based intellectual control. ^[2] Fig 1 is fundamental of fuzzy control system. Its core is fuzzy control unit. The rules of fuzzy control unit are actualized by computer program. Computer gains the accurate value through interrupt sampling, and then compare with setting value to gain error signal (E). Normally error signal (E) is used as import quantity. The accurate value of error signal (E) will be fuzzification and turn into fuzzy value. Fuzzy value of error (E) can be expressed by fuzzy language, which generate one sub-aggregate e (e is a fuzzy vector) of fuzzy language aggregate, and then doing fuzzy decision basing composition rules which is inferred by e and fuzzy control rules R (fuzzy operator). By this mean fuzzy control value (u) will be gain. ^[2]

3. DESIGN OF FUZZY CONTROL

3.1 The think of design

With the development of computer technique, technical personnel make use of artificial intelligence methods and take adjust experience as knowledge to save into computer. According to site practical situation, computer cans self-adjust PID parameters. This is the combination of classical PID and advanced expert control. Fuzzy self-adjust PID controller makes error (E) and error change (EC) as input, and can satisfy the requirements of self-adjust PID parameter asked by E and EC at differ time. Using fuzzy rules online amend PID parameters is self-adjustment fuzzy controller. Fuzzy self-adjustment PID controller composes with two parts, parameter adjustable PID controller and fuzzy controller (e.g., fig 2). Its device think is followed. Firstly, build up fuzzy relation between three parameters of PID control with E and EC, namely fuzzy rules. Than using E and EC as input variables, online amending PID parameter through fuzzy rules in order to satisfy the requirements of self-adjustment PID parameters asked by E and EC at differ time. In this system, the device core is fuzzy controller that because the quality of fuzzy controller directly affects the selection of K_p , K_i and K_d , accordingly influences the control system precision. ^[3]

The design of fuzzy controller contains contents as follows mainly:

(1) Confirm the input variables and output variables of fuzzy controller;

(2) Choose the domains of the input variables and output variables of fuzzy controller and confirm the parameters of fuzzy controller (e.g., quantization parameter, proportion parameter);

(3) Design the fuzzy rules of fuzzy controller;

(4) Confirm the method of fuzzification and defuzzification, i.e., the methods of fuzzy consequence and fuzzy calculation;

(5) Workout the practice program of fuzzy control algorithmic.

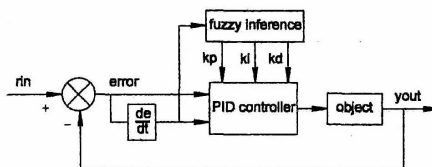


Figure 2: the structure of self-adjustment controller

3.2 The forming of fuzzy control table

3.2.1 Confirming of evaluate table of fuzzy variable.

When the fuzzy set and domain of fuzzy variable E (error), EC (error change), U (control value) are certain, we must setup membership function to fuzzy language variable, i.e., evaluate the fuzzy variable, it is to certain the membership of the elements in domain to fuzzy language variable.

3.2.2 Establishment of fuzzy control table

Fuzzy self-adjust PID is based on PID algorithmic, through calculating E (error), EC (error change) at the real time, it goes along fuzzy consequence using the fuzzy rules, goes along parameter adjustment by consulting matrix table. The core of fuzzy control design is summing up the engineer designer's knowledge and practice operation experience, establishing suitable fuzzy control rules table, so that getting the fuzzy control tables aiming at the adjustment of K_p , K_i , K_d apart.

(1) The fuzzy rules table of K_p

Δk_p EC E	NB	NM	NS	ZO	PS	PM	PB
NB	PB	PB	PM	PM	PS	ZO	ZO
NM	PB	PB	PM	PS	PS	ZO	ZO
NS	PM	PM	PM	PS	ZO	NS	NS
ZO	PM	PM	PS	ZO	NS	NM	NM
PS	PS	PS	ZO	NS	NS	NM	NM
PM	PS	ZO	NS	NM	NM	NM	NB
PB	ZO	ZO	NM	NM	NM	NB	NB

(2) The fuzzy rules table of Ki

Δkp \ EC E	NB	NM	NS	ZO	PS	PM	PB
NB	NB	NB	NM	NM	NS	ZO	ZO
NM	NB	NB	NM	NS	NS	ZO	ZO
NS	NB	NM	PM	NS	ZO	PS	PS
ZO	NM	NM	NS	ZO	PS	PM	PM
PS	NM	NS	ZO	PS	PS	PM	PB
PM	ZO	ZO	PS	NM	PM	PB	PB
PB	ZO	ZO	PS	PM	PM	PB	PB

(3) The fuzzy rules table of Kd

Δkp \ EC E	NB	NM	NS	ZO	PS	PM	PB
NB	PS	NS	NB	NB	NB	NM	ZO
NM	PS	NS	NB	NM	NM	NS	ZO
NS	ZO	NS	NM	NM	NS	NS	ZO
ZO	ZO	NS	NS	NS	NS	NS	ZO
PS	ZO	ZO	ZO	ZO	ZO	ZO	ZO
PM	PB	NS	PS	PS	PS	PS	PB
PB	PB	PM	PM	PM	PS	PS	PB

3.3 Defuzzification

When the fuzzy rules of Kp, Ki and Kd established, the self-adjustment of them could base the following method. System error E and error change of E-EC define as the domain on fuzzy set: E, EC={-5,-4,-3,-2-1,0,1,2,3,4,5}.

Fuzzy subset E, EC={NB, NM, NS, ZO, PS, PM, PB}, the elements in the subset represent {Negative Big, Negative Middle, Negative Small, Zero, Plus Big, Plus Middle, Plus Small}. If E, EC, Kp, Ki, Kd obey normal school, we could get the memberships of all fuzzy subsets. Basing on the membership evaluate table of all fuzzy subsets and all parameter fuzzy control models, using the fuzzy matrix table of fuzzy composing consequence designing PID parameter, we could get the modify values used in the following calculates:

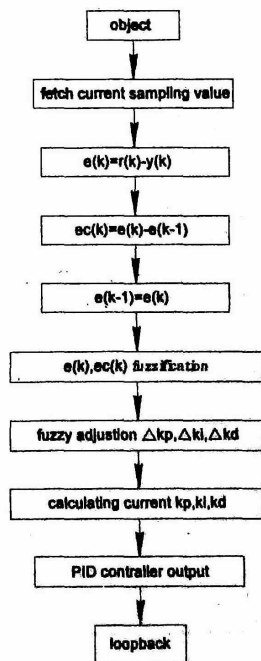
$$Kp=Kp'+[E, EC] p$$

$$Ki=Ki'+[E, EC] i$$

$$Kd=Kd'+[E, EC] d$$

In the process of online running, control system modifies the PID parameters online and automatically through the results of processing, consulting tables, calculating on fuzzy control rules. The flow chat shows in Figure 3.

Figure 3: online auto-modifying workflow graph



3.4 Analysis of simulation results

The conditions of simulation:

(1) VAV Box is composed by 4-6 bisect vanes, forming a throttle adjustable air door, its adjust range is 100%~10%;

(2) The air conditioning room used in simulation is 30 m²; the heat volume of heat retainer is 400 kJ/ °C;

(3) The refer temperature of indoor is 26 °C, the temperature of supply air in VAV Box is 18°C, the load of indoor is 5kW.

At one moment we throw a disturb difference in temperature of + 2 °C to the room, and we could get the change course of VAV Box air damper opening degree as showing in Figure 4. At the same time, we could do some research in VAV Box air damper using PID control, at the same conditions, we get the control curve, showing by the dashed line in Figure 4.

We could get the following from Figure 4, the change range of air damper opening degree is smaller using fuzzy control than PID control, fuzzy control could follow the change of temperature in real time, its ability of adaptation to the unsureness of model is better. In practice, we could modify the control table based on the results of running.

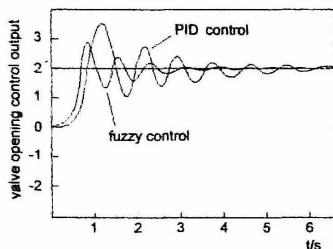


Figure 4: VAV terminal air damper control output

4. CONCLUSION

In this article, fuzzy Self-adjustment PID Controller includes the advantages of PID control and fuzzy control, which can adjust PID parameters online. Comparing with normal PID temperature control system, fuzzy Self-adjustment PID Controller not only has better control accuracy and the capacity of adaptation of controlled plant model, but also has simpler structure. This can reduce computation and implement project easily. Simulation experiment reduces the blind engineering practice, and provides theories for designing and setting up practice temperature controller.

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