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CONTROL OF AIR-CONDITIONER WITH INVERTER USING EVAPORATING PRESSURE AS MIDDLE-TARGET VIA FUZZY METHOD

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ABSTRACT

In this paper, a control method for inverter air conditioner is presented, which is to use evaporating pressure as middle-target via fuzzy method. It is a method to control in cascade stage. Simulation results of performance of the control method, comparing with a traditional fuzzy method, were obtained.

Key words: inverter air conditioner, middle-target, fuzzy control, evaporating pressure

INTRODUCTION

Inverter air-conditioners are used widely, because of its advantages of saving energy and comfort. The control method is the emphasis for the research. At present, their control method in fashion is fuzzy method, which decides the rotational speed of the compressor directly by the deviation between the room's temperature and the setting temperature (it represents load). But there is a disadvantage in the control method, which hasn't considered the dynamical characteristics of the air-conditioner systems. An air-conditioner system has different time delays according to different conditions. This disadvantage will result in a longer transitional time and a bigger overshooting. Then a middle-target for control is needed, which can not only reflect the load of the room but also represent the dynamical characteristics of the air-conditioner. It is the evaporating pressure (which is can be represented by the suction pressure). In this paper, a set of fuzzy control method is put forward, which is to control the evaporating pressure as middle-target for controlling the room's temperature. The simulation about the control method is carried, its results are compared with the simulation results of a fuzzy control method. The simulation is based on lumped parameter mathematical models.

MODELING

In this paper, the dynamical simulation is based on lumped parameter mathematical models, which are include the condenser, the evaporator, the inverter compressor, the electric expansion valve and the room. The frequency of the compressor is from 25 Hz to 80 Hz. The delay time of the room is 40 seconds. The sampling period for control is selected as 4 seconds, which is the result of simulation[1][2].

CONTROL METHOD

1. Effects of Controlling the Evaporating Pressure

When the evaporator of an air-conditioner absorbing heat, there are two important processes of heat transfer, they are inside the tube and outside the tube.

Inside the tube: $Q = G * q$

(In the equation, Q is the cooling capacity, G is the amount of refrigerant flow, q is the refrigerating capacity of per unit refrigerant).

Outside the tube: $Q = \alpha * (t_{air} - t_{tube})$

(In the equation, α is the coefficient of heat transfer, t_{air} is the average temperature of the air, t_{tube} is the average temperature of the wall of the tube).

When the speed of fan is constant, the Q is decided by the t_{tube} directly. And the evaporating pressure decides the t_{tube} when the superheat degree is unchanged. So it is important for the system to control the evaporating pressure when the air conditioner cooling. In an air-conditioner system, the evaporating pressure can be controlled via adjusting the rotational speed of the compressor.

2. Control strategy

The strategy is of variable structure. In the strategy, the sampling period is 4 seconds. In this paper, the superheat degree is maintained at 3℃ by an electric expansion valve independently.

(1) When the room temperature is two degrees higher than the setting temperature, the compressor runs at the highest frequency so that the temperature can reach the range of the setting temperature as soon as possible.
(2) When the room temperature is two degrees lower than the setting temperature, the compressor stops.
(3) When the room temperature is in the range of ±2℃ around the setting temperature, the control method is converted to the method of using evaporating pressure as middle-target via fuzzy method (it is named FUZ-P method for short in the paper). The method put forward is to control the evaporating pressure as the middle-target for controlling the room's temperature. In the method, the load of the room is represented by two input values, the deviation between the room temperature and the setting temperature (e) and the mutation rate of the deviation (Δe). According to e and Δe, an output (**u**) can be got by checking a control table, the table is calculated out via a fuzzy algorithm, **u** is corresponding to the temperature deviation needed for heat transfer. The deviation is subtracted from the room's indoor temperature, then the result is the setting evaporating temperature. The setting evaporating pressure corresponds to the setting evaporating

temperature from the refrigerant property, and the setting pressure is the final output of the fuzzy reasoning. The aim for control is reset every four periods via the fuzzy algorithm. Then control the suction pressure according to the setting pressure by the compressor in the following four periods, and the definite action is decided via a PI control method after each sample.

Fig.1 shows the block diagram of the control method using evaporating pressure as the middle-target via fuzzy method (FUZ-P method), which is a principle of controlling in cascade stage. It uses the evaporating pressure as the middle-target so that the contradiction, which is caused by the deferent dynamical characteristics of the room object and the air-conditioner system, is solved well. Since the inner ring has the capacity of compensating disturbances quickly, a lot of disturbances can be compensated in the inner ring before they reach the outer loop. The method is good in holding the room temperature steadily.

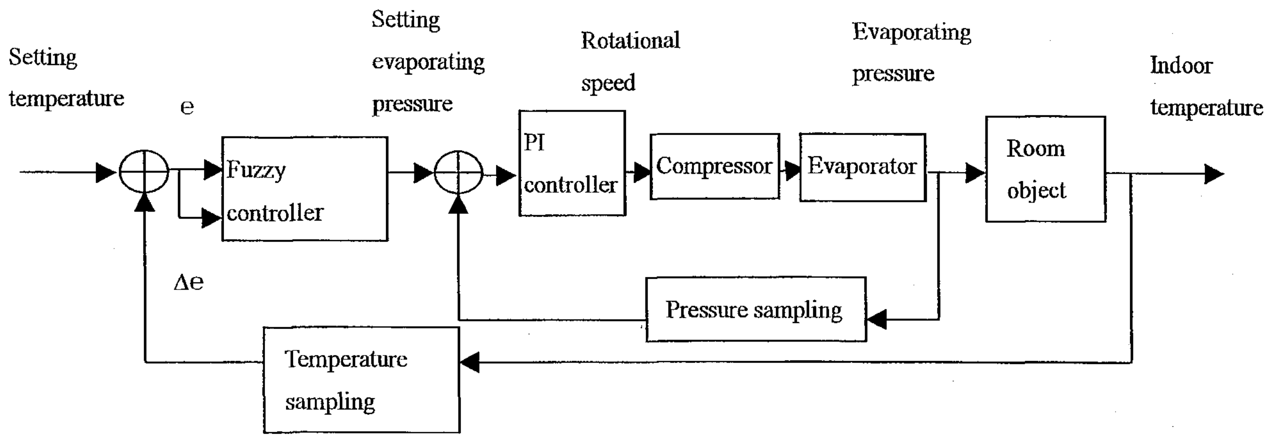

Fig. 1 The block diagram of control

The key of the FUZ-P method is to decide the temperature deviation needed for heat transfer, then the appropriate setting evaporating pressure can be got.

3. Fuzzy Reasoning

In the paper, e and Δe are fuzzified to fuzzy quantity by the algorithm of transferring intensity. The algorithm of the biggest degree of dependence generates the output (**u**).

e is in the range of -2℃~+2℃, Δe is in the range of −1.6℃/min~+1.6℃/min, these two physical values are both quantified to the integers from −6 to +6. The values correspond to each other in linearity from the universe of physics to the universe of integer. Eight fuzzy subsets NL, NM, NS, NO, PO, PS, PM, PL are defined for the input universe of discourse. Their membership functions are shown in table 1. Seven fuzzy subsets NL, NM, NS, O, PS, PM, PL are defined for the output universe of discourse. Their membership functions are shown in table 2. The control rules are described in table 3.

As below, table 1, 2, 3 are the basis of the fuzzy reasoning.

Table 1 Membership functions of the inputs

e &Δe	−6	−5	−4	−3	−2	−1	−0	+0	+1	+2	+3	+4	+5	+6
PL	0	0	0	0	0	0	0	0	0	0	0.1	0.4	0.8	1.0
PM	0	0	0	0	0	0	0	0	0	0.2	0.7	1.0	0.7	0.2
PS	0	0	0	0	0	0	0	0.3	0.8	1.0	0.5	0.1	0	0
PO	0	0	0	0	0	0	0	1.0	0.6	0.1	0	0	0	0
NO	0	0	0	0	0.1	0.6	1.0	0	0	0	0	0	0	0
NS	0	0	0.1	0.5	1.0	0.8	0.3	0	0	0	0	0	0	0
NM	0.2	0.7	1.0	0.7	0.2	0	0	0	0	0	0	0	0	0
NL	1.0	0.8	0.4	0.1	0	0	0	0	0	0	0	0	0	0

Table 2 Membership functions of the outputs

u	−7	−6	−5	−4	−3	−2	−1	0	+1	+2	+3	+4	+5	+6	+7
PL	0	0	0	0	0	0	0	0	0	0	0	0.1	0.4	0.8	1.0
PM	0	0	0	0	0	0	0	0	0	0.2	0.7	1.0	0.7	0.2	0
PS	0	0	0	0	0	0	0	0.4	1.0	0.8	0.4	0.1	0	0	0
0	0	0	0	0	0	0	0.5	1.0	0.5	0	0	0	0	0	0
NS	0	0	0	0.1	0.4	0.8	1.0	0.4	0	0	0	0	0	0	0
NM	0	0.2	0.7	1.0	0.7	0.2	0	0	0	0	0	0	0	0	0
NL	1.0	0.8	0.4	0.1	0	0	0	0	0	0	0	0	0	0	0

Table3 control rules

u		Δe							
		NL	NM	NS	NO	PO	PS	PM	PL
	NL	NL	NL	NM	NM	NM	NS	0	0
	NM	NL	NM	NS	NS	NS	0	PS	PM
	NS	NL	NM	NS	NS	NS	0	PM	PL
e	0	NL	NM	NS	0	0	PS	PM	PL
	PS	NL	NM	0	PS	PS	PS	PM	PL
	PM	NM	NS	0	PS	PS	PS	PM	PL
	PL	0	0	PS	PM	PM	PM	PL	PL

Then the control table is generated, in which two inputs correspond to one output.

Table 4 control table (corresponding between inputs and output)

u		Δe												
		−6	−5	−4	−3	−2	−1	0	+1	+2	+3	+4	+5	+6
e	−6	−7	−7	−7	−7	−7	−7	−7	−7	−7	−4	−4	0	0
	−5	−7	−7	−7	−5	−5	−5	−5	−5	−4	−4	−1	0	0
	−4	−7	−7	−5	−4	−4	−4	−4	−4	−4	−4	−1	0	0
	−3	−7	−4	−4	−4	−4	−4	−4	−4	−4	0	0	0	0
	−2	−4	−4	−1	−1	−1	−1	−1	0	0	0	0	1	1
	−1	−4	−4	−1	−1	−1	−1	−1	0	0	1	1	1	1
	+0	−4	−4	−1	−1	−1	−1	0	1	1	1	1	1	4

−0	−4	−1	−1	−1	−1	−1	0	1	1	1	1	4	4
+1	−1	−1	−1	−1	0	0	1	1	1	1	1	4	4
+2	−1	−1	0	0	0	0	1	1	1	1	1	4	4
+3	0	0	0	0	4	4	4	4	4	4	4	4	7
+4	0	0	1	4	4	4	4	4	4	4	5	7	7
+5	0	0	1	4	4	5	5	5	5	5	7	7	7
+6	0	0	4	4	7	7	7	7	7	7	7	7	7

The method of qualification for the output (discourse universe of **u** corresponding to the temperature deviation needed for heat transfer.) is shown in figure 2. It is a result of simulation.

From figure2, the definite setting value of temperature deviation for heat transfer is got. Then subtract the deviation from the room's indoor temperature in real time, the result is the setting evaporating temperature, then the setting evaporating pressure is got.

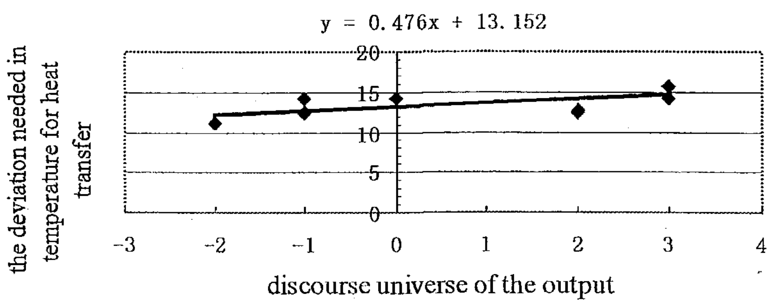

Fig.2 corresponding relation

RESULTS AND DISCUSSIONS

Because the FUZ-P method in this paper is put forward aiming at the limitation of the traditional fuzzy control method, the FUZ-P method is compared by a traditional fuzzy method (it is named FUZ method for short in the paper) on the basis of simulation. The two methods both use the method of checking the control table. The quantification of inputs and the fuzzy reasoning processes are the same for these two methods, but the final output of the FUZ's reasoning is the rotational speed of the compressor, its control action is decided after each sample, the sampling period is 4 seconds. The final output of the FUZ-P's reasoning is the setting evaporating pressure, then control the evaporating pressure according to the value via PI method by the compressor, the control action is decided after each sampling period of 4 seconds too, but the setting evaporating pressure is reset every 4 periods. For the PI method, the proportion constant is 2.75, and the integral constant is 2.75, which are decided by simulations. The simulations for comparison are carried under 4 different operating modes. Described as below:

1. Running with the Indoor Load Unchanged

condition 1: the indoor load is 1800W, the initial temperature of the room is 32℃, the outdoor temperature is 32℃, the setting temperature is 27℃. The air conditioner runs for 4 hours. The delay time of the room is 40 seconds. Figure 3 shows the curve of cooling under the operating mode.

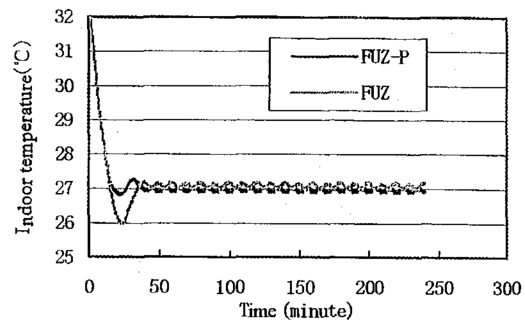

Fig.3 Running with the indoor load unchanged

From the figure 3, we can know FUZ-P and FUZ have the same speed of cooling. But the FUZ-P method has the better control precision, less overshooting, faster speed of getting equilibrium. The definite performance is listed in table 5.

Table 5 performance comparing between FUZ-P and FUZ methods

	overshooting (%)	Transitional time (min)	Temperature fluctuation (℃)
FUZ-P	5. 54	33	±0. 12
FUZ	20. 48	39	±0. 2

2. Running with the Indoor Load Changed

Running with the load step-changed can be used to evaluate the capacity of adapting to the varied load for an air-conditioner.

Condition 2: the initial conditions are the same as condition 1. The air conditioner runs for 4 hours, after 100 minutes, the load is step-changed from 1800W to 2500W. The results are described as figure 4. From figure 4 we can know , after the indoor load is changed , the air conditioner using FUZ-P method responds quickly and reaches the equilibrium faster, the varied load doesn't result in a worse precision, which is ±0.12 ℃ yet, for the method uses the evaporating pressure as the middle-target, which can pursue the changing of the load quickly. But the FUZ method hasn't considered about the dynamical characteristics of the air conditioner system, and it gets worse control result. Its precision becomes worse too, from ±0.2 ℃ to ±0.3 ℃. These prove that FUZ's capacity of adapting to the varied load is worse than FUZ-P's.

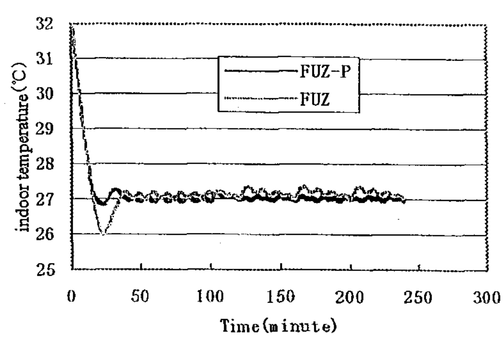

Fig.4 Running with the indoor load changed

3. Running with the Setting temperature Step-changed.

It is important to get a good control effect after the setting indoor temperature being changed, according to a good control method.

Condition 3: the initial conditions are the same as condition 1. After the air conditioner runs for 100 minutes, the setting indoor temperature is changed from 27℃ to 26℃. The result of simulation is described as figure 5. Figure 5 indicates, FUZ-P method gets the more placid transition than FUZ, and there is not any overshooting nearly, its control precision is unchanged (±0.12 ℃). But FUZ method gets a worse control precision, from ±0.2 ℃ to ±0.3 ℃. These prove that its capacity of adapting to the varied setting indoor temperature is worse than FUZ-P's.

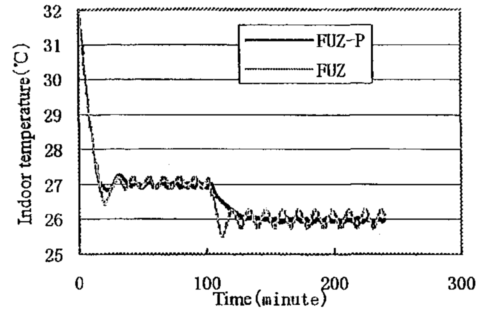

Fig.5 Running with the setting temperature step-changed

4. Running with the Room Object Changed

It is impossible to know all the rooms' dynamical characteristics. So a good control method needs a good adaptability for all kinds of room objects.

Condition 4: the initial conditions are the same as condition 1, however, the delay time of the room is changed from 40 seconds to 20 seconds. The result of figure 6 indicates, both the control methods can adapt to the change of the room object. But FUZ-P method has the better adaptability than FUZ, because the method's ability of controlling the system is improved via using the evaporating pressure as the middle-target.

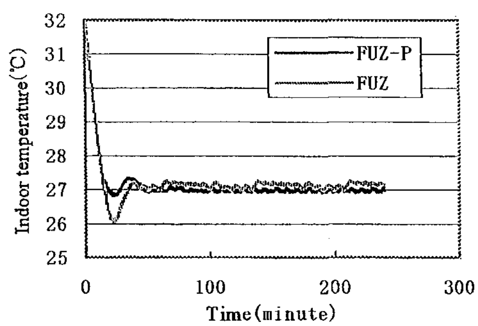

Fig.6 Running when the room object changed

CONCLUSION

The control method of using evaporating pressure as middle-target is a control method by controlling the evaporating pressure. The method considers about the different characteristics of the room and the air conditioner. By using the evaporating pressure as middle-target, the ability of controlling the whole system is improved, then the dynamical response and the precision of controlling can be guaranteed to reach a precise range. The results of the simulations prove the FUZ-P method has the better capacity of adapting to different loads, setting indoor temperatures, and room objects.

On the other hand, the set of control method is important for multi-system air conditioners. In a multi-system air-conditioner, the loads and the setting indoor temperatures of different rooms are different. If the traditional fuzzy control method is applied, it will become too complicated to be feasible. However, in the multi-system air-conditioner, the suction pressure is the only one, so the control method of FUZ-P will be effective for controlling multi-system air-conditioners.

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