Research of room temperature for inverter air conditioner based on Fuzzy Neural Network Control

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Abstract. The indoor temperature control process in air-conditioned room is a multiple-input multiple-output (MIMO), nonlinear and time-delay system. Whereas the traditional off-on control methods, traditional PID control and conventional fuzzy control, exist some advantages and disadvantages, so this paper has provided the fuzzy neural network control modality to improve the current control approaches. Analysis on the simulation of the model as mentioned above is established, and simulation results show that the fuzzy neural network control has a series of positive qualities such as rapidity, good stability and strong anti-interference, so as to achieve a good temperature regulation in inverter air conditioner rooms.

1. FOREWORD

With the development of society, the component of inverter air conditioner market has claimed an ever-growing in the market. Therefore, the research of the inverter air conditioner is becoming more and more significant. The new inverter air conditioner standard was promulgated on June 1, 2013, the threshold of inverter air conditioner energy efficiency limit has increased to 3.9, the energy consumption lower of inverter air conditioning become a focus point for each manufacturer and universities.

At present, the inverter air conditioner control mainly based on PID control. Under the accurate mathematical model, to some extent, with its simple structure, good stability, reliable operation, easy to adjust, PID can make accurate control come true. But, the model is difficult to be constructed, with large lag, nonlinear, time-varying complex characteristics of air conditioning refrigeration system control object, and it makes it difficult to achieve ideal control effect for traditional PID.

Fuzzy control system has advantages of quicker response, smaller overshoot and less sensitive to parameter variations. It relies on the language rules by expert control experience, so it shows good robustness and more effective for the nonlinear and complex controlled member. The neural network has the characteristics of self-organizing, adaptive, self-learning, it solves the problems depended on experts of the conventional fuzzy air conditioning temperature control mutation, membership function and fuzzy control rules. If combining the fuzzy control with neural network as the air conditioning temperature control, not only solved the puzzle of controlled member by the difficulty to precisely define its mathematical model, but also solved the puzzle of fuzzy control moderate depended on expert experience too much. And it makes the control system of autonomous learning ability realize intelligent control

2. LINK ANALYSIS

Air conditioning system is mainly composed of control system and cooling system. In the process of the control of the air conditioner, the controller is control system, actuator is complex refrigeration system, the controlled member is room, feedback element is a temperature sensor, the set target temperature of the air conditioner is the goal. Figure 1 shows air conditioner control system schematic diagram.

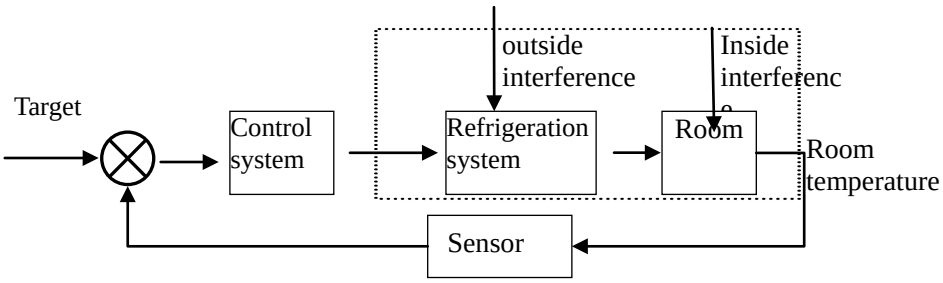

Figure 1 Air conditioner control system diagram

In the separate simulation research of air conditioning system of control system, we should set up the precise mathematical model like the above 1- links contained dotted box. But the room temperature is affected by the room size, window size, indoor heat source heat, personnel entering and leaving, wall insulation, direct sunlight and so on. So it is very difficult to build precise mathematical model. This paper is based on related articles and some assumptions, using the lumped parameter method to establish the mathematical model and the Laplace transform and first-order inertia link with delay, and establishing a mail function relation between the indoor temperature change and the frequency of compressor, and it is as follows:

$$G_{(s)} = \frac{T(s)}{f(s)} = \frac{K_0 e^{-\tau s}}{T_0 s + 1} = \frac{0.4 e^{-60 s}}{1800 s + 1} \qquad (1)$$

where, *T (s)* for the temperature change; *f (s)* is the frequency of the compressor； ; K_0 represents a gain; T_0 is the time constant; τ is delay time.

3. DESIGN FUZZY CONTROLLER

3.1 Fuzzification

The inputs of the fuzzy controller are temperature deviation e (the difference between the current indoor temperature and the target temperature) and the rate of change of the temperature deviation ec (temperature deviation change rate of time). When people introduce the basic domain of the input of fuzzy controller in most of the literatures and textbooks, they almost give the basic domain in the form of opposite number such as [-m, m].But in the actual room temperature control process of the inverter air conditioner, it is generally either from a fall or from rise to the target. When actual output largely deviates from the target value, we hope it is faster to reach the target; when the actual output is close to the target, we hope that it keeps a stable target. The advantage of doing this is that it can both meet the requirement of the rapid control and achieve a good steady-state performance in the process.

In China, the target temperature range of the indoor air conditioning is generally set between 16 ℃ ~ 32 ℃, and our country has not yet set up detailedly concerned regulations on the subject that at what temperature during summer and winter seasons we can open air conditioning. However, there exists express provision, namely, in the units in all public buildings, the summer indoor air temperature is not less than 26 ℃, and the winter indoor air temperature is no higher than 20 ℃. In this paper, as to the summer cooling, the basic domain of the temperature deviation e and the temperature deviation change rate ec are respectively taken for [-3,10] ℃ and [-3,3] ℃ / min. The corresponding domain of fuzzy sets are both expressed as [3,3], and the corresponding vague language can be expressed like this, namely {NB, NM, NS, ZO, PS , PM, PB}. The quantitative factors of e and ec are respectively ke=0.5、kec=1,. Fuzzy membership functions corresponding language is taken as a combined form of a triangle and trapezoid, NB and PB were taken up half down the ladder and board the ladder, and the others are triangles. Its membership function graph below:

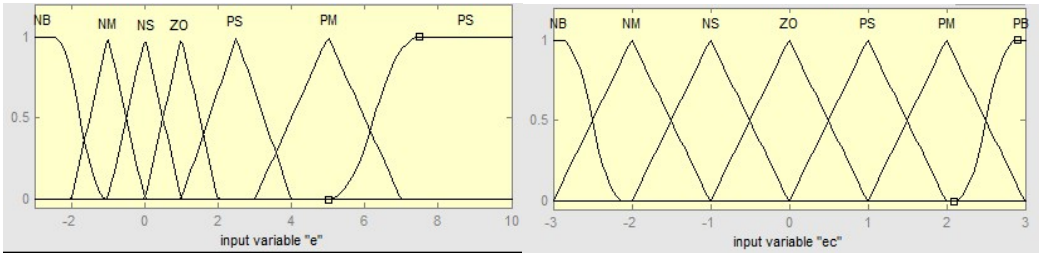

Figure 2 e and ec of the membership function curve distribution

3.2 Fuzzy Reasoning

Fuzzy reasoning is the formation of fuzzy control rules, which is the core of fuzzy control. In this paper, Mamdani inference method is used, and the rule is: "if ... and ... then ..." form, a total of 7 × 7 = 49 fuzzy rules.

3.3 Defuzzification

Fuzzy controller output u is the corresponding operation frequency of the compressor. Scope of the current inverter air conditioner operating frequency is substantially 20~120 Hz. Although manufacturers, like Gree, Midea and others, have introduced inverter air conditioner whose operating frequency can reach as low as 1 Hz, it is not considered here. So the basic domain of the output u is [20,120] Hz, and the corresponding fuzzy set theory domain is [3,3], and the corresponding fuzzy language is { NB,NM, NS, ZO, PS, PM, PB}. The membership functions corresponds to the fuzzy language are: NB and PB were taken up half down the ladder and board trapezoid, triangle others have taken. In this paper, center of gravity is taken for the defuzzification process, and the scale factor is ku=16.7.

4. NEURAL NETWORK LEARNING

Based fuzzy control and application of neural network learning, decision-making process to achieve fuzzy control. Its purpose is to optimize the fuzzy rules use of neural network learning method. Make the fuzzy rule is a smart and flexible rules table after learning, rather than relying on the expertise invariably stored computer after prior summary decisions. Fuzzy neural network control model diagram shown in Figure 3 established.

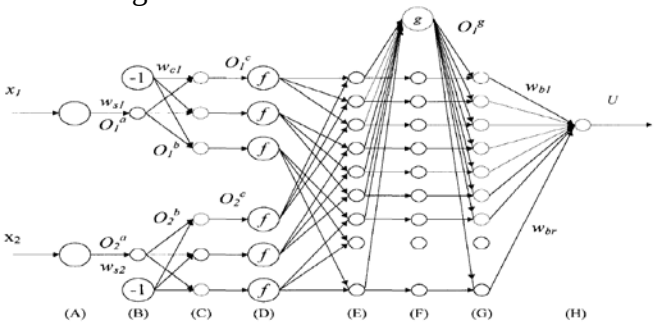

Figure 3 Fuzzy neural network control model

Fuzzy Neural Network need to be learned, mainly including central value and width witch attach to function, besides weight comes from the first layer and the last layer. It adopts the method of error back propagation algorithm to change connective weights of network, thus, to realize the process of autonomous learning. The error function is defined as this:

$$E=\frac{1}{2}\sum_{i=1}^{m}(y_{di}-y_i)^2 \qquad (2)$$

Where, m is the samples number of learning, y_{di} is the target temperature, y_i is the current room temperature.

Network connection weights adjustment formula:

$$w(k+1)=w(k)+\eta\left(-\frac{\partial E}{\partial w}\right)+\alpha\left[w(k)-w(k-1)\right] \qquad (3)$$

where η is the learning rates, η>0； α is the smoothing factor, 0<α<1.

5. BUILDING SIMULATION MODELB

Using the fuzzy toolbox under MATLZB to design fuzzy controller, saving the designed fuzzy controller, and then entering fuzzy = readfis ('fuzzy.fis') in MATLZB's work space for reading fuzzy controller using in simulation model. When to emulate, set the indoor initial temperature for 36 ℃, latency links for 60s, simulation time for 1500s, fixed step for 1s. The established structure of fuzzy neural networks simulation model as shown in Figure 4.

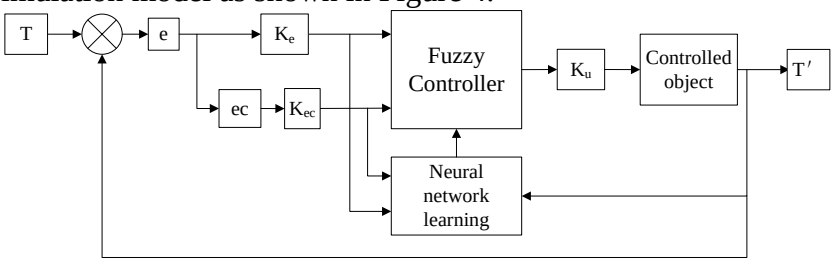

Figure 4 Fuzzy neural network simulation model structure diagram

6. RESULTS ANALYSIS

To validate the superiority of the established control system model, the paper respectively use PID control algorithm, fuzzy control algorithm and fuzzy neural network control algorithm to simulate in the MATLZB environmental conditions, and the simulation time is 1500s. Figure 5 shows the comparison diagram of optimal results from three control algorithms after the simulation.

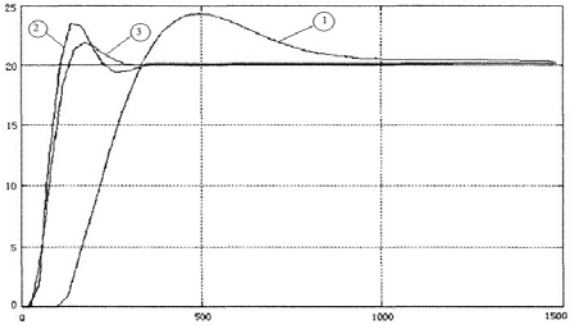

Figure 5 Comparison chart of simulation results from three control algorithm

As shown in figure above , ① is simulation results of PID control algorithm, ② is simulation results of fuzzy control algorithm, ③ is fuzzy neural network control algorithm. According to the simulation results, PID control results are rather dependent on the accuracy of the controlled object model. Considering the different room model and the same set of PID parameters, the simulation results vary widely. the different models of the room, the same set of PID parameters simulation results vary widely. In addition, PID control overshoot amount is larger, and the response speed is slow. Fuzzy Control on the reaction rate has improved to some extent, but the overshoot is still large. What's more, for the control effect of fuzzy control largely depends on the expertise, so it can't realize the adaptive regulation. In both response speed and the amounts of overshoot, ③ curve it is better than PID control and fuzzy control methods. Therefore, a fuzzy neural network method shows several advantages on the room temperature control in the frequency conversion air conditioning, and can realize the stable, rapid and accurate control on the system. But the fuzzy neural network control theory is far from mature, especially on the online learning algorithms, fuzzy rules optimization, system design optimization and other aspects remains to do more further researches.

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