Simulation and Design of Fuzzy Temperature Control for Heating and Cooling Water System

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Abstract

A computer simulation model has been suggested for temperature controlling of heating and cooling water System. The objective of this paper is to find a suitable solution by designing the intelligent controller for temperature controlling of heating and cooling Water system, such as fuzzy logic and to investigate the controllability of this model under various changes of temperature. In fuzzy logic control, Mamdani model is used to control the system. The suggested system uses the concept of fuzzy logic system where the fuzzy rule base consists of a collection of fuzzy IF–THEN rules. The fuzzy inference engine uses these fuzzy IF–THEN rules to determine a mapping from fuzzy sets in the input universe of discourse to fuzzy sets in the output universe of discourse based on fuzzy logic principles. The results illustrated the ability and robustness of the suggested system for temperature controlling.

Keywords: *Simulation, Temperature Control and Fuzzy Logic*

1. Introduction

Computer simulation models are widely being used in problem solving and decision making [1]. In this paper a simulation model was used for temperature control. The temperature control of conditioning system is very complex system, because of the nonlinearities and uncertainties of a system [2]. There are many modes to regulate the temperature like, ON/OFF, proportional derivative (PD) and proportional integral derivative (PID) [3]. On late fuzzy logic control (FLC) has become very popular over the conventional control logic (CCL), mainly the process of FLC is simply to put the realization of human control strategy, where CCL heavily relies on the mathematical formulations [3, 4]. The motivation behind this research is to find an improved method and a new technique of control by exploring the fuzzy system in the area of temperature control.

There are many papers addressed the fuzzy control in the temperature control system. Othman et al. utilized the fuzzy logic control for non linear car air conditioning [2]. Mongkolwongrojn et al. chose Implementation of Fuzzy Logic Control for Air Conditioning Systems [5]. Nasution presented a development of fuzzy logic control for vehicle air conditioning system [6]. Wang et al. showed an adaptive two-stage fuzzy temperature control for an electro heat system [7]. Alipoor et al. provided a fuzzy temperature control in a batch polymerization reactor using ANFIS method [8].

In this paper, we first illustrate the configuration of the central air conditioning system. Then, we introduce control process and components of it, after that fuzzy logic control. Finally, some simulation results and the algorithm of control system are presented.

2. SYSTEM CONFIGURATION

2.1. Central Air Conditioning System

This system is used to serve one area. Figure 1. shows the main components of central air conditioning system, as the following [9, 10]:

1- One air blower.
2- One water chiller unit.
3- One water boiler unit.
4- One cooling tower for cooling condenser of chiller unit.
5- Pumps recycling water.

The airflow can be designed with low, medium or high pressure according to system requirements.

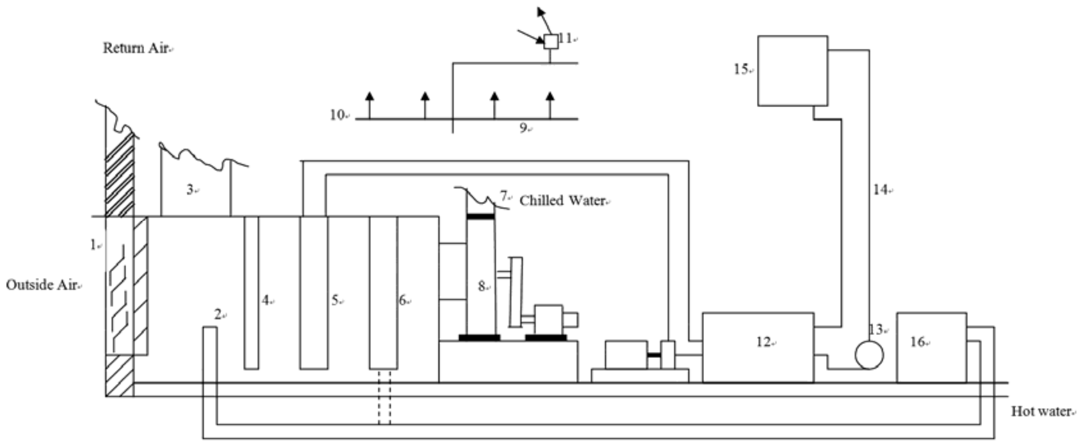
2.2. Pipes system

It is closed pipes system. The pumps are recycling the water in the coils of heating or cooling, the hot water for winter and cold water for summer. The essence of pipes system is to connect the air conditioning units with water chiller or water boiler while the pumps recycle the water. Pipes system of water chiller and water boiler may consist of two or four pipes according to system requirements [9, 10].

2.3. Valves

The conditioning pipes system consists of two types of valves as following [9, 10]:

1- Cut off the coil supply from cooling and heating media or connecting it with main resource of media (cold or hot water).
2- Regulating the streaming amount of conditioning media (water) in the pipes (conditioning coils)



1- Outside Air
2- Pre heating
3- Return Air
4- Filter
5- cooling coil and dehumidifying
6- Post heating
7- Air Supply Unit
8- Fan
9- Airflow System
10- Air conditioned Area
11- Temperature Sensor
12- Chiller Water
13- Water Pump
14- Water Pipes
15- Cooling Tower
16- Water Boiler

Figure 1. Block diagram of Central air conditioning syste

3. Control Process

As mentioned from system configuration, the control process must execute the following steps:

1- Operating of water boiler and connecting the pipes system with hot water in winter.
2- Operating of water chiller and connecting the pipes system with cold water in summer.
3- Regulating the water streaming through the system to obtain different degrees of heating and cooling.
4- Stopping the conditioning system.

3.1. Components of control system

1- Actuator of water boiler
2- Actuator of water chiller
3- Valve to change between hot water at winter and cold water at summer, according to conditioning system (heating / cooling)
4- Valve actuator to regulate the water streaming through the pipes system.
5- Sensor to read the temperature.
6- Control system program.

4. Fuzzy Logic Control

In Fuzzy control, two inputs for the system are chosen, namely the temperature (T) and a change of temperature (CHT). The temperature is read from sensor and the change of temperature by taking the difference between the current temperature and desired temperature ($25C^{\circ}$). The output of the system is a streaming water ratio (O) that is sent to micro controller of a servo motor to control the valve. The negative of O value determines the type of conditioning is heating and the positive for cooling. The Mamdani model is used in the system, which is the most commonly seen inference method. The Mamdani model is intuitive, it has widespread acceptance and it is well suited to human input so it is popular for control problems, in particular for dynamic nonlinear systems [11].

The steps of fuzzy logic control for conditioning system are:

1- Set the base-rules inference system from the linguistic description of expert.
2- Set the membership functions and fuzzy sets of inputs and output depending on the description of previous point and experience of control system designer.
3- Steps of the fuzzification process, inputs matching and defuzzification. The outputs will represent the control actions.

4.1.Rules Base Inference System

The linguistic description of expert can be set as rules (IF…THEN). These rules of control system can be written as following:

IF the temperature is mild and the change of temperature is zero THEN the conditioning system must be stopped.

IF the temperature is mild and the change of temperature is big positive THEN the cold water streaming must be increased (Normal Cooling).

IF the temperature is cold and the change of temperature is zero THEN the hot water streaming must be increased (Normal Heating).

The other rules can be written in the same manner.

4.2. Design of Membership Functions

There are many type of membership function (Gaussian, Triangular...). Choosing the appropriate membership function depends on the required application, the expert of control system designer and linguistic description of system actuator. The triangular form of membership function is the most common, computational efficiency and has been used extensively [12, 13]. So it will be used in this work. Figures 2- 4 show the designing of membership functions and fuzzy sets for conditioning control system.

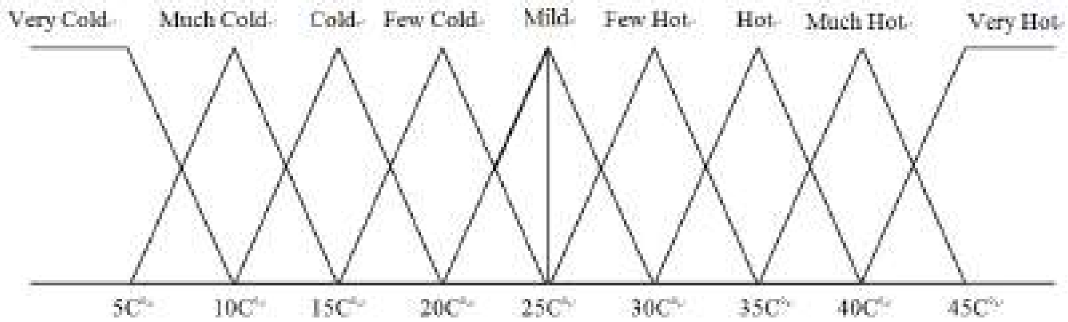


Figure 2. Temperature Membership Functions

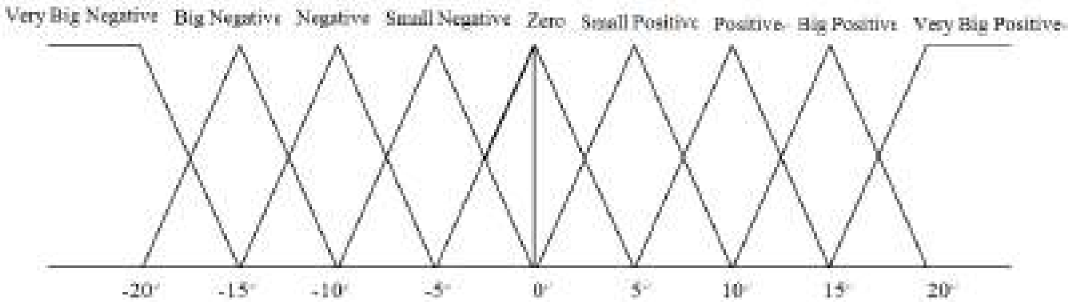


Figure 3. Membership Functions of Temperature Changing

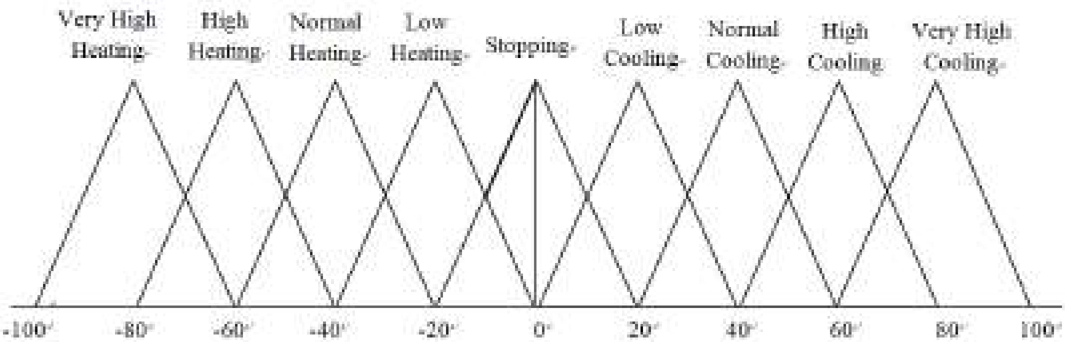


Figure 4. Membership Functions of Water Streaming ratio in pipes system and corresponding conditioning

For easily we can set numbers represent the expert linguistic description and fuzzy sets as shown in table 1.

Table 1. Values represent the linguistic description

Temperature	Temperature Change	Conditioning Type	Value
Very Cold	Very Big Negative	Very High Heating	-4
Much Cold	Big Negative	High Heating	-3
Cold	Negative	Normal Heating	-2
Few Cold	Small Negative	Low Heating	-1
Mild	Zero	Stopping Conditioning System	0
Few Hot	Small Positive	Low Cooling	1
Hot	Positive	Normal Cooling	2
Much Hot	Big Positive	High Cooling	3
Very Hot	Very Big Positive	Very High Cooling	4

From the values of table 1. and IF…THEN rules that have been set before from expert, the all rules mapping can be set as shown in table 2.

Table 2. Rules mapping represents all rules of conditioning system

Temperature Change \ Temperature	4	3	2	1	0	-1	-2	-3	-4
4	4	4	4	4	4	3	2	1	0
3	4	4	4	4	3	2	1	0	-1
2	4	4	4	3	2	1	0	-1	-2
1	4	4	3	2	1	0	-1	-2	-3
0	4	3	2	1	0	-1	-2	-3	-4
-1	3	2	1	0	-1	-2	-3	-4	-4
-2	2	1	0	-1	-2	-3	-4	-4	-4
-3	1	0	-1	-2	-3	-4	-4	-4	-4
-4	0	-1	-2	-3	-4	-4	-4	-4	-4

4.3. Simulation Results

Ten inputs for the system are chosen randomly. They are temperature (T) and a change of temperature (CHT). The results of the system is a streaming water ratio (O) that is sent to control the valve. The negative sign of value represents the heating type and the positive sign of value represents the cooling type as shown in table 3.

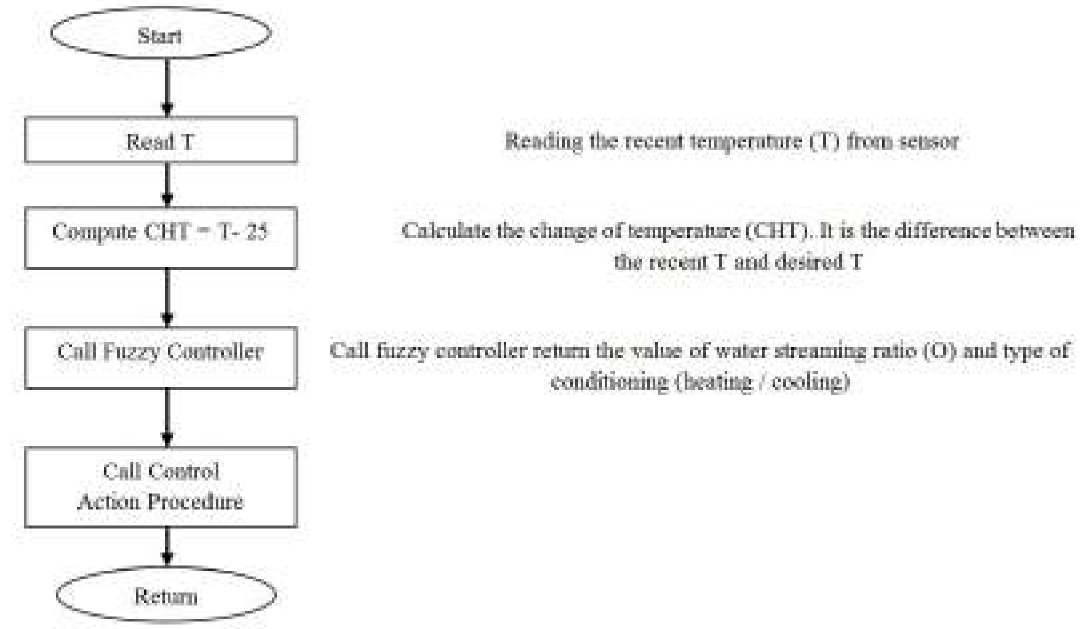
Table 3. Represents the simulation results of fuzzy controller

Temperature (T)	Change of Temperature (CHT)	Water Streaming ratio (O)	Type of Conditioning
33	8	58.55	Cooling
28	3	18.55	Cooling
17	-8	-58.55	Heating
42	17	79.99	Cooling
7	-18	-79.99	Heating
22	-3	-18.55	Heating
48	23	100	Cooling
3	-22	-100	Heating
1	-24	-100	Heating
50	25	100	Cooling

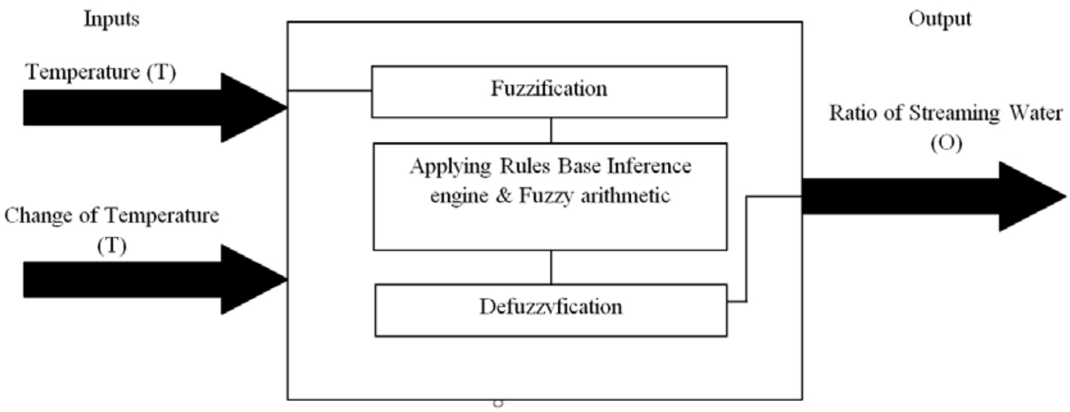
5. Discussion and Conclusion

An optimization method for the operation of conditioning system is achieved by fuzzy control system and implemented automation system. The fuzzy control system determines a required water ratio precisely to regulate the temperature instead of using trials for adjusting the water ratio when applying conventional control. It is an important factor of the given control system eventually reaches an equilibrium state, after which the temperature barely needs to be adjusted anymore. A conventional control method causes the waste of hot or cold water, which means not optimal utilization of energy. The fuzzy logic control means: accuracy of temperature control and saves energy by rationing the cold or hot water streaming. Thus fuzzy logic is more efficiently used in temperature control system. The idea discussed can be extended to conditioning systems that consist of numerous stations and for using an optimal fuzzy system based on genetic algorithm which will be used to retune the parameters of fuzzy control system [14].

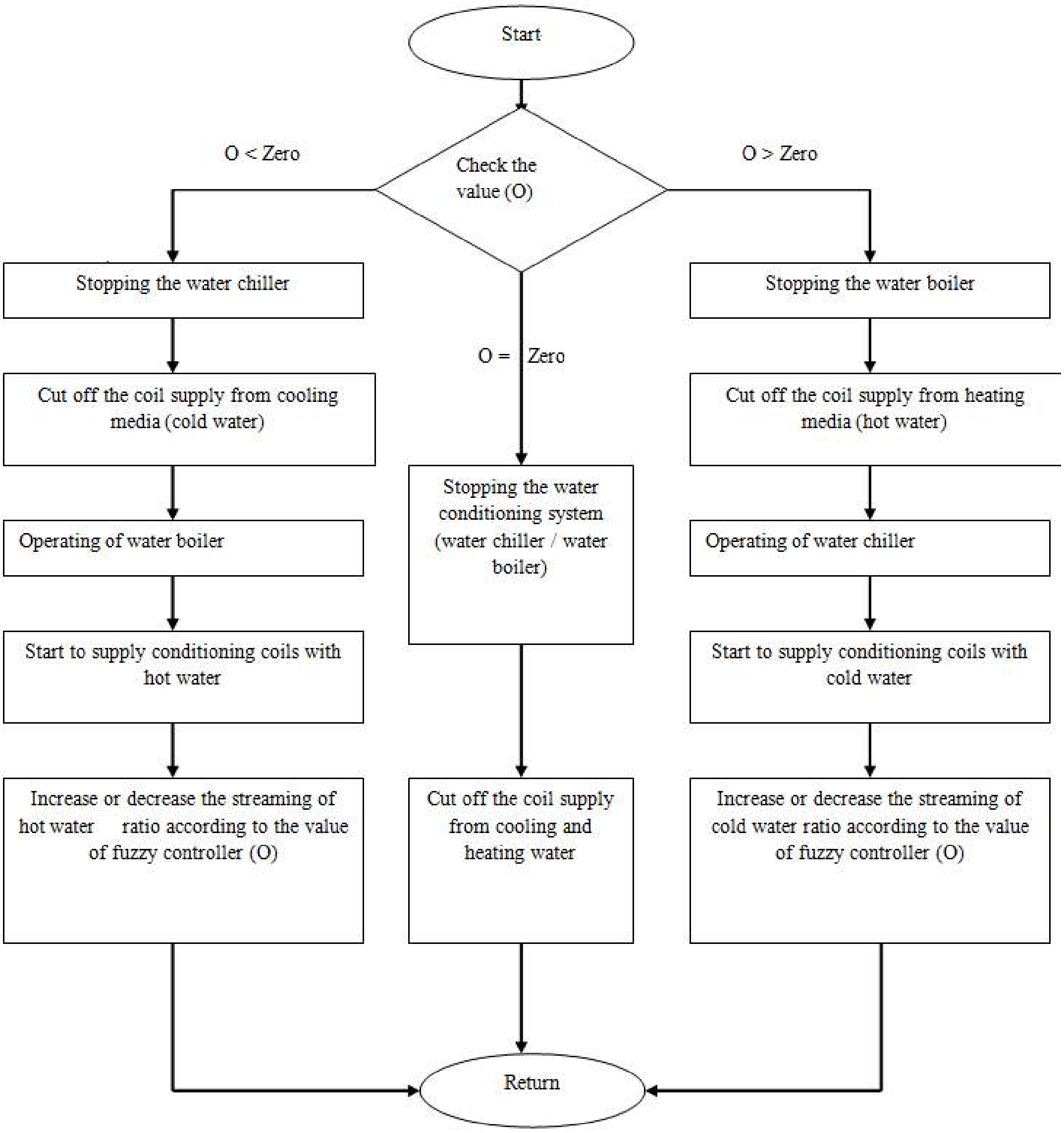
6. Algorithm of Control System



7. Fuzzy Controller



8. Algorithm of Control Action Procedure



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