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Application of the Fuzzy-logic Controller to the New Full Mathematic Dynamic Model of HVAC System

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Abstract— ***This paper is presented the application of the fuzzy-logic controller which is used to control the parameters of full dynamic mathematical dynamic model of the HVAC system. Fuzzy-logic controller has been proposed to maintain the temperature and the humidity close to the targeted values. More over it is shown that the fuzzy-logic controller can be control the parameters of the HVAC system very well rather than PID controller***.

Index Terms— **HVAC components, PID-controller, fuzzy-logic. Fuzzy rules, fuzzy control system.**

I. INTRODUCTION

The model which is work on it is [1]. This Model is a new and complete mathematical dynamic model of HVAC (Heating, Ventilating, and Air Conditioning) components such as heating/cooling coil, humidifier, mixing box, ducts and sensors. All of these components are proposed and simulated in Matlab/Simulink platform. The proposed model is a full dynamic model of HVAC system that includes least approximations and assumes. Initially, the most important issue of HVAC (Heating, ventilating and Air-Conditioning) systems factories was to maintain the zone conditions in predefined values related to occupants' thermal comfort. However, with start of energy crisis, the amount of energy consumption of these equipments became important. In order to, evaluate these two options, the designer have been started to modeling and design of new type of HVAC system components. Some study has been focused on HVAC modeling. For instance, [2] have used heat transfer and energy balance principles to identify a linear model to represent a non-linear model of a cooling coil.[3] has presented a transient model for a HVAC system for some components such as humidifier and mixing box, but no specific model for cooling/heating coils was given. [4] provided a model for cooling coil with empirical parameters under the assumptions of constant air flow and water flow. [5, 6] presented two cooling coil models that were too complex and iterative computations. Many researchers studied HVAC dynamic models using empirical or theoretical methods. [7] developed a nonlinear model of a heat exchanger loop. [8] presented a validation of the cooling coil, mixing box and a fan for a VAV (Variable Air Volume) system. Fig. 1 shows the full dynamic mathematic model of the HVAC components. Since the original system has a nonlinear behavior, it is difficult to control the parameters of the HVAC system as a point of control designer. With the goal of performance enhancement of HVAC systems by means of controlling temperature and RH, several studies have been conducted based on simple on/off and proportional (P)-integral (I)-derivative (D) control methodologies, and more complex algorithms such as non-linear, multivariable, AI methodologies as well as their combinations[9, 10]. The most widely used control algorithm for HVAC systems is based on PID. However, it must be noted that the PID control methodology, as a linear controller, is suitable for linear systems and HVAC systems are inherently non-linear and bi-linear [11]. Temperature and RH controls, on individual basis, have counter effects on each other [12, 13]. Therefore the main purpose is to use the suitable controller for nonlinear and complex system.. In this case implement the fuzzy-logic controller to the full dynamic mathematical HVAC system. The paper is organized as follows: Section II summarized an application of Fuzzy-logic controller to the HVAC system. In Section III fuzzy-logic controller is used to control the humidity and temperature of the full dynamic mathematic model of HVAC system. Finally In section IV comparison of the PID controller and fuzzy-logic are discussed.

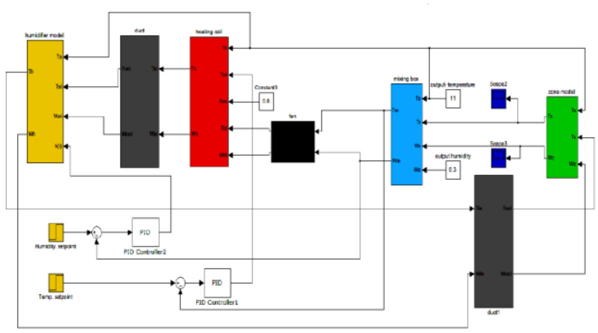

Fig. 1 Shows The Model Of The HVAC System-Full Dynamic Mathematics Model[1]

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II. APPLICATION OF THE FUZZY-LOGIC CONTROLLER ON HVAC SYSTEM

Many application of the fuzzy-logic have been studied in two decades. Almost any control system can be replaced with a fuzzy logic based control system. This may be overkill in many places however it simplifies the design of many more complicated cases. So fuzzy logic is not the answer to everything, it must be used when appropriate to provide better control[14]. Fuzzy systems are capable of approximating any real function on a compact fuzzy subset; such approximators have often been found superior to conventional modeling, especially when information being processed is inexact uncertain [15, 16]. Main advantages of fuzzy logic in approximator, as compared to conventional approaches, is that no mathematical model is needed, and it is possible to use all available information about the process in the design of the fuzzy approximated scheme. A fuzzy logic approximated converts a set of linguistic rules, based on expert knowledge, into an automatic approximation strategy. Employing fuzzy IF-THEN rules can model qualitative aspects of human knowledge and reasoning processes without employing precise quantitative analysis[17, 18]. Status of fuzzy logic in 1998 is vastly different than that in 1978. Mathematical tools of fuzzy logic are established [19] and basic theory is in place. Fuzzy logic based applications are ranging from consumer products and industrial systems to biomedicine, decision analysis and recognition technology's[20]. Fuzzy controllers can control nonlinear process model and time-delay process model significantly better than linear controller[21]. Fuzzy rule base (FRB) is the heart of fuzzy control system since all design parameters are used to assist and interpret these fuzzy rules and make them usable to design a fuzzy controller for a specific control problem[22]. Many researchers studied fuzzy controller to control the parameters of HVAC system. For cold store application of HVAC,[23] designed a fuzzy controller for temperature and relative humidity (RH) in refrigeration system by considering their thermodynamic coupling. An attempt has also been made to replace the linear proportional control by maintaining interior environment of automobile[24]. Fuzzy controller is designed fuzzy control to control blower speed with dependency on engine coolant temperature and in-car set point. [25] investigated a new approach of fuzzy timing, Petri Net, for distributed temperature control to achieve optimum air temperature inside a car considering the comfort for each passenger, has also been developed; optimum HVAC control is applied to AC system for a car and fuzzy controller is used to independently control temperature at various locations inside a car.[26] employed a HVAC system controller with a control algorithm using fuzzy logic reasoning and rough set theory. In this case fuzzy logic reasoning has shown better performance in both temperature and RH control than rough set method. More over [27] worked on a nonlinear controller for a variable air volume (VAV) flow in HVAC system which is capable of maintaining comfort conditions within a thermal space with time-varying thermal loads acting upon the system. [28] worked for the improvement of the refrigerant flow control method by using an electronic expansion valve (EEV) and employing the fuzzy self-tuning (PID) control method. Experimental results show that the new control method can feed adequate refrigerant flow into the evaporator in various operations. [29] also worked on the control of EEV with fuzzy techniques using dynamic model of multi-evaporator air conditioners.[30] worked on fuzzy predictive control scheme based on a fuzzy model of a process and a discrete optimization technique (branch-and-bound), combined with an inverse model control law and applied this technique to an HVAC system consisting of a fan-coil unit installed in a test cell. A sugeno-fuzzy controller[31] based on identified fuzzy model, resulted in better and constant performance overall the operating range of fan-coil unit.

III. FUZZY-LOGIC CONTROLLER

The reason for using fuzzy logic in control applications stems from the idea of modeling uncertainties in the knowledge of a system's behavior through fuzzy sets and rules that are vaguely or ambiguously specified[32] A block diagram for a fuzzy control system is given in Fig. 2.

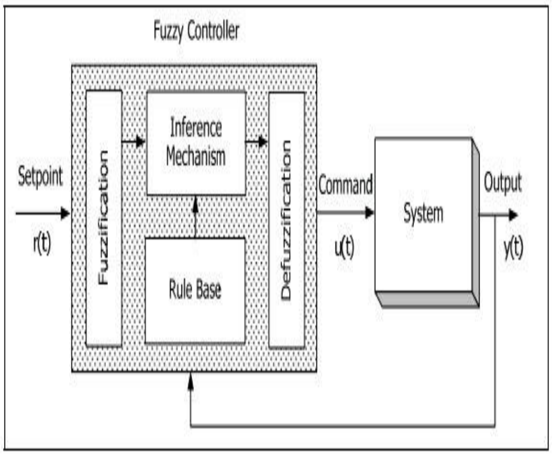

Fig. 2 fuzzy control system[32]

The fuzzy controller consists of the following four components[32]:

1. Rule base: set of fuzzy rules of the type "if-then" which use fuzzy logic to quantify the expert's linguistic descriptions regarding how to control the plant.
2. Inference mechanism: emulates the expert's decision-making process by interpreting and applying existing knowledge to determine the best control to apply in a given situation.
3. Fuzzification interface: converts the controller inputs into fuzzy information that the inference process can easily use to activate and trigger the corresponding rules.
4. Defuzzification interface: converts the inference mechanism's conclusions into exact inputs for the system to be controlled.

The fuzzy control system, then, with its inputs and outputs, would be as shown in Fig. 3.

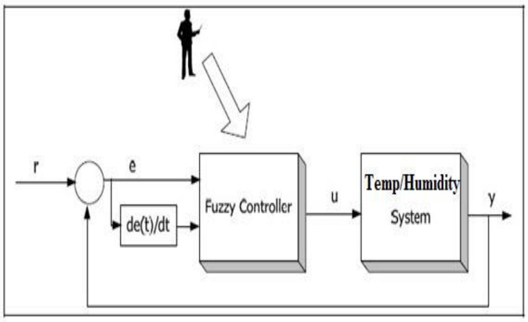

Fig. 3 Fuzzy controller for system[32]

In Fig. 4 shows how to derive the fuzzy rules by observation of system response.

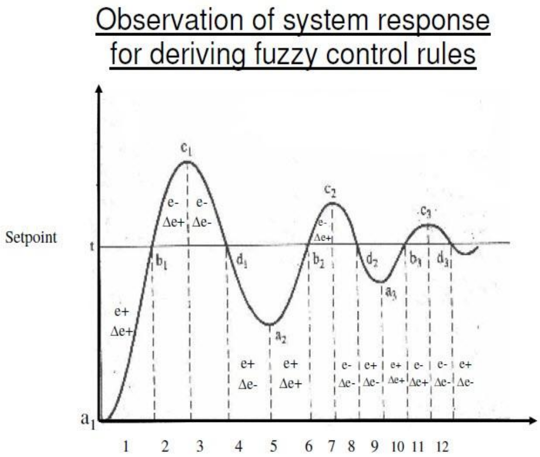

Fig. 4 observation of system response[33]

The HVAC system consists of two inputs and two outputs. The HVAC system is nonlinear and complexity for using the PID controller to control the temperature and humidity of the HVAC system. There for the fuzzy-logic is used which is comfortable for tuning of the nonlinear system. The fuzzy rules are following as:

For the first input:

- If (humidity is high) and derivative of humidity is positive) then speed of valve is increased (1)
- If (humidity is low) and derivative of humidity is negative) then speed of valve is decreased. (2)
- If (humidity is fixing) and derivative of humidity is zero) then speed of valve is fixed. (3)

For the second input:

- If (temp is high) and derivative of temp is positive) then speed of valve is increased. (4)
- If (temp is low) and derivative of temp is negative) then speed of valve is decreased. (5)
- If (temp is fixing) and derivative of temp is zero) then speed of valve is fixed. (6)

For simplification a matrix can be used for presenting the rules which is called fuzzy rule matrix. Table 1, and 2 are shown fuzzy rule matrix for humidity and temperature respectively.

De / E	low	Fix	high
Positive	Decrease	-----------	------------
Negative	-------------	Fix	------------
Zero	-----------	------------	Increase

Table 2 fuzzy rule matrix for humidity

De / E	low	Fix	high
Positive	Decrease	-----------	------------
Negative	-------------	Fix	------------
Zero	-----------	------------	Increase

Table 3 fuzzy rule matrix for temperature

IV. COMPARISON OF THE PID CONTROLLER AND FUZZY-LOGIC

In this section PID controller and fuzzy-logic controller are discussed. According to the amount of the AIE it is clear that the Fuzzy-logic controller can be controlled better the parameters of the HVAC system rather than PID controller. Because of nonlinearity of the system fuzzy-logic can be suitable for controlling of the system. Table 4 is shown the amount of the IAE for both PID and fuzzy-logic controller.

Model	Controller	IEA for Temperature	IEA for Humidity
HVAC	PID controller	1.205e004	127.6
	Fuzzy logic	4043	75.84

More over in Fig. 5 and 6 show the outputs of the HVAC system.

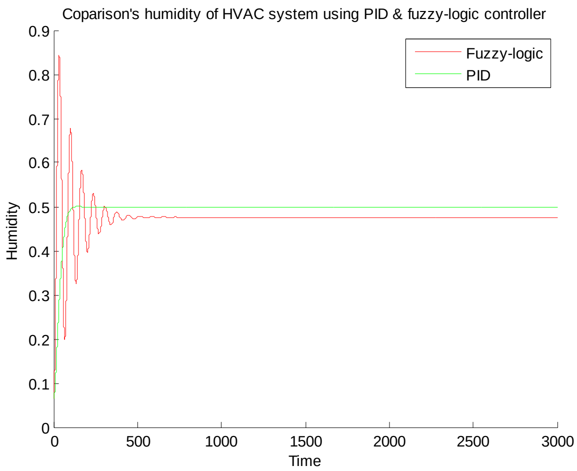

Fig. 5 comparison of Humidity of HVAC system.

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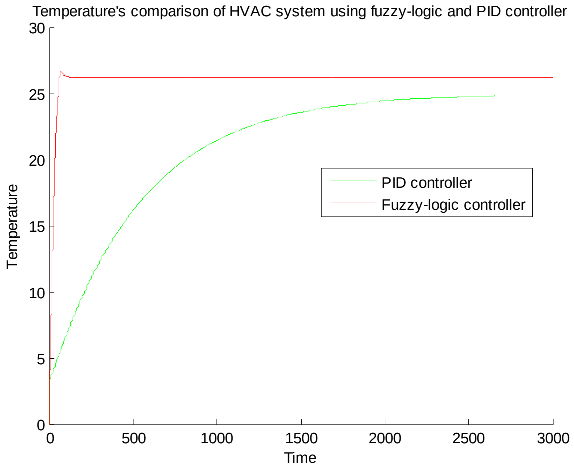

Fig. 6 comparison of the temperature of HVAC system

V. CONCLUSION

This paper presents the full dynamic mathematical model of HVAC system which is used PID controller to control two main parameters of any HVAC system which are temperature and humidity respectively[1]. Since the HVAC system is a nonlinear and it is difficult to get the whole model of the HVAC system it is prefer to consider a controller to control the nonlinearity of the system. Fuzzy logic is one of the best controllers which can control the parameters of the HVAC system. It is expected that fuzzy-logic controller can be control the parameters of the HVAC system very well. Fuzzy techniques has gained attention in HVAC system[22]. While this is the first time that fuzzy-logic is used to the full dynamic mathematical model of HVAC system. According to the IEA it is clear that this controller can be control very well the parameters of the HVAC system rather than PID controller.

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