Designing Fuzzy Controller for Air Conditioning Systems in order to Save Energy Consumption and Provide Optimal Conditions in Closed Environments (Indoors)

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Abstract

Today air conditioning systems have been considered by all people as one of welfare requirements in buildings and closed environments. Since a considerable part of energy loss occurs in ordinary modern systems, new strategies and solutions are developed in the field in order to save amount of energy consumption and observe environmental considerations. Fuzzy control is one of these methods which provide a basic powerful rule for decisions made to guarantee optimal use of cooling and heating system. Hence in this research project data measured by environment humidity and temperature were used as input variables and fan speed controller, humidifier, heaters, and compressors were used as output variables to regulate air flow rate and create humidity, cooling and heating conditions in the environment using fuzzy logic for system control.

Keywords: fuzzy controller, heating systems, cooling systems, air conditioning system

1. Introduction

As it can be seen in Fig(1), an optimized air conditioning system involves 4 heaters, 2 compressor machines for cooling and a humidifier to provide optimal humidity of closed environment. With a PLC central necessary to achieve higher efficiency goals and better environmental aspects in air conditioning systems. Fuzzy logic, in a broad sense, is referred to fuzzy sets, a set with unlimited borders. Fuzzy logic is widely used in device controllers. As a quantity of ordinary logic it provides concepts such as" relatively correct" and " relatively incorrect" for conditions between "correct" and "incorrect".

controller, humidity and temperature sensors in closed environment, such systems provide the best efficiency in measurement and accurate control, economically and environmentally. Fuzzy logic strategy-based operation and control seems

Fuzzy logic is designed based on control system, being flexibly developed in design and implementation of system. Since its implementation is with "if-then", the complicated differential equations are replaced with the logic. Such technology provides a place for graphic user, making it more comprehensible for those who haven't knowledge about information process control. Another important key of designing fuzzy logic-based control is automatic and steady regulation of working priority of some control variables which finally provides achieving a long procedure without need for intervening in control.

2. Determining Design Parameters and Fuzzy Reasoning Algorithm

Use of fuzzy reasoning is, in general, very simple and easy and use of it in conditioning industry is highly necessary for places which need accurate control such as laboratories, communication and military devices conditioning systems and all indoors which need precise and quick control. The controller is responsible for controlling humidity, cooling and heating rate, according to the desired point regulated by the user. In this research project it was assumed that required humidity, cooling and heating load was designed for the worst environmental condition and function of controller is just to regulate and synthesize different factors creating welfare conditions. Designing a fuzzy controller algorithm includes following cases:

a) Defining system inputs and outputs:

3 input variables and 4 output variables were used in this project for HVAC system control.

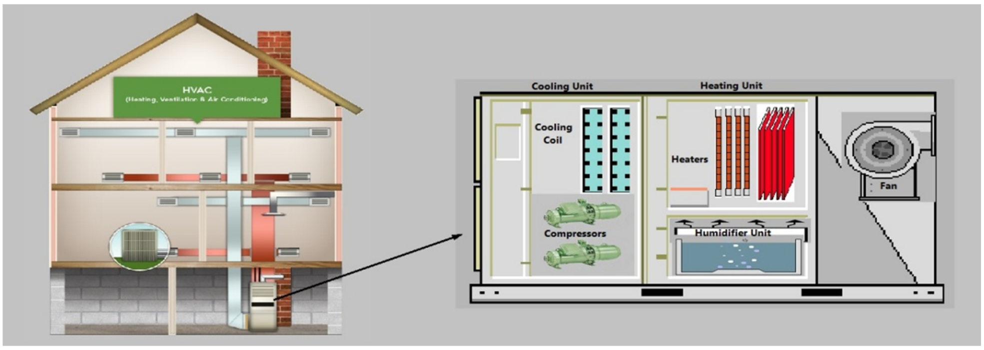

Fig.1. Air Conditioning Systems Designed by Fuzzy Logic

Temperature difference between closed environment and users considered temperature (T_{Room}-$T_{setpoint}$), difference between relative humidity of closed environment and users demanded humidity which can be regulated in controller and finally temperature change rate were defined as input parameters of the system. Output variable of the system, on the other hand, involves speed control of fan which has been defined at 6 states, humidifier with 6 working modes, 4 electric heaters which provide 5 heating modes and finally cooling function with 2 compressors which provided 3 different states.

b) Membership Functions and Conditions of Input and Output Variables:Skill and expertise and domination on considered system are needed to define system logic for system inputs and outputs. Membership functions determination algorithm is as follows: first a general structure was defined for functions of each variable, then considering collected data, they were edited to achieve final form. In this article, a microcontroller was used to implement control system of temperature degree and fuzzy logic-based humidity. The system acts to control considered environment's temperature by controlling compressors, heaters and fan speed. Microcontroller, on the other hand, controls fan speed and structure humidity based on humidity conditions. In this project temperature difference variable has been classified as a group of states such as zero temperature difference, low heat temperature difference (small positive), low cooling difference (small negative), average heat difference (positive), average cooling difference (Negative), high heat difference (Large Positive) and high cooling difference (Large Negative). Environment relative humidity difference to required humidity was, also, classified like thermal classification. This means that as humidity difference becomes positive, it means higher relative humidity has been generated compared to user's created point and as humidity difference moves toward negative, it means that more humidification is needed. Moreover the other parameter which should be considered in temperature regulation is speed rate of temperature changes to time which influences decisions made for turning the heater and compressors on and off and speed of fan (Fig.2). it should be noted that as the number of membership functions parameters increase, level of accuracy is increased accordingly, since with increase of parameters and increase of rules more accurate controlling conditions govern the system. These parameters are, in fact, those fuzzy and ambiguous words which are used in writing rules.

Moreover output parameters of fan are off state, Very Low Cycle, Low Cycle, Mid Cycle, High Cycle and very High cycle. For heating system which has 4 electric heaters, five states have been defined as follows: Off, Low including a heater which is on, Mid including two heaters which are on, High including 3 heaters which are turned on and Very High which involves all heaters which are On at the same time. For cooling, 2 compressors were used in this research project which include three states of Off Low and High, when two compressors are turned off, the condition is provided for on compressors and two compressors to be turned on.(Fig.3).

Parameters and membership rate of each parameter, the next step of designing process is fuzzy rules generation. System knowledge is required for fuzzy rules generation which are expressed as “if then” using fuzzy rules. Rules which are used in fuzzy reasoning are called “fuzzy if then rules”.This process is created by connection of an input crisp value to a fuzzy value which is called fuzzification. Our objective is to bond inputs to outputs using understandable linguistic terms instead of mathematical relations.The basis for writing all of the rules is natural language and human feeling which causes to achieve the ideal and real results. In general, 245 fuzzy “if then” rules were defined in this project to consider all states which can possibly occur in the environment which have direct relationship with number of fuzzy input and output parameters defined for the membership functions.

Different factors are influential in writing such rules. For example the function of compressors in reducing humidity can be mentioned or combination of temperature difference rate and humidity with fan speed performance is another case. For example if thermal difference is even very low and relative humidity is very low, then fan will not work with its totalpower, rather it will transfer the humidity to the room with half of its power, though the humidifier comes to the circuit with its total power to impede saturated air entrance to the room at the time of humidification. These rules were obtained based on standards of air conditioning systems and experts experiences in the field and dominance to the major improves the definition of such

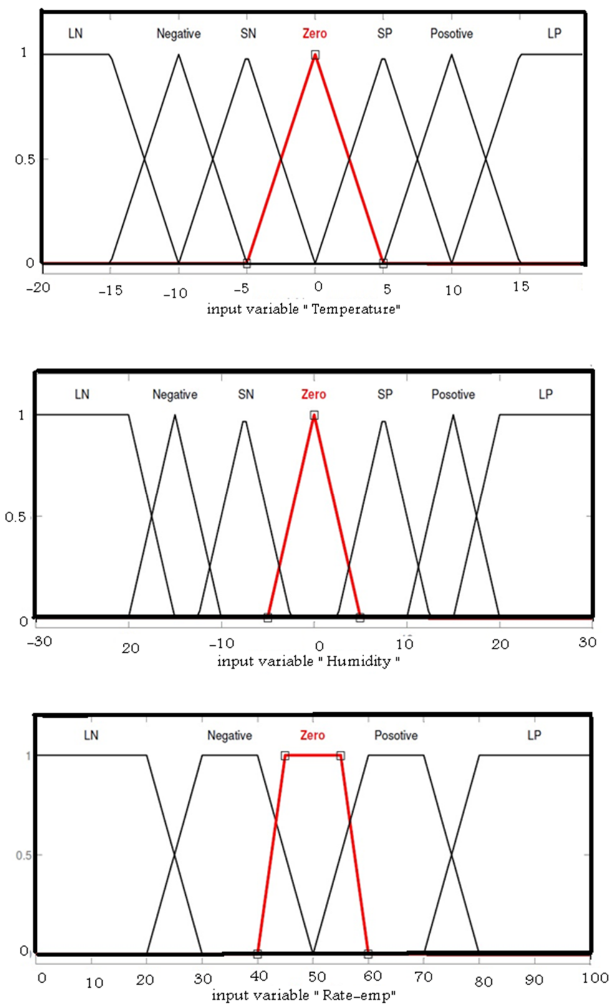

Fig.2. Membership Function for Input Variable

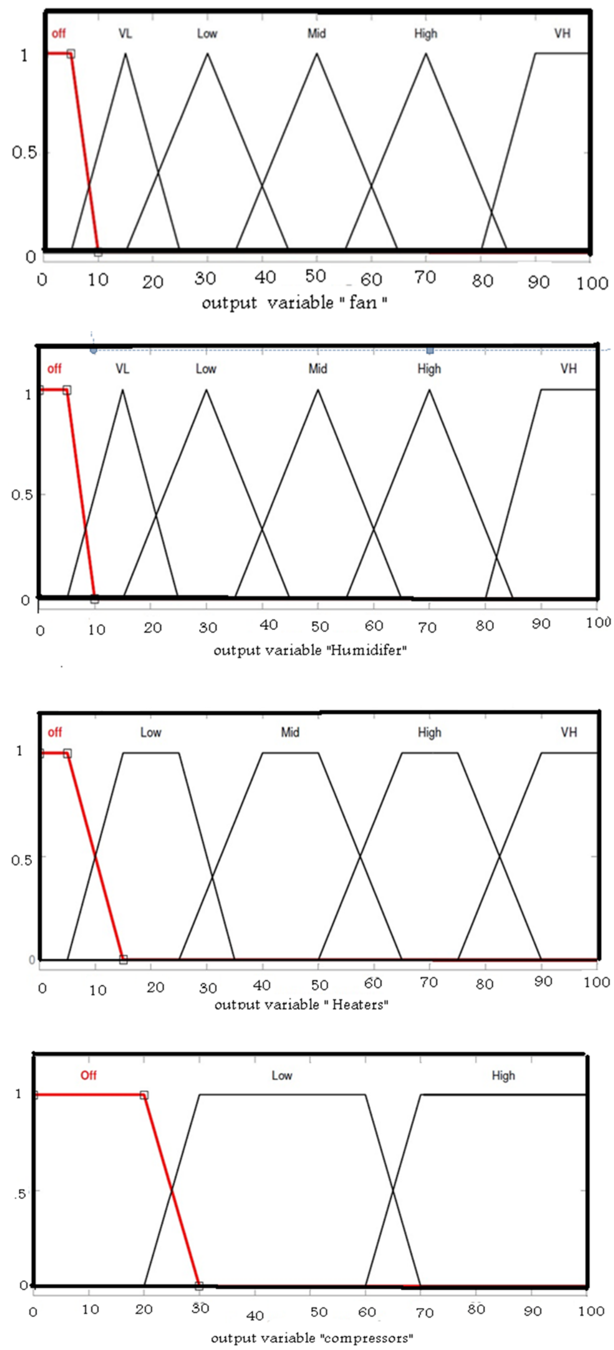

Fig.3. Membership Function for Output Variable

fuzzy rules more accurately. Some examples of fuzzy rules are as follows:

1- If Temperature Difference is " Large positive " and Rate Temperature is "Large Positive" and Humidity is "Large Positive" Then Fan is "Very High", Humidifier is "Off" , Heaters is "Off" , Compressors is "High" .

2- If Temperature Difference is "Small positive" and Rate Temperature is "Large Positive" and Humidity is "Zero" Then Fan is "Mid", Humidifier is "Low", Heaters is "Off", Compressors is "Low"

3- If Temperature Difference is "Zero" and Rate Temperature is "Large Negative" and It should be noted that there are two inferential methods in this regard: first method is Mamadani's fuzzy inferential..

Humidity is "Large Positive" then Fan is "Low", Humidifier is "Off", Heaters is "Low", Compressors is "Off".

4- If Temperature Difference is " Small Negative " and Rate Temperature is "Large Positive" and Humidity is "Small Negative" Then Fan is "Very Low", Humidifier is "Mid", Heaters is "Low" , Compressors is "Off" .

5- If Temperature Difference is " Negative " and Rate Temperature is "Zero" and Humidity is "Large Negative" Then Fan is "High", Humidifier is "Very High" , Heaters is "Mid" , Compressors is "Off" .

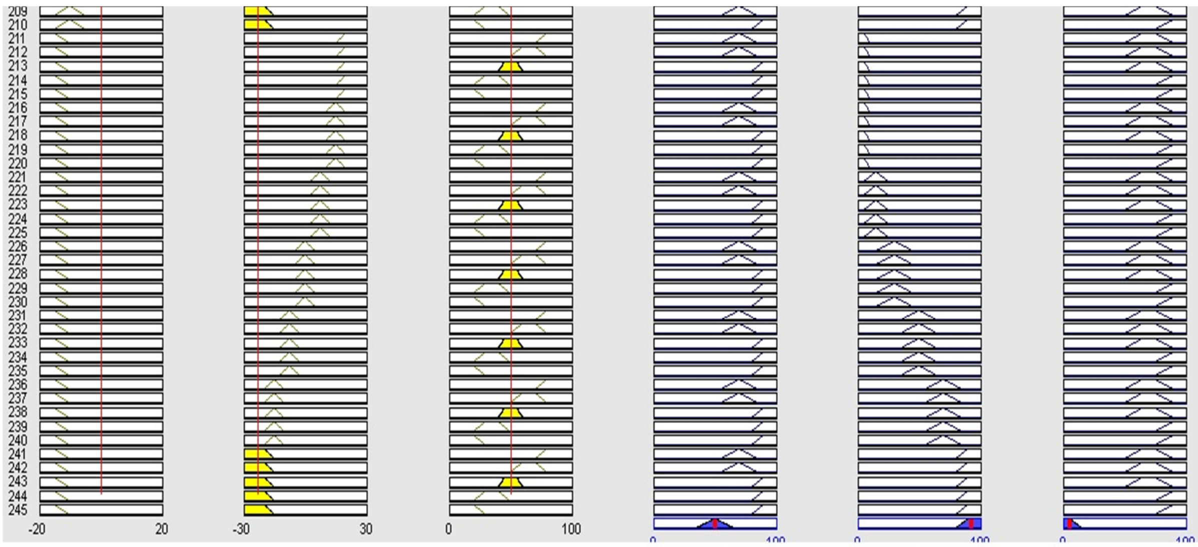

Fig .4. Schematic of Mamadani's Reasoning Method model which was developed by Ibrahim Mamadani (PhD) in 1975 and the second method is Takagi Sogono's fuzzy inferential model which was developed in 1985. These two inferential methods are similar at most cases like fuzzification of inputs and fuzzy operators but the main difference between them is that Sogno's output is a function member which can be linear or consistent, this is while in Mamadani's inferential model it is expected that the output to be membership functions of fuzzy sets. We used Mamadani's method in this project.

Centroid (center of gravity) rule was used to obtain final result where an individual result is obtained for each rule. This becomes more important when results of all rules are obtained at the same time. There are different types of methods to display the issue. Centroid is the most applied one. Fig.4 shows some parts of these rules. Establishing shaded surfaces, final centroid is obtained in defuzzification way.

Note that all of the diagrams were simulated by MATLAB software.

3-Results

Considering air and humidity input variables and using Fuzzy method we could generate an ideal control to sudden changes and different conditions. This method helps us to prevent sudden and rapid tuning on and off of outputs and these factors cause optimal use of energy and optimization of environmental aspects and also improvement of life time of the system and keeps long time intervals of system servicing and maintenance. (Fig.5 shows temperature and humidity changes to fan power. Suppose that the optimal temperature defined by user for considered space is 21 centigrade. In this case if the environment temperature is 36 degree, then temperature difference will be 15 centigrade which is relatively high temperature difference to optimal difference. So fan enters with high power to the circuit and its cycle speed is reduced slowly and continuously as it approaches the optimal point. Moreover, if temperature difference is negative and this temperature difference is high to optimal temperature, then fan speed will change slowly. It should also be noted that according to Fig. (5) humidity changes result in change of fan speed. Fig. (6) shows fan speed changes considering temperature changes and temperature change rate to time.

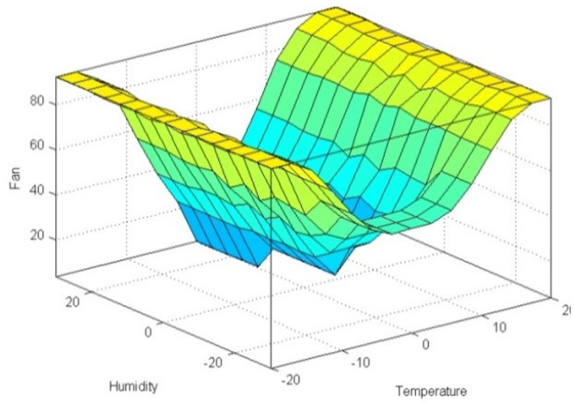

Fig.5. power change input to fan in ratio of closed environment humidity and temperature

Fig. (7) shows a state in which heaters come to circuit considering temperature changes and temperature change rate in ratio of time. Fig. (8) shows compressor performance regarding temperature variables in system cooling state.

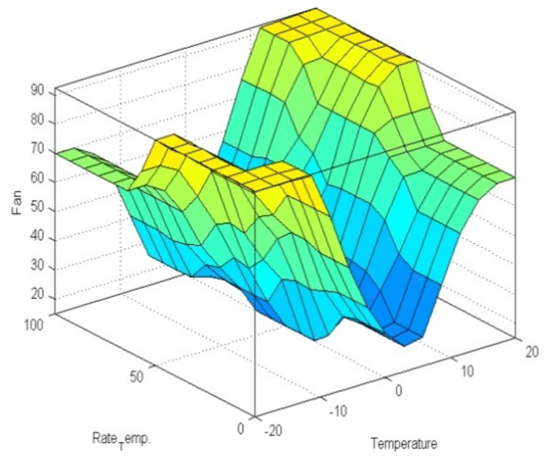

Fig.6.change in input power to fan in ratio of temperature and temperature change rate

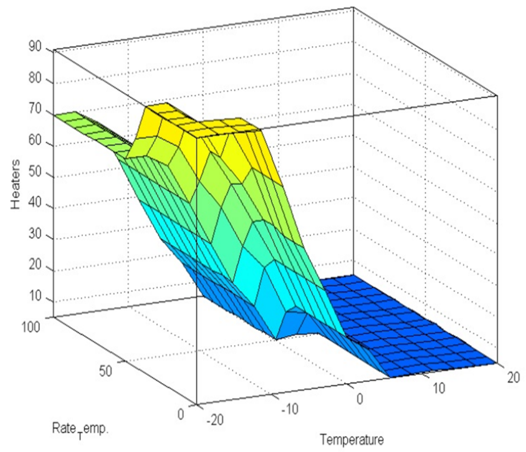

Fig.7.input power change to heaters in ratio of temperature and temperature changes rate

Comparing Figures (7) and (8), it can be seen that as the number of different states of outputs is increased a gentle and continuous slope will be obtained. Hence in heating state which uses four heaters gentler slope is seen compared to cooling state which uses 2 compressors.

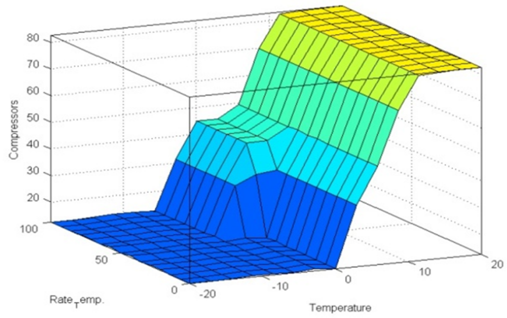

Fig.8. input power changes to compressors in ratio of temperature and changes rate

Conclusion

In general, due to complexity and non-linearity of air conditioning systems (HVAC), a linear and continuous control algorithm is required for system and as it can be seen in diagrams an ideal linear state is generated which imposes least shock to the system. Hence the advantages of this technique are: saving energy consumption and its management, generating an optimal humidity and temperature point, preventing sudden and repeated on and off of system, simple and understandable design, easy troubleshooting and self-improvement of the system considering different humidity and temperature changes. This technique will be an appropriate alternate for HVAC control classic systems.

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