CHAPTER 5

EFFECTS OF FUZZY LOGIC IN COOLING SYSTEMS

5.1 Air Conditioning System

The air conditioning systems are usually found in homes and publicly capsulated areas to make snug surroundings. Air conditioners and air conditioning systems are integral part of nearly each establishment. It includes atmosphere, energy, machinery, physical science, and automatic management technology [160] [161].

5.1.1 Air Conditioning System with Fuzzy Logic

Fuzzy Logic may be a straightforward however, very powerful drawback solving technique with in depth relevancy. It's presently employed in the fields of business, systems management, physical science and traffic engineering. A fuzzy logic deals with uncertainty in engineering by attaching degrees of certainty to the solution to a logical question. A fuzzy logic system (FLS) will be outlined as the nonlinear mapping of an information set to a scalar output data. Fuzzy logic is employed for management machine and shopper merchandise. Several applications have successfully uses fuzzy logic management. Examples are environmental management, domestic merchandise and automotive system etc [162].

The fuzzy sets are quantitatively outlined by membership functions. These functions are generally very straightforward functions that cover a fixed domain of the worth of the system input and output. Fuzzy logic management is primarily rule based system and therefore the performance of it depends on its control rules and membership functions.

Fuzzy logic management based air conditioning system consists of two inputs that are actual temperature and room temperature dew point (humidity). While measuring actual temperature, the User temperature (Ut) is subtracted from actual temperature for realization of the Temperature distinction (Td) and sent it for fuzzification.

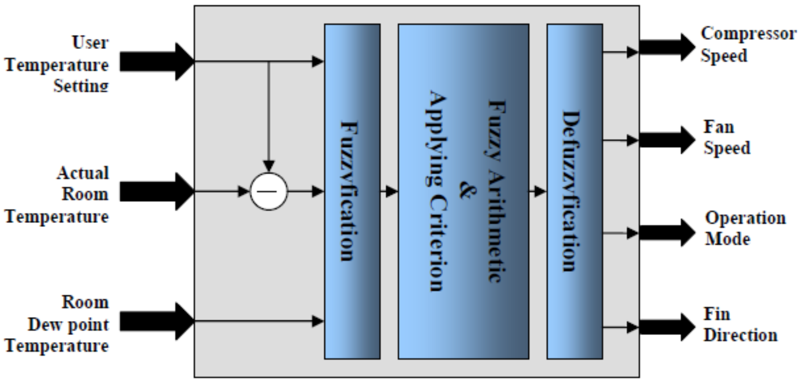

Figure 5. 1 Block diagram of controller

Fuzzy arithmetic and criterion is applied on the input variables and outcome is defuzzified to induce output and these output signals are distributed to manage the compressor speed. During this case, the range of Actual temperature is taken to be 15ºC to 50ºC and range of it is taken to be 18ºC to 30ºC, therefore the Temperature distinction arises between -3ºC to 32ºC. The input has 2 membership functions. The size over that membership functions for temperature is represented between 0ºC- 50ºC and membership functions for humidness is represented between 0%-100%. The output additionally has four membership functions particularly compressor speed, Fin direction, Fan speed and Operation mode. the principles base for coming up with is as "IF Temperature is just too cold AND humidness is dry THEN compressor speed is Off, Fin direction is Away, Fan speed is Off and Operation mode is AC” and so on [163] [164].

Table 5.1 Fuzzy rules for proposed design.

	Input		Output			
Rules	Temperature	Humidity	Compressor Speed	Fin Direction	Fan Speed	Operation Mode
1	Too Cold	Dry	Off	Away	Off	AC
2	Too Cold	Refreshing	Off	Away	Off	AC
3	Too Cold	Comfortable	Off	Away	Off	AC
4	Too Cold	Humid	Off	Away	Very Low	AC
5	Too Cold	Sticky	Very Low	Towards	Low	Dehumidifier
6	Cold	Dry	Off	Away	Off	AC
7	Cold	Refreshing	Off	Away	Off	AC
8	Cold	Comfortable	Very Low	Away	Very Low	AC
9	Cold	Humid	Very Low	Towards	Low	AC
10	Cold	Sticky	Low	Towards	Low	Dehumidifier
11	Warm	Dry	Very Low	Away	Very Low	AC
12	Warm	Refreshing	Very Low	Away	Very Low	AC
13	Warm	Comfortable	Low	Away	Low	AC
14	Warm	Humid	Medium	Towards	Medium	Dehumidifier
15	Warm	Sticky	Medium	Towards	Medium	Dehumidifier
16	Hot	Dry	Low	Away	Low	AC
17	Hot	Refreshing	Medium	Away	Medium	AC
18	Hot	Comfortable	Medium	Towards	Medium	AC
19	Hot	Humid	Fast	Towards	Fast	Dehumidifier
20	Hot	Sticky	Fast	Towards	Fast	Dehumidifier
21	Too Hot	Dry	Medium	Away	Medium	AC
22	Too Hot	Refreshing	Medium	Towards	Medium	AC
23	Too Hot	Comfortable	Fast	Towards	Fast	Dehumidifier
24	Too Hot	Humid	Fast	Towards	Fast	Dehumidifier
25	Too Hot	Sticky	Fast	Towards	Fast	Dehumidifier

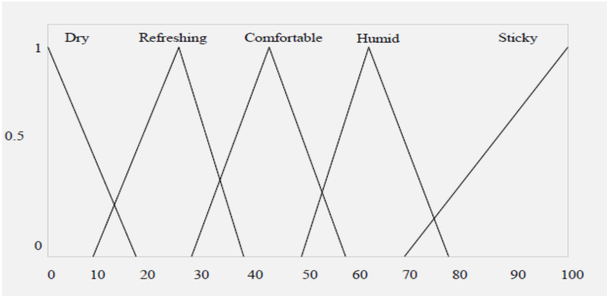

Figure 5. 2 Temperature Membership Functions

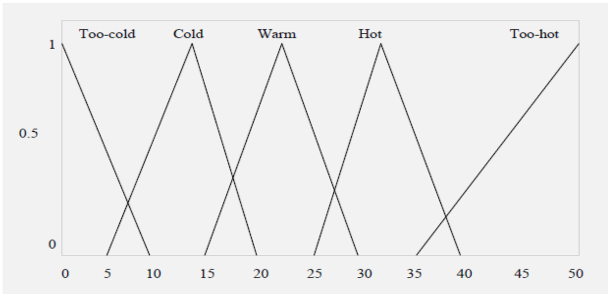

Figure 5. 3 Humidity Membership Functions

5.1.2 Air Conditioning System with Neuro Fuzzy System

One of the key issues of the fuzzy logic management is that the problem of selection and style of membership functions for a given downside. Neural networks provide the likelihood of finding the matter of standardization. Neural Fuzzy Systems will generate formal logic rules and membership functions for advanced systems that a standard fuzzy approach could fail. Hence, combining the adaptive neural networks and formal logic management forms a system known as neuro-fuzzy system. Neuro-fuzzy system is based on the neural network that learned from fuzzy If-Then rules. Neural network performance is dependent on the quality and quantity of training samples presented to the network. Neural networks can solve many problems that are either unsolved or inefficiently solved by existing techniques, including fuzzy logic [165] [166].

Neuro Fuzzy management primarily based air conditioning system additionally consists of 2 inputs that are actual temperature and space room (humidity). The input, temperature takes the name “input1” (In1) and range is taken to be 0ºC to 40ºC for membership function. Similarly, the input, humidness takes the name “input2”(In2) and range is taken to be 5% to 85% for membership function. The output, compressor speed amendment the name as “output1”(Out1), Fin direction named as “output2”(Out2), Fan speed named as “output3”(Out3) and Operation named as “output4”(Out4). The principles are applied consequently in table 5.2.

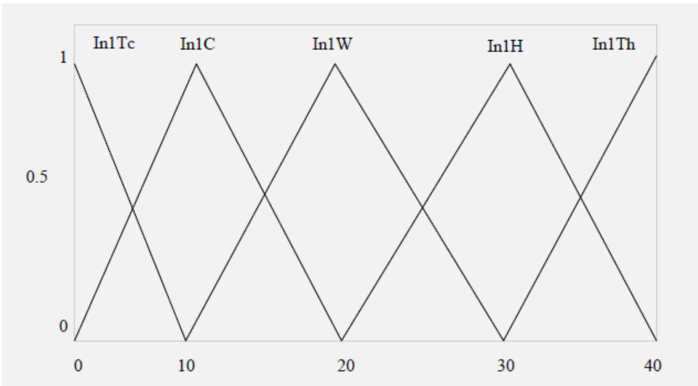

Figure 5. 4 Input1 Membership Functions

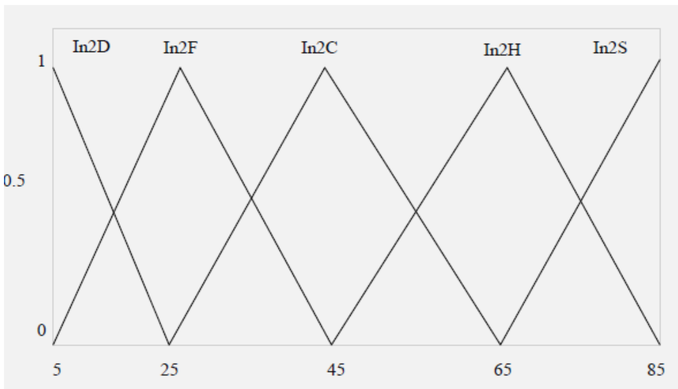

Figure 5. 5 Input2 Membership Functions

Table 5.2 Neuro Fuzzy rules for proposed design

	Input		Output			
Rules	Temperature (Input1)	Humidity	Compressor Speed	Fin Direction	Fan Speed	Operation Mode
1	In1Tc	In2D	Out1Of	Out2A	Out3Of	Out4AC
2	In1Tc	In2R	Out1Of	Out2A	Out3Of	Out4AC
3	In1Tc	In2C	Out1Of	Out2A	Out3Of	Out4AC
4	In1Tc	In2H	Out1Of	Out2A	Out3Vl	Out4AC
5	In1Tc	In2S	Out1Vl	Out2To	Out3L	Out4D
6	In1C	In2D	Out1Of	Out2A	Out3Of	Out4AC
7	In1C	In2R	Out1Of	Out2A	Out3Of	Out4AC
8	In1C	In2C	Out1Vl	Out2A	Out3Vl	Out4AC
9	In1C	In2H	Out1Vl	Out2To	Out3L	Out4AC
10	In1C	In2S	Out1L	Out2To	Out3L	Out4D
11	In1W	In2D	Out1Vl	Out2A	Out3Vl	Out4AC
12	In1W	In2R	Out1Vl	Out2A	Out3Vl	Out4AC
13	In1W	In2C	Out1L	Out2A	Out3L	Out4AC
14	In1W	In2H	Out1M	Out2To	Out3Of	Out4D
15	In1W	In2S	Out1M	Out2To	Out3M	Out4D
16	In1H	In2D	Out1L	Out2A	Out3L	Out4AC
17	In1H	In2R	Out1M	Out2A	Out3M	Out4AC
18	In1H	In2C	Out1M	Out2To	Out3M	Out4AC
19	In1H	In2H	Out1F	Out2To	Out3F	Out4D
20	In1H	In2S	Out1F	Out2To	Out3F	Out4D
21	In1Th	In2D	Out1M	Out2A	Out3M	Out4AC
22	In1Th	In2R	Out1M	Out2To	Out3M	Out4AC
23	In1Th	In2C	Out1F	Out2To	Out3F	Out4D
24	In1Th	In2H	Out1F	Out2To	Out3F	Out4D
25	In1Th	In2S	Out1F	Out2To	Out3F	Out4D

5.1.3 Experimental Results

Result of this experiment is predicated on Fuzzy rules and Neuro Fuzzy rules. The Figure 5.2 and Figure 5.3 shows input values for fuzzy logic management and Figure 5.4 and Figure 5.5 shows input values for Neuro Fuzzy management. Supported these input, acquire results when simulation of fuzzy logic management based air conditioning system that are shown in following figures. The figure 5.6 shows the compressor speed memberships of air conditioning system. Compressor speed may be either off or may be varied between 10 to 100%. Figure 5.7 shows the fan speed memberships of air conditioning system.

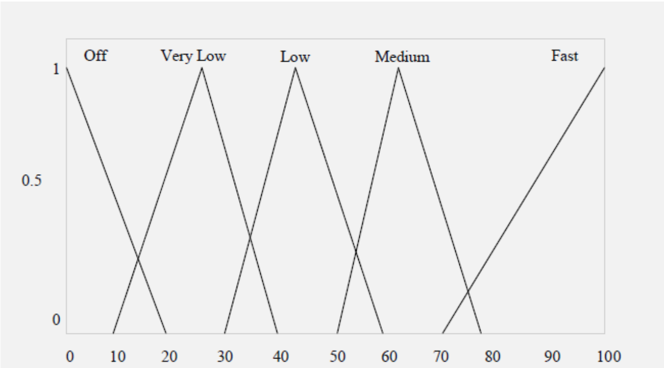

Figure 5. 6 Compressor speed membership function

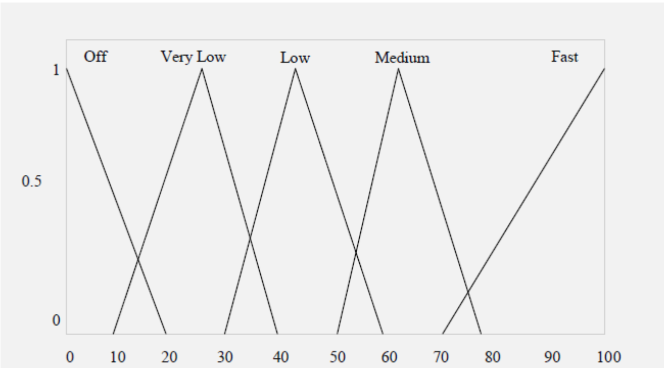

Figure 5. 7 Fan speed membership function

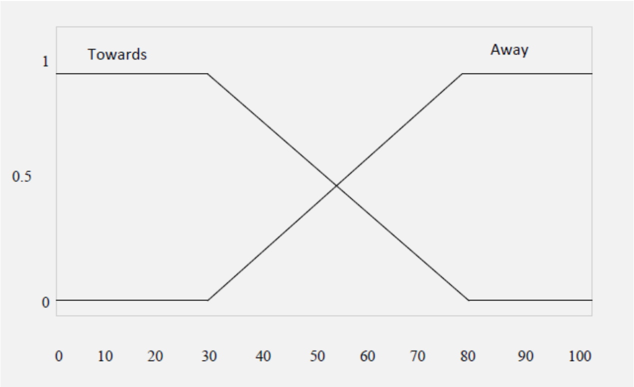

Figure 5. 8 Operation mode membership function

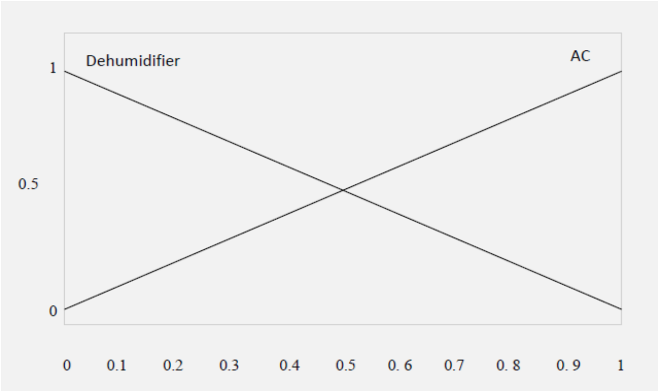

Figure 5. 9 Fan direction membership function

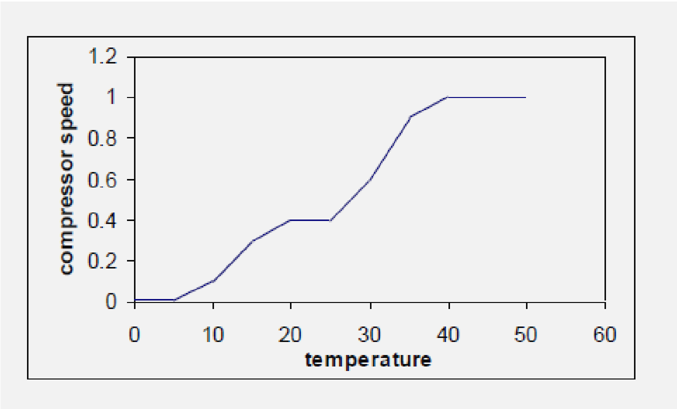

Figure 5. 10 Compressor speed with temperature

The figure 5.8 shows the operation mode memberships of air conditioning system. Mode of operation decides whether AC works like a dehumidifier only or normal. The figure 5.9 shows the fan direction memberships of air conditioning system. Fin direction directs air from the AC towards or away from occupants.

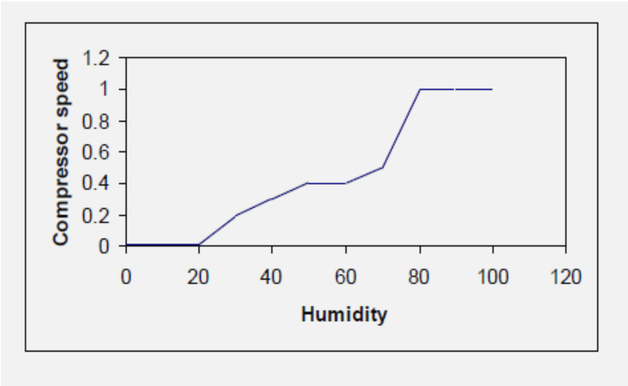

Figure 5. 11 Compressor speed with humidity

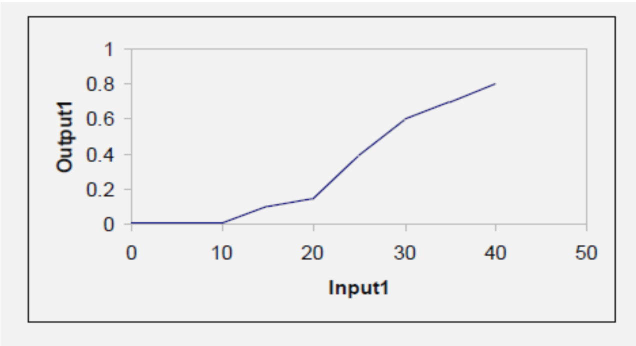

Figure 5. 12 Output with input1 (Temp)

The figure 5.10 shows compressor speed with respect to temperature by using fuzzy rules. The figure 5.11 shows compressor speed with respect to humidity by using fuzzy rules. The figure 5.12 shows the output1 with respect to input1 by using neuro fuzzy rules. The figure 5.13 shows the output1 with respect to input2 by using neuro fuzzy rules.

Figure 5. 13 Output with input 2 (Humidity)

5.2 Duct System

The duct system is an air distribution system. It is basically used to supply cool air into the required areas. The traditional ducting system designed with one duct, which was used to supply air from cooler to room, they do not use the return duct. Supply duct used to deliver the cool air into the room from the cooler. Cooler receives air from the outer surroundings. Sometimes exhaust fan are used in order to reduce humidity. The room temperature is incredibly less as compared to temperature of outer surroundings. So at every time it is needed that cooler fan and water pump must run at high speed to maintain the low temperature. It results in higher consumption of power.

5.2.1 Traditional Duct System

The traditional ducting system designed with one duct, which was used to supply air from cooler to room, they do not use the return duct. Supply duct used to deliver the cool air into the room from the cooler. Cooler receives air from the outer surroundings. Sometimes exhaust fan are used in order to reduce humidity. The room temperature is incredibly less as compared to temperature of outer surroundings. So at every time it is needed that cooler fan and water pump must run at high speed to maintain the low temperature. It results in higher consumption of power.

5.2.2 Two Way Duct System Using Fuzzy Logic Control System

This model is intended for autonomous ducting system to regulate the entire process and to maintain the room environment cool and non-humid. This system is solely used to convert the high temperature into low temperature; it is ineffectual to convert the low temperature to high temperature. Subsequently, this duct system maintains the temperature, if temperature is high.

The proposed model works on two ducts, one is the supply duct and another is the return duct. These ducts are connected between the air cooler and the room. A cooler fan supplies cool air from the cooler to the room and it utilizes one exhaust fan to supply air from the room to the cooler. The starting point of the supply duct is connected at the front of the cooler wherever the cooler fan located and ending point is connected with the grills of any room. This duct is employed for supplying the cool air from the cooler into the room. The starting point of the return duct is connected with the room wherever the exhaust fan is to be found and the ending point is connected at the rear of cooler. This duct is employed for ventilation and provides the room air to the cooler. The air supplied by the return duct must be cooler than the environment. In the proposed design the cooler receives air from the room, not from the outer surroundings and the room temperature is extremely less as compared to the outer surroundings. By the rotation of the cooled air from the cooler to the room and the room to the cooler this technique maintains the desired room temperature at a considerably low speed of cooler fan and pump, leading to a low consumption of power.

This work is proposed to compute the speed of cooler fan, pump and exhaust fan with the help of Mamdani type of fuzzy inference system. This model uses six triangle membership functions for temperature that is determined over a scale range from 0ºC to 55ºC and five triangle membership functions for humidity that determined over a scale range from 0% to 100%. Membership functions for fuzzy sets can be defined in many ways as long as they follow the rules of the definition of a fuzzy set. Tables 5.3 and 5.4 show membership functions and ranges for input variables Temperature and Humidity respectively.

Table 5.3 Membership function and range of input variable “Temperature”

Membership Function	Range
Too Cold	0-10
Cold	5-20
Normal	10-30
Warm	20-40
Hot	35-50
Very Hot	45-55

Table 5.4 Membership function and range of input variable “Humidity”

Membership Function	Range
Dry	0-25
Refreshing	10-45
Moist	30-70
Wet	55-90
Too Wet	80-100

The shape of the membership function used defines the fuzzy set and so the decision on which type to use is dependent on the purpose. The choice of membership function depends on the aspect of fuzzy logic; it allows the required values to be interpreted in desired form. Temperature is measured as Too cold, Cold, Normal, Warm, Hot, Very hot. Humidity is measured as Dry, Refreshing, Moist, Wet, Too wet. Fan, pump and exhaust fan are measured as Stop, Very slow, Medium, High, Very high. Fig. 5.14 and 5.15 show plot of membership functions for input variables Temperature and Humidity respectively. Table 5.5 shows membership functions and ranges for output variables speed of fan, speed of pump and speed of exhaust fan. Fig. 5.16, 5.17 and 5.18 shows plot of membership functions for output variables speed of fan, speed of pump and speed of exhaust fan respectively.

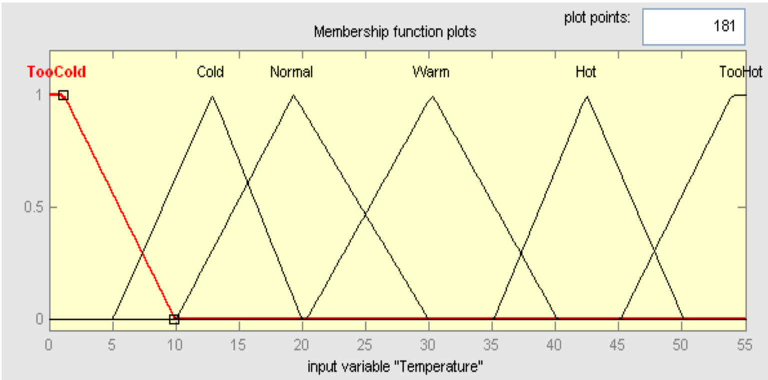

Figure 5. 14 Membership function for input variable “Temperature”

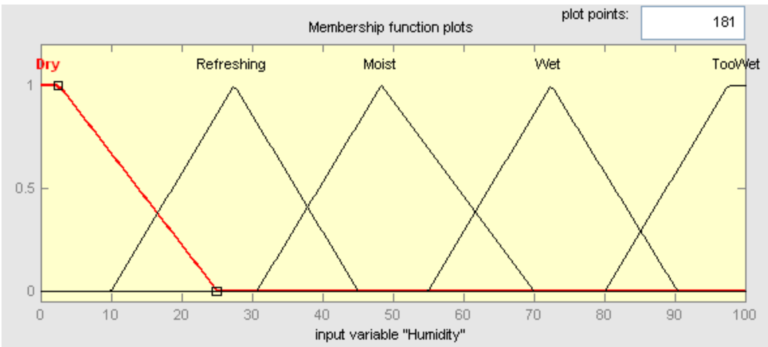

Figure 5. 15 Membership function for input Variable “Humidity”

Table 5.5 Membership function and range of output variables Fan, Pump and Exhaust Fan Speed

Membership Function	Range
Stop	0-5
Very Slow	0-35
Slow	20-60
Medium	40-80
High	60-90
Very High	80-100

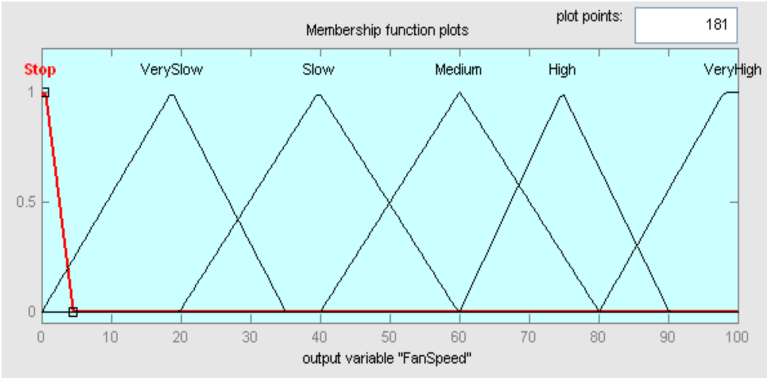

Figure 5. 16 Membership function for output Variable “Fan Speed”

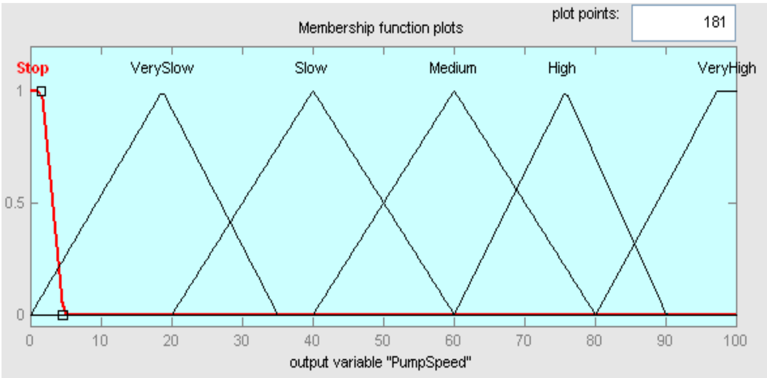

Figure 5. 17 Membership function for output Variable “Pump Speed”

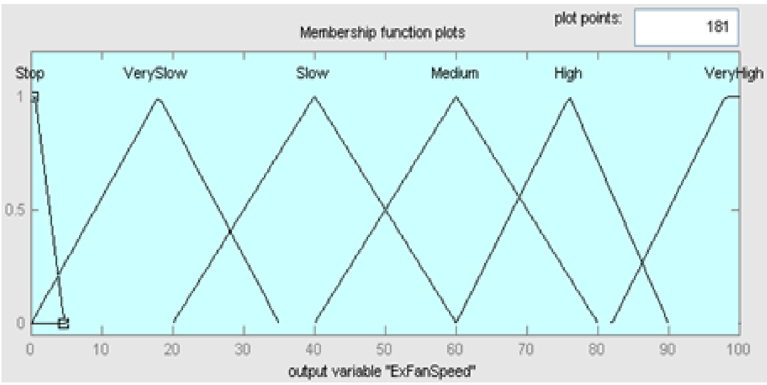

Figure 5. 18 Membership function for output Variable “Exhaust Fan Speed”

Table 5.6 Set of proposed rules

Rules	Temperature	Humidity	Fan Speed	Pump Speed	Duct In Speed
1	Too Cold	Dry	Stop	Stop	Stop
2	Too Cold	Refreshing	Stop	Stop	Stop
3	Too Cold	Moist	Stop	Stop	Stop
4	Too Cold	Wet	Stop	Stop	Stop
5	Too Cold	Too Wet	Very Slow	Stop	Stop
6	Cold	Dry	Very Slow	Very Slow	Stop
7	Cold	Refreshing	Very Slow	Very Slow	Very Slow
8	Cold	Moist	Very Slow	Stop	Very Slow
9	Cold	Wet	Slow	Stop	Slow
10	Cold	Too Wet	Slow	Stop	Slow
11	Normal	Dry	Very Slow	Very Slow	Very Slow
12	Normal	Refreshing	Slow	Very Slow	Very Slow
13	Normal	Moist	Medium	Slow	Slow
14	Normal	Wet	Medium	Very Slow	Slow
15	Normal	Too Wet	Medium	Stop	Medium
16	Warm	Dry	Medium	Medium	Slow
17	Warm	Refreshing	Medium	Medium	Medium
18	Warm	Moist	High	Slow	Medium
19	Warm	Wet	High	Slow	High
20	Warm	Too Wet	High	Stop	High
21	Hot	Dry	High	High	Medium
22	Hot	Refreshing	High	High	Medium
23	Hot	Moist	High	High	High
24	Hot	Wet	Very High	Medium	High
25	Hot	Too Wet	Very High	Slow	Very High
26	Too Hot	Dry	Very High	Very High	Very High
27	Too Hot	Refreshing	Very High	Very High	Very High
28	Too Hot	Moist	Very High	High	Very High
29	Too Hot	Wet	Very High	Medium	High
30	Too Hot	Too Wet	High	Slow	High

This work use 30 rules fuzzy logic that are based on IF THEN statement. The generalized form of logical decision is as follow:

If A, then B.

A.

Therefore, B.

This form strictly followed in case of logical decision, B can only be if A. Fuzzy logic loosens this strictness by saying that B can mostly be if A is mostly or:

If A, then B.

mostly A.

Therefore, mostly B.

Where A and B are now fuzzy numbers. The reasoning above requires a set of rules to be defined. These rules are linguistic rules to relate different fuzzy sets and numbers. The general form of these rules is: "if x is P then y is Q," where x and y are fuzzy numbers in the fuzzy sets P and Q respectively. These fuzzy sets are defined by membership functions. There can be any number of input and output membership functions for the same input as well, depending on the number of rules in the system. For example, a system could have membership functions that represent slow, medium, and fast as inputs. Table 5.6 contains thirty rules. These rules are based on IF THEN statement. For example:

IF Temperature is Cold and Humidity is Dry THEN Fan Speed is Very Slow, Pump Speed is Very Slow and Exhaust Fan is Stop.

5.2.2.1 Structure of Proposed Model

The architecture of proposed model of fuzzified ducting system consists of a cooler with fuzzy logic control system. The cooler is placed on the roof of the building and it has a fan to circulate air, a water pump to lift water from tank and spread it on the grills of grass. Two exhaust fans are placed in the duct: one to pull air from room and transfer it into cooler and the other to push air from the room to the surrounding environment. Sensors are required to keep track of room temperature and humidity in the environment. Fuzzifiers of fuzzy logic control system communicate with sensors. It uses defuzzifiers for each output connected via actuators. Fig. 5.19 shows a detailed architecture of the proposed system.

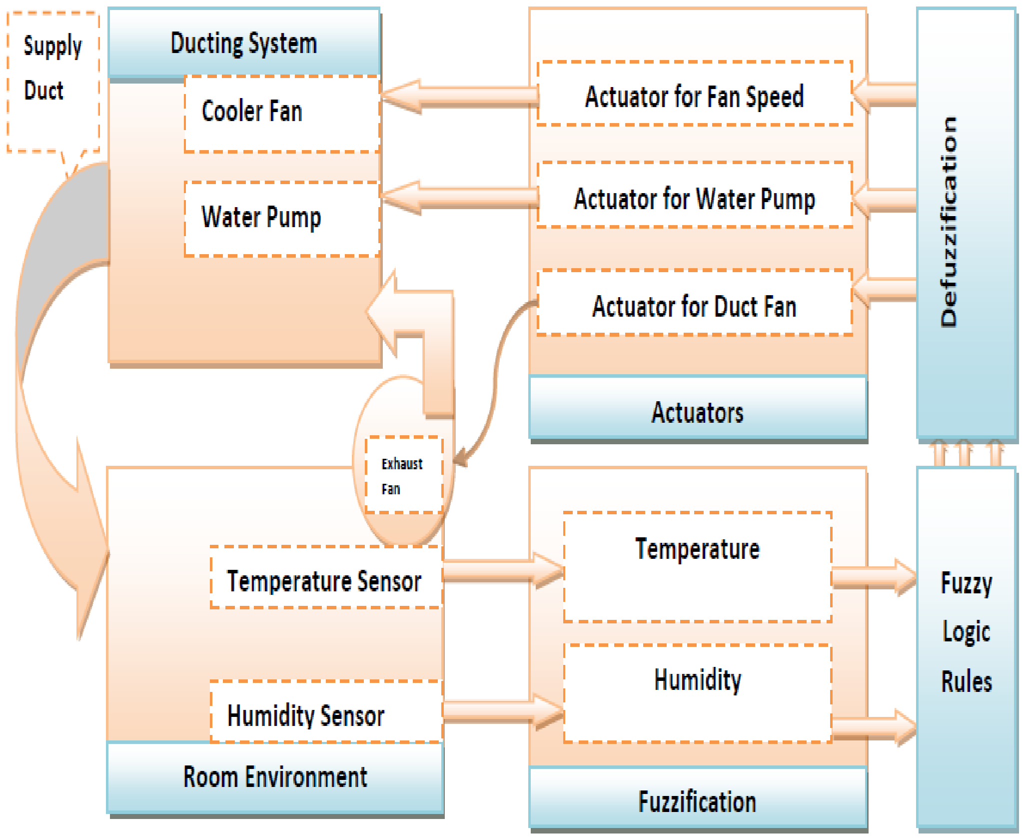

Figure 5. 19 Architecture of duct system

5.2.2.2 Working of Proposed Model

This model works on the basis of measured temperature and humidity. So firstly measure the room temperature and humidity points for exploitation the value of temperature and humidity. We have to apply fuzzy base rules on these measured values to find the crisp value of cooler fan speed, speed of pump and speed of the exhaust fan. As per the calculation of the crisp value, we have to set the speed of all the output (speed of cooler fan, speed of pump and speed of exhaust fans).

For example, if measured temperature is 27 ºC and humidity point is 50%, the calculated crisp value of cooler fan speed will be 68.6, crisp value for speed of pump will be 40 and crisp value for speed of exhaust fan will be 53.6. Now according to the crisp values we can set the speed of all output (speed of cooler fan, speed of pump and speed of exhaust fan) with help of actuators.

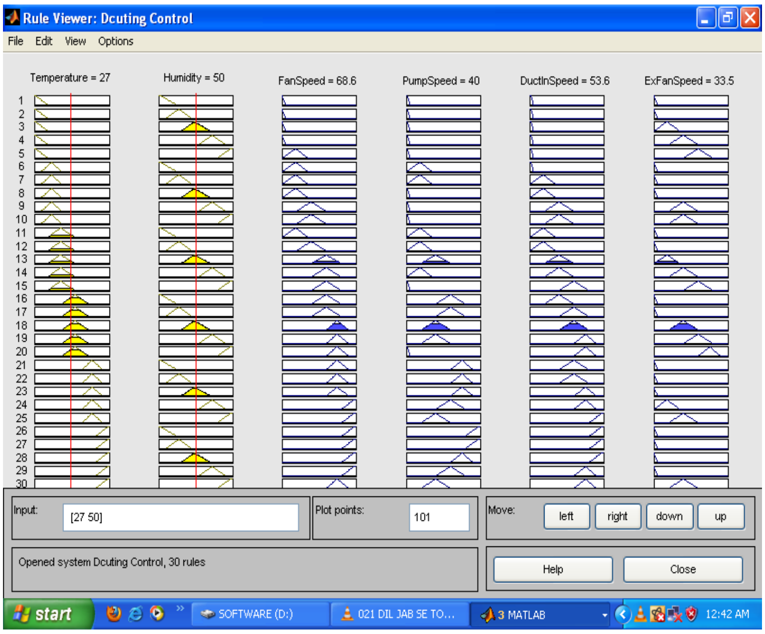

Figure 5. 20 Calculation of Crisp value using Mat-lab

5.3 Comparison between traditional duct system and two way duct system

Fuzzified two-way ducting system gives better result as compare to traditional duct system with the help of two duct, one is supply duct and another is return duct.

Table 5.7 Results of traditional duct system and two way duct system

Input		Traditional duct system			Two way duct system		
Temp.	**Humidity**	**Fan Speed**	**Pump Speed**	**Exhaust Speed**	**Fan Speed**	**Pump Speed**	**Exhaust Speed**
9.50	14.5	1.6	30.4	23.4	1.75	1.75	15.2
12.9	6.92	21.4	35.2	21.3	14.3	14.3	13.4
6.25	70	23.6	25	33.3	14.5	1.79	31.6
40	10	75.9	89.1	22.4	75	75	60
43	70	N/A	N/A	N/A	93.5	60	75
49	10	N/A	N/A	N/A	86.1	86.1	69.9

5.4 Conclusion

The proposed research finds that Neuro fuzzy algorithm is better than fuzzy logic algorithm in air conditioning system. Neuro logic algorithm gives a better control than fuzzy logic. Subsequently, this model works with a fuzzified duct system with two ducts, (one is the supply duct and another is the return duct) and one exhaust fan in order to rotate constant air inside the room.