

# Design and Implementation of Fuzzy Logic Controller for Split Air-conditioner system to simultaneous control of Temperature and Humidity

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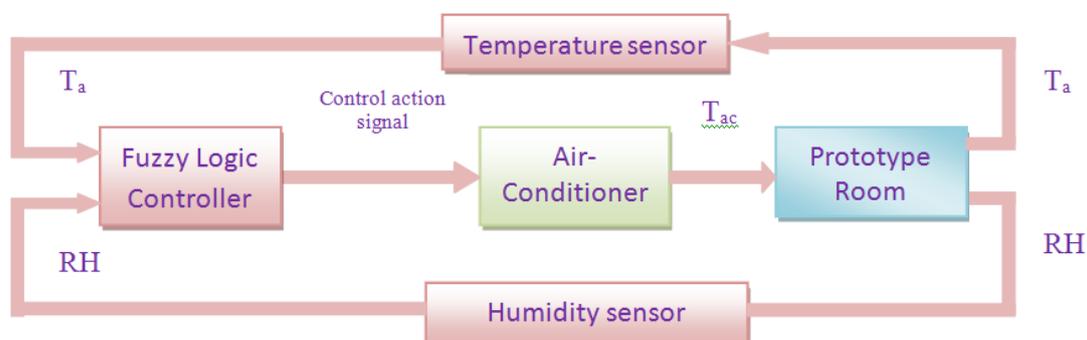
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**Abstract:** This paper reports the design and implementation of Fuzzy Logic Controller (FLC) for Split Air-Conditioner to simultaneous control of Temperature and Humidity. In present study the fuzzy logic control is applied to vary the Room Temperature and Humidity by modulating the compressor speed in such a way to maintain thermal comfort within acceptable limits. The FLC has employed in MATLAB-simulink for computer imitation and also on hardware platform using commercially available 8-bit ATmega 328 microcontroller through embedded C-coding for factual exercise. Experiment is carried out with different scenarios. The results obtained shows that the values for Fanger's PMV index lies between -0.34 to 0.5 and PPD index below 10% which is within acceptable limits. Thus Fuzzy Logic controller offered an effective solution to accelerate the dehumidifying action and brought the relative humidity within acceptable limits, which can be prominently used in Split Air-Conditioners.

**Index Terms** - Fuzzy Logic Controller, Split Air-conditioner, Compressor speed, Fanger's PMV index, MATLAB-Simulink.

## I. INTRODUCTION

In summer season one of the contributors to discomfort is the moisture. Removal of moisture from homes with air-conditioners requires additional control technique along with temperature control. Since air is able to hold only a finite amount of water vapor and that amount is dependent on air temperature. Warm air can clutch more moisture than cold air. In air-conditioner the evaporator is made from the copper coils carry cold refrigerant on which air from home is blown, so moisture from the air condenses onto the evaporator coil which is captured and removed away. The quantity of moisture removal depends upon the evaporator coil temperature. Lower the evaporator coil temperature, higher will be the moisture removal. During hot-humid climate it is necessary to lower the air temperature and reduce the humidity [1]. Moisture removal can be increased by blowing air more slowly. Thus by modulating the blower speed the moisture removal rate can be controlled [2]. Moisture removal also depends on equipment sizing and its operation. If an air-conditioner is oversized, it will operate for only short period of time and that will reduce moisture removal performance. The right sized equipment will operate fairly constant which improves moisture removal process. The Air-conditioners cool the homes by removing heat and moisture from the air. The proposed air conditioning system with fuzzy logic controller shown in figure1 has been installed in a prototype room to vary the Room Temperature and Humidity in such a way to maintain thermal comfort within acceptable limits that obeys Fanger's PMV index. This is achieved by adjusting the evaporator coil temperature.



**Figure 1: Block diagram of Room- Temperature and Humidity control using Fuzzy controller**

## II. DESIGNING OF FUZZY LOGIC CONTROLLER

Fuzzy logic is a methodology for expressing operational laws of a system in linguistic terms instead of mathematical equations. Now it is becoming formal technique because of its salient features. Fuzzy controller was more robust, more energy efficient and

faster in responding to changes compared with PID controller [3]. Also with fuzzy logic control a steady temperature is achieved with 8.92% energy saving compared to ON-OFF control [4]. Self-tuning fuzzy controllers designed by *Huang and Nelson(1999)* for HVAC system by regulating the steam flow rate proves excellent achievement in dynamic performance parameters, fast rise time without overshoot[5].

Fuzzy logic is implemented in following three phases:

- Fuzzification (crisp input to fuzzy set mapping)
- Inference (fuzzy rule generation)
- Defuzzification (fuzzy to crisp output transformation)

The designed FLC shown in figure 2 has two input fuzzy variables: *temperature (T)* and *humidity (H)*, one output fuzzy variable: *count (u)*. The *temperature (T)* is the current (measured) value of air temperature of room and *humidity (H)* is the current (measured) value of relative humidity of room. The *count* means a value in the range 0 to 255 that decides the magnitude of output voltage signal. The Universe of Discourse for (*T*) is 10°C to 50°C, for (*H*) it is 20% to 80%, for (*u*) it is 0 to 255. The ranges of input and output variables chosen from Knowledge data base are depicted in tables 1, 2 and 3. Fuzzy membership functions after tuning being applied are shown in figures 3, 4 and 5.

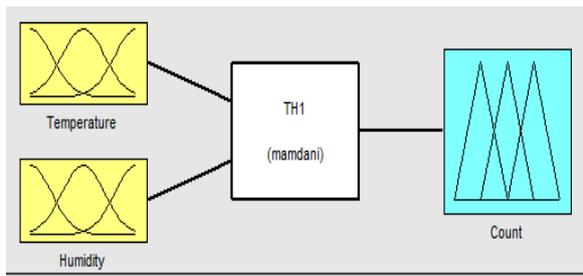


Figure 2: MISO FIS

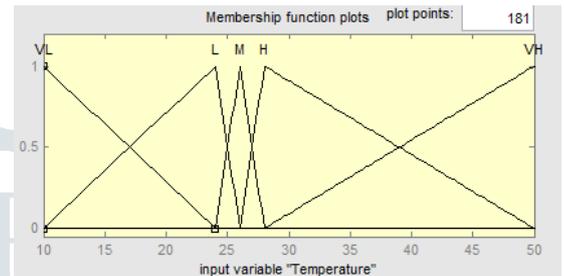


Figure 3: MFs for input variable 'temperature'

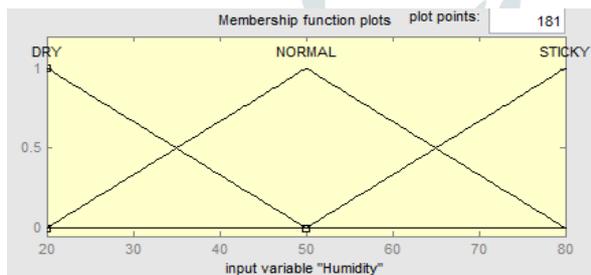


Figure 4: MFs for input variable 'humidity'

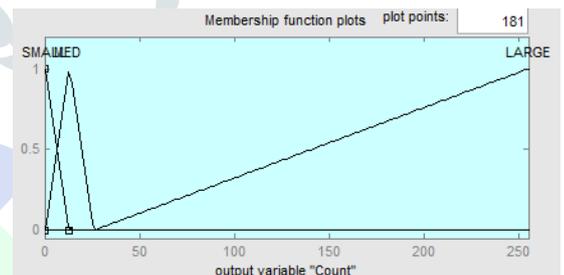


Figure 5: MFs for output variable 'count'

Table 1: Fuzzy set for Input variable 'temperature'

MF No.	Fuzzy sets	Intervals
1	VERY LOW (VL)	[10 10 24]
2	LOW (L)	[10 24 26]
3	MEDIUM (M)	[24 26 28]
4	HIGH (H)	[26 28 50]
5	VERY HIGH (VH)	[28 50 50]

Table 2: Fuzzy set for Input variable 'humidity'

MF No.	Fuzzy sets	Intervals
1	DRY (D)	[20 20 50]
2	NORMAL (N)	[20 50 80]
3	STICKY (S)	[50 80 80]

Table 3: Fuzzy set for Output variable 'count'

MF No.	Fuzzy sets	Intervals
1	SMALL	[ 0 0 13]
2	MEDIUM	[ 0 13 26]
3	LARGE	[ 13 255 255]

Rule Base: The 15 rules of inference are as shown in table 4.

Table 4: Rule base for Temperature and Relative Humidity control

Count (c)		Relative Humidity (H)		
		D	N	S
Temperature (T)	VL	SMALL	SMALL	SMALL
	L	SMALL	SMALL	MED
	M	SMALL	MED	LARGE
	H	MED	LARGE	LARGE
	VH	LARGE	LARGE	LARGE

Table 4: Rule base for Temperature and Relative Humidity control

The Rule View of FIS is shown in figures 6.

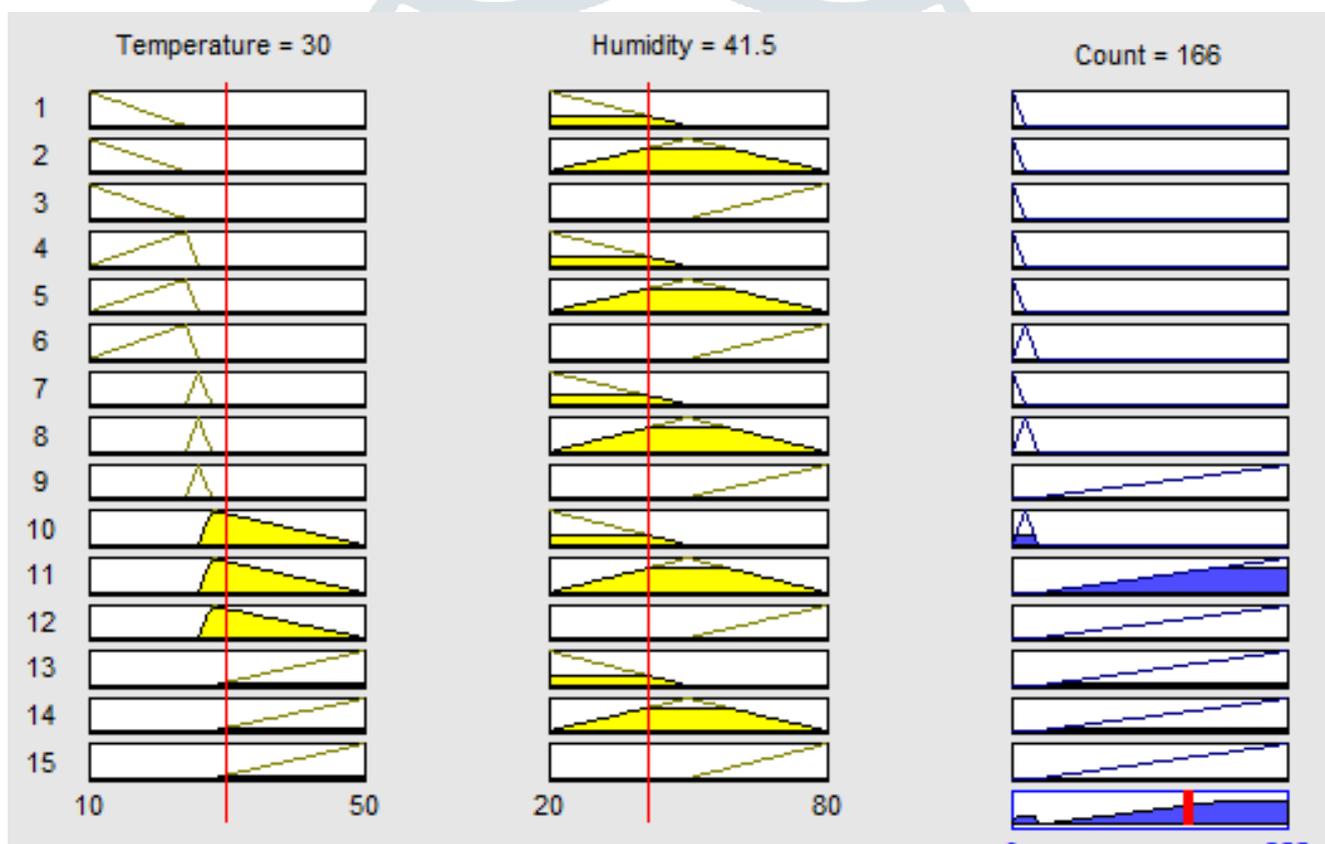


Figure 6: Rule View of FIS for Temperature and Relative Humidity control

### III. SIMULINK MODEL OF AN OVERALL SYSTEM

During experimentation an isolated prototype room of dimension 0.61m \* 0.76m \*0.91m made from thermocol with thickness 0.038m is considered into which an evaporator unit of split AC is mounted. The Simulink model of an overall system created using energy balance equations is shown in figure 7[6]. It consists of different modules such as Thermal model of prototype-room, Humidity model of prototype-room, Thermal model of an Air-conditioner model and MISO type Fuzzy logic controller.

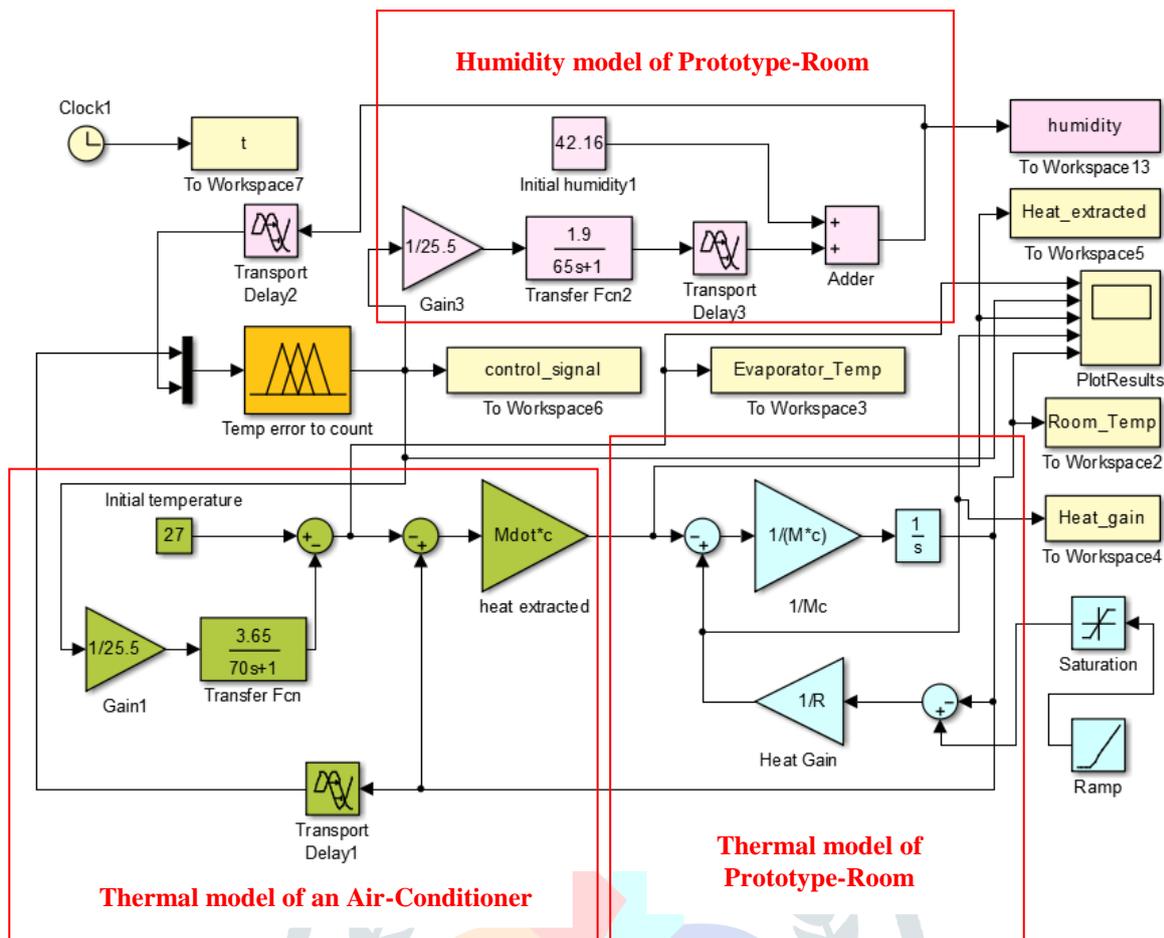


Figure 7: MATLAB Simulink model of plant having prototype room and air-conditioner with fuzzy logic controller with MISO FIS for Temperature and Relative humidity control

IV. PSEUDO CODE

The part of code designed for FISs in Arduino integrated development environment is shown below.

```

1. Case II: else if ((t<=24 && t<26) && (h<50)) then
2.     {d1=(26-t)/2; // degree of MF L of temperature
3.     d2=(t-24)/2; // degree of MF M of temperature
4.     d3=(50-h)/30; // degree of MF DRY of humidity
5.     d4=(h-20)/30; // degree of MF NORMAL of humidity
6.     if (d1<d3)
7.     { a1= d1;}
8.     else
9.     {a1= d3;}
10.    if (d1<d4)
11.    {b1= d1;}
12.    else
13.    {b1= d4;}
14.    if (d2<d3)
15.    {c1= d2;}
16.    else
17.    {c1= d3;}
18.    if(a1>b1)
19.    {{if(a1>=c1)
20.     {m1=a1;}
21.     else
22.     {m1=c1;}}}
23.    else if (b1>=c1)
24.    {m1=b1;}
25.    else
26.    m1=c1;
27.    if (d2<d4)

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28.     {m2= d2;}
29.     else
30.     {m2= d4;}
31. cr =((m1*Peak of MF SMALL of count)+(m2* Peak of MF MED of count))/(m1+m2); // calculate crisp value of
count
32. end}
    
```

**V. EXPERIMENTAL OBSERVATIONS**

Experiment has carried out for half an hour and the data logged for various quantities has tabulated.

Table 5: Sample of Experimental observations (without disturbances)

Time (sec)	Temp (C)	Humi dity (%)	d1	d2	d3	d4	Count (cr)	PWM (%)	PMV	PPD (%)
0	26.03	31.21	0.99	0.01	0.63	0.37	10.47	4.11	0.25	6
5	25.78	31.16	0.11	0.89	0.63	0.37	7.35	2.88	0.18	6
10	26.29	31.14	0.85	0.15	0.63	0.37	39.08	15.32	0.33	7
15	26.32	31.04	0.84	0.16	0.63	0.37	41.33	16.21	0.34	7
20	26.66	30.94	0.67	0.33	0.64	0.36	68.76	26.96	0.44	9
25	26.73	30.86	0.63	0.37	0.64	0.36	73.15	28.69	0.45	9
30	25.73	30.75	0.13	0.87	0.64	0.36	7.23	2.83	0.16	6
35	25.93	30.58	0.04	0.96	0.65	0.35	7.17	2.81	0.22	6
40	26.29	30.57	0.85	0.15	0.65	0.35	38.93	15.27	0.32	7
45	25.63	30.66	0.18	0.82	0.64	0.36	7.2	2.82	0.13	5
50	25.78	30.71	0.11	0.89	0.64	0.36	7.21	2.83	0.18	6
55	24.88	30.74	0.56	0.44	0.64	0.36	7.51	2.94	-0.09	5
60	25.02	30.89	0.49	0.51	0.64	0.36	7.73	3.03	-0.04	5

Table 6: Sample of Experimental observations (with disturbances)

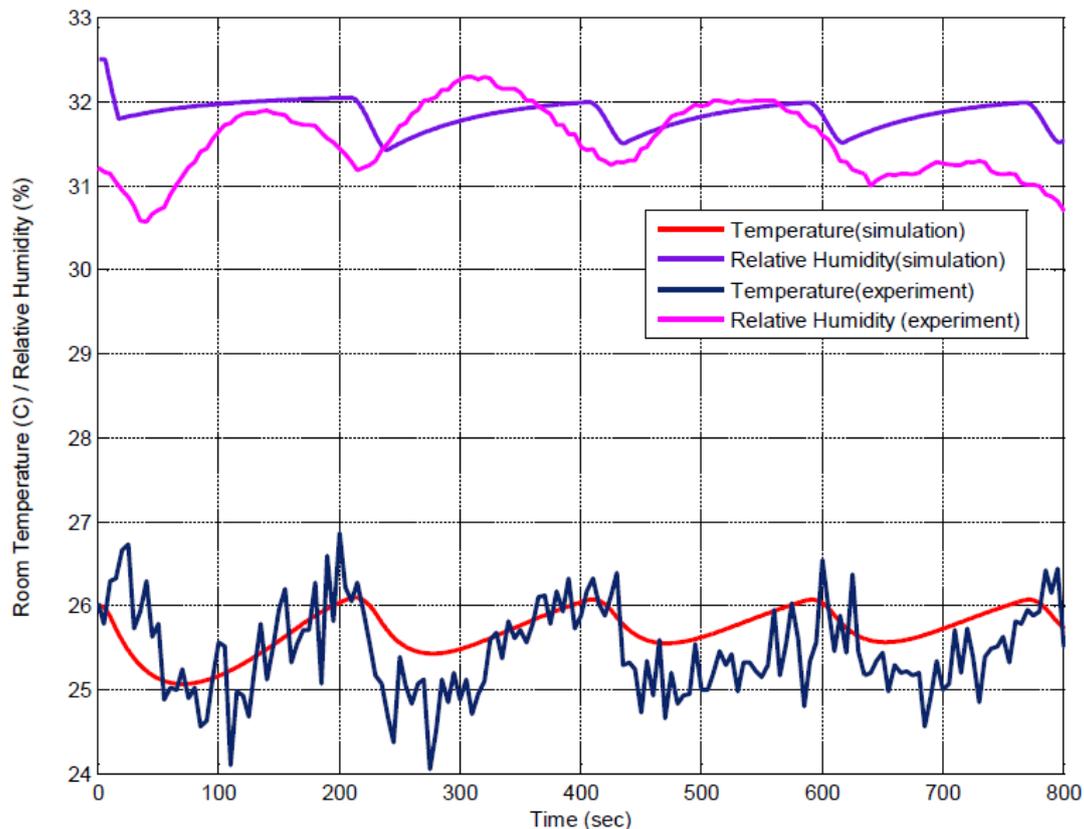
Time (sec)	Temp (C)	Humi dity (%)	d1	d2	d3	d4	Count (cr)	PWM (%)	PMV	PPD (%)
0	26.73	34.21	0.63	0.37	0.53	0.47	74.46	29.2	0.48	10
5	26.9	34.21	0.55	0.45	0.53	0.47	85.09	33.37	0.53	11
10	26.95	34.24	0.52	0.48	0.53	0.47	87.71	34.4	0.55	11
15	26.61	34.26	0.69	0.31	0.52	0.48	66.04	25.9	0.45	9
20	26.61	34.25	0.69	0.31	0.52	0.47	66.03	25.9	0.45	9
25	26.66	34.24	0.67	0.33	0.53	0.47	69.5	27.26	0.46	9
30	26.93	34.24	0.54	0.46	0.53	0.47	86.51	33.93	0.54	11
35	26.71	34.27	0.65	0.35	0.52	0.48	72.85	28.57	0.48	10
40	27.1	34.31	0.45	0.55	0.52	0.48	89.79	35.21	0.59	12
45	26.64	34.2	0.68	0.32	0.53	0.47	67.77	26.58	0.45	9
50	26.66	33.86	0.67	0.33	0.54	0.46	69.42	27.22	0.46	9
55	27.12	33.93	0.44	0.56	0.54	0.46	88.39	34.66	0.59	12
60	26.44	33.88	0.78	0.22	0.54	0.46	52.71	20.67	0.38	8
65	27	33.9	0.5	0.5	0.54	0.46	86.55	33.94	0.56	12
70	26.71	33.86	0.65	0.35	0.54	0.46	72.76	28.53	0.47	10
75	26.78	33.26	0.61	0.39	0.56	0.44	77.43	30.36	0.49	10
80	26.9	33.31	0.55	0.45	0.56	0.44	83.94	32.92	0.52	11
85	26.66	33.79	0.67	0.33	0.54	0.46	69.4	27.22	0.46	9
90	27.03	34.94	0.49	0.51	0.5	0.5	91.09	35.72	0.58	12
95	26.73	36.15	0.63	0.37	0.46	0.54	74.89	29.37	0.5	10

100	25.85	37.77	0.07	0.93	0.41	0.59	9.33	3.66	0.25	6
105	25.46	40.23	0.27	0.73	0.33	0.67	10.07	3.95	0.15	5
110	25.17	42.36	0.41	0.59	0.25	0.75	9.27	3.63	0.08	5
115	25.12	43.82	0.44	0.56	0.21	0.79	9.05	3.55	0.08	5
120	24.15	44.71	0.93	0.07	0.18	0.82	4.73	1.86	-0.2	6
125	24.71	45.23	0.65	0.35	0.16	0.84	7.18	2.82	-0.04	5
130	23.49	45.44	0.65	0.35	0.16	0.84	4	1.57	-0.39	8
135	23.32	45.46	0.65	0.35	0.16	0.84	4	1.57	-0.44	9
140	23.9	45.01	0.65	0.35	0.16	0.84	4	1.57	-0.28	7
145	23.78	44.3	0.65	0.35	0.16	0.84	4	1.57	-0.32	7
150	23.71	43.56	0.65	0.35	0.16	0.84	4	1.57	-0.34	7

**VI. RESULT AND DISCUSSION**

**6.1 without disturbance signals:**

Figure 8 shows the simulated and experimental results of simultaneously controlled Room Temperature and Relative Humidity (without disturbance signals). The experimental results of room temperature and relative humidity shown by blue and pink lines respectively are in good agreement with the simulated results shown by red and violet lines respectively. From table 5, it is seen that the Room Temperature and relative humidity varies between 24.05°C to 26.73°C and 31.21% to 32.29% respectively to maintain thermal comfort. Throughout the experiment the calculated values for PMV index lies between -0.32 to 0.5 and PPD index below 10%.



**Figure 8: Simultaneous control of Room Temperature and Relative humidity (without disturbance)**

**6.2 with disturbance signals:**

Figure 9 shows the experimental results of Temperature and Relative Humidity (with disturbance signals) by blue and pink lines respectively. The humidity has been increased at certain instances by adding water droplets. It is seen that as humidity increases the room temperature as well as evaporator coil temperature decreases to condensate the water droplets there by accelerating the dehumidifying action and finally keeps the relative humidity in acceptable limits. From table 6, it is seen that by applying disturbances inside a room, the relative humidity has increased suddenly to a value (45.46%) then immediately the evaporator\_coil\_temperature and Room Temperature (23.32°C) drops below which causes dehumidifying action prominently and hence reduces the relative humidity to previous level. During disturbances, the PMV(0.59) and PPD(27%) indices goes beyond acceptable limits, but after condensation of water droplet it reside within acceptable limits. The system has performed well in maintaining the comfort level based on temperature and relative humidity parameters.

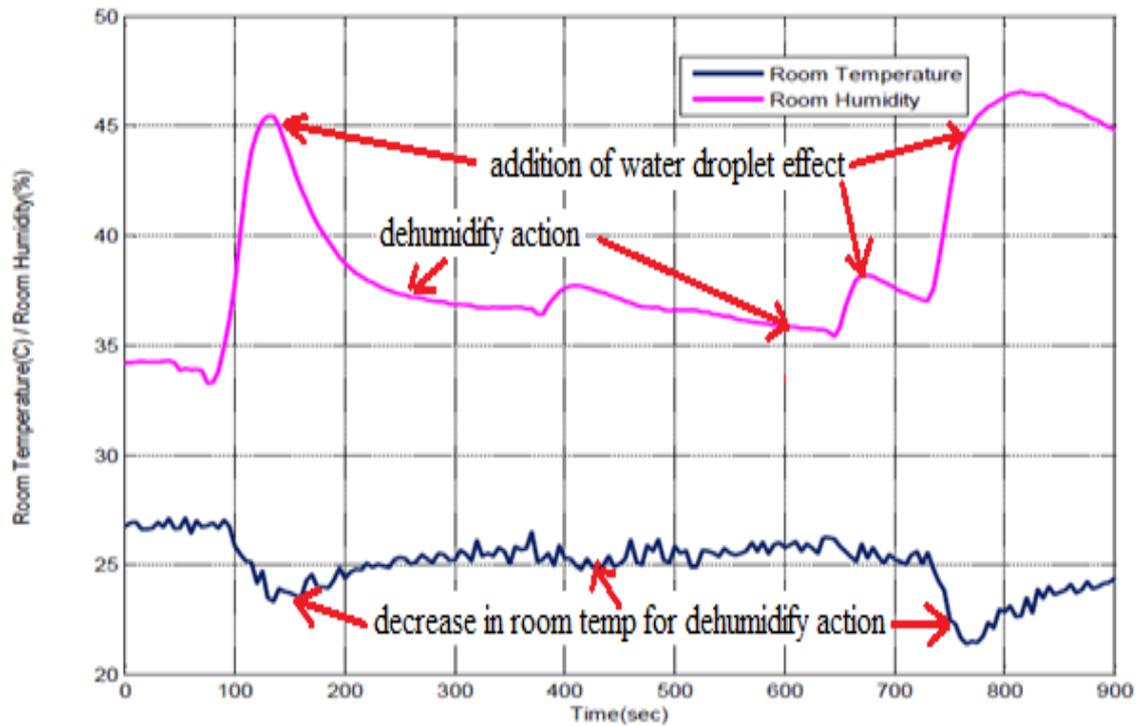


Figure 9: Simultaneous control of Room Temperature and Relative humidity (with disturbance)

## VII. CONCLUSION

Fuzzy Logic Control algorithm is successfully designed and embedded in commercially available 8-bit ATmega328 microcontroller. It offered an effective solution to accelerate the dehumidifying action and brought the relative humidity within acceptable limits, which can be prominently used in Split Air-Conditioners.

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