Fuzzy Logic based Analysis of Livestock Sheds Atmosphere

S. Tayyaba, H. Rasheed, M. W. Ashraf and M. S. Khan

***Abstract*—Seventy percent of population in Pakistan lives in villages. The basic source of income in villages is agriculture and livestock. Because of lack of awareness and modern method (technology) the production rate of live stock products like milk and meat are very low. If the growth rate of the animal's increases then the production of milk and meat can be increased. This is only possible by using the new and lattice technology in control sheds of animals. Some important factors like the temperature, humidity and light can be controlled by using fuzzy logic controller. This is easiest and cheapest way of controlling these factors by applying fuzzy logic controller on air conditioner, heat, exhaust fan and curtains. Here, authors have presented design and simulation of low cost automatic environment controller for live stock sheds. Environmental control consists of temperature, humidity level and light as inputs and air conditioner, heat, exhaust fan and curtains as outputs. Mamdani model is used to verify the mathematical and simulated based results. Research results show that the controller can provide the most suitable conditions for the growth of animals.**

***Index Terms*—Automatic Controller, Automatic Curtains, Simulation, Fuzzy Logic, Live Stock Sheds.**

I. INTRODUCTION

Live stock sector play an important role in the economical growth of any country. It provides milk and protein for the human diet. It is also the sources of income and possible employment opportunities. The main livestock products are organic fertilizer, milk, and meat. Livestock shares about 11.9 in GDP in Pakistan [1]. The main exports of Pakistan is included animal bones, bone base products, wool, hair, wastes material, milk, dry milk, butter, meat, and live animals [2]. These products can be increase by providing more suitable environment. By using new technology in control sheds of animals or by installing control live stock sheds the production rate of these products can be increased. Fuzzy logic is an important controller that can be installed in any live stock sheds for the environment control. An idea has been presented to construct an fuzzy logic based system, fuzzification and deffuzification to analyze the system [3]. The design of air cooling system was presented for a room by using Fuzzy logic technique with inputs temperature and humidity and outputs cooler fan, water pump and exhaust fan [4]. The body measurement of Holstein cows was performed by using image analysis and estimated their weights by using fuzzy logic [5]. Fuzzy and neuro fuzzy based method has been adopted for modeling and feeding intensity of Graylag Geese on reed [6].

The impact of live stock intensification on small holder farms using village poultry has been studied. It has been also observed the integrated agriculture–aquaculture systems, small ruminants, and dairying the studies [7]. Fuzzy logic based technique has been used to study the cattle drinking water quality index. This represents the good quality of consumed water that has been used by the cattle [8]. Building of a discrete event multi model simulation tool of livestock farming systems has been presented. This study regrouping several mathematical models and reproducing cattle herd performances through an individual based model [9]. In this study author has presented sensor based system that measured yield, temperature and electrical conductivity of milk. The animal activity also monitored by using automatic system by using detection based technique. Fuzzy logic has been used to classify mastitis and estrus alerts to reduce the number of false-positive alerts and not to change the level of detected cases of mastitis and estrus [10]. Fuzzy logic based technique has been used for the evaluation of livestock slaughtering [11].

Fuzzy logic is kind of technique that has been proposed and implemented in various filed, industrial control system, liquid control system, home appliances control, robotics, automobile industry, agriculture and live stock industry. This technique has advantage on other methods that it can estimate the behavior of intermediate state. Response of multiple steps can be observed between the maximum and minimum values.

Here, authors have presented the extension of their work that has been presented in NCMCS15. They have presented easiest and cheapest way of controlling live stock sheds environment. Fuzzy logic controller has been used to control temperature and humidity by using air conditioner, heat, exhaust fan and curtains as out parameters. Simulated results were compared by using mathematical model. This kind of research is useful to improve the production rate of milk and meat by providing control environment to the cattle. Increment of product and growth rate of cattle can be useful to enhance the economy of country.

II. SIMULATION

Fuzzy logic tools are used in MATLAB for simulation. FLC comprises of three input parameters for "Automatic Environmental Controller of Livestock Sheds" These input

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parameters are Temperature (T), Humidity (H) and Light (L). Each input variable is labeled by a set of three fuzzy characteristics sets as follow:

T (Temperature) = {Low, Medium, Normal} = {L, M, N}
H (Humidity) = {Less, Normal, High} = {L, N, H}
L (Light) = {Dim, Normal, Intense}

Similarly, the four outputs variables Heater, Air Conditioner, Exhaust and Curtain can also be written as a set of three fuzzy sets values as:

Heater (H) = {Low, Medium, High} = {L, M, H}
Air Conditioner (A) = {Low, Medium, High} = {L, M, H}
Exhaust (E) = {Low, Medium, High} = {L, M, H}
Curtain(C) = {Low, Medium, High} = {L, M, H}

We use 27 fuzzy rules for FIS by using "X^n" formula, Where X is number of fuzzy sets and n is number of inputs. FLC is comprises of three inputs with three membership functions and four outputs also with three membership functions. Fig. 1 shows three input variables: Temperature, Humidity, Light and Heater, Air Conditioner, Exhaust and Curtain as outputs.

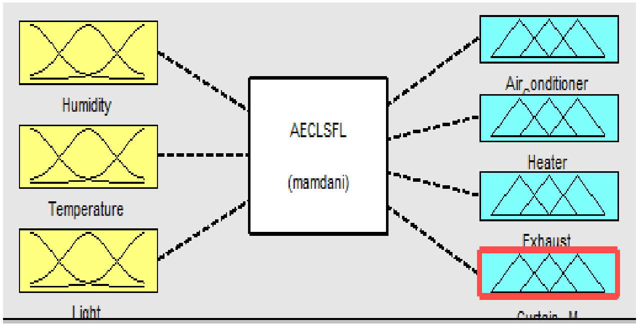

Fig. 1. Fuzzy logic based control system

Fig. 2, Fig. 3 and Fig. 4 show membership functions of input variables. Membership functions can be chosen according to real values of input membership functions and output membership functions but here we use ranges from 0 to100% for the inputs and outputs both. To implement Fuzzy Logic Controller (FLC), Fuzzy Logic Inferring (FIS) has been used.

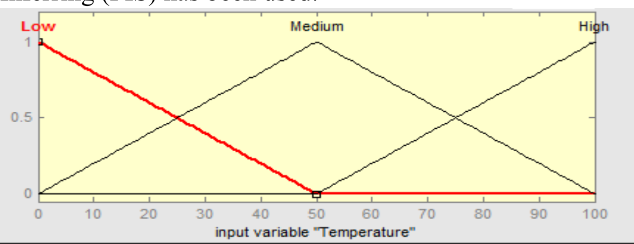

Fig. 2. MFs graph for Input Variable "Temprature"

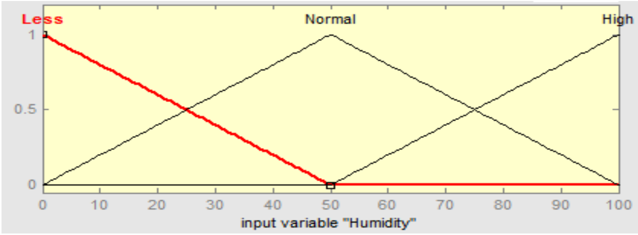

Fig. 3. MFs graph for Input Variable "Humidity"

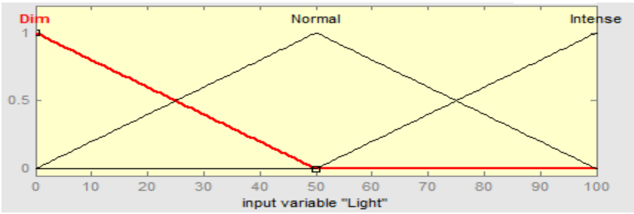

Fig. 4. MFs graph for Input Variable "Light"

The Fig. 5, Fig. 6, Fig. 7 and Fig. 8 show the membership functions of outputs.

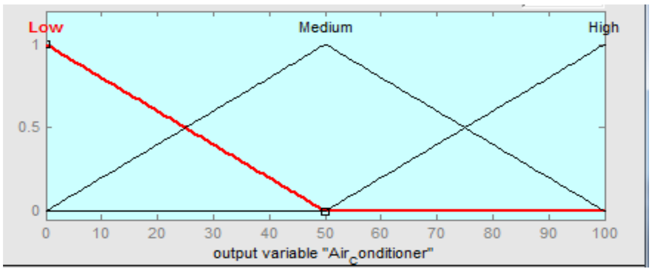

Fig. 5. Graphs of MFs for the Output Variable "Air Conditioner"

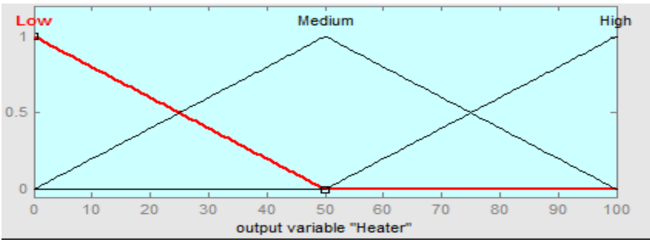

Fig. 6. Graphs of MFs for the Output Variable "Heater"

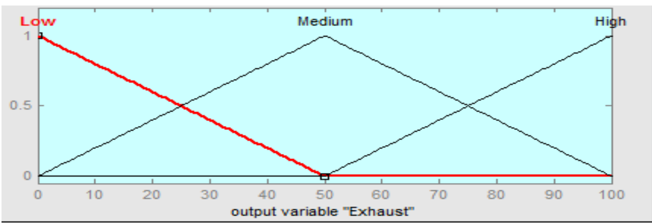

Fig. 7. Graphs of MFs for the Output Variable "Exhaust"

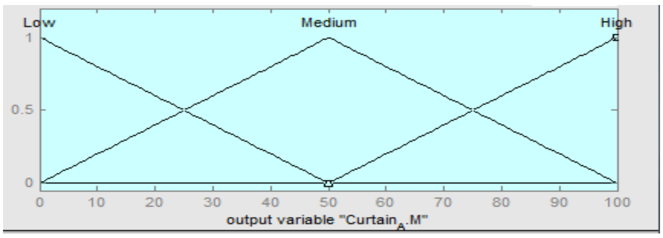

Fig. 8. Graphs of MFs for the Output Variable "Curtain"

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The membership functions input variables and output variables with their ranges are shown in Table I. Here, ranges of membership functions are used as follows:

MF1 range is 0-50
MF2 range is 0-100
MF3 range is 50-100

TABLE I Inputs and outputs MFs with their ranges

MFs	Ranges	Temperature	Humidity	Light	Air Conditioner	Heater	Exhaust	Curtain
MF1	0-50%	Low(L)	Less(Le)	Dim(D)	Low(L)	Low(L)	Low(L)	Low(L)
MF2	0-100%	Medium(M)	Normal(N)	Normal(N)	Medium(M)	Medium(M)	Medium(M)	Medium(M)
MF3	50-100%	High(H)	High(H)	High(H)	High(H)	High(H)	High(H)	High(H)

Twenty Seven (27) fuzzy logic rules were used for fuzzy logic control that is further preceded in MATLAB editor.

The observations are shown in Table II. This table shows the observation using “If” and “THEN” condition.

TABLE II Combination of inputs and outputs

Temperature	Humidity	Light	Air Conditioner	Heater	Exhaust	Curtain
L	Le	D	L	M	L	H
L	Le	N	L	M	L	M
L	Le	I	L	M	L	L
L	N	D	L	M	M	H
L	N	N	L	M	M	M
L	N	I	L	M	M	L
L	H	D	L	H	H	H
L	H	N	L	H	H	M
L	H	I	L	H	H	L
M	Le	D	M	L	L	H
M	Le	N	M	L	L	M
M	Le	I	M	L	L	L
M	N	D	M	L	M	H
M	N	N	M	L	M	M
M	N	I	M	L	M	L
M	H	D	M	M	H	H
M	H	N	M	M	H	M
M	H	I	M	M	H	L
H	Le	D	H	L	L	H
H	Le	N	H	L	L	M
H	Le	I	H	L	L	L
H	N	D	H	L	M	H
H	N	N	H	L	M	M
H	N	I	H	L	M	L
H	H	D	H	L	H	H
H	H	N	H	L	H	M
H	H	I	H	L	H	L

A rules viewer graph is shown in Fig. 9 that indicates 27 rules. It has been observed that the values of inputs like humidity, temperature and light are 41.5, 24.5 and 71.3 respectively. The value of outputs like air conditioner, heater, exhaust and automatic curtains are 34.3, 65.1, 49 and 46.2 respectively.

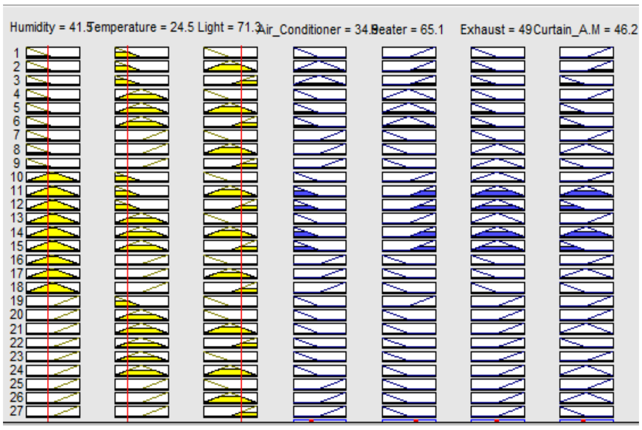

Fig. 9. Rules viewer with 27 rules

Surface viewer graph with various inputs and outputs are shown in Fig. 10, Fig. 11 and Fig. 12.

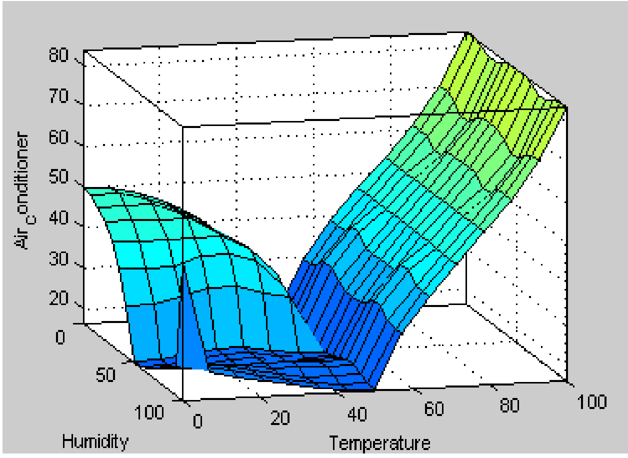

Fig. 10. Relationship among humidity, temperature and air conditioner

This shows that temperature is low, humidity is high then the air conditioner should be low.

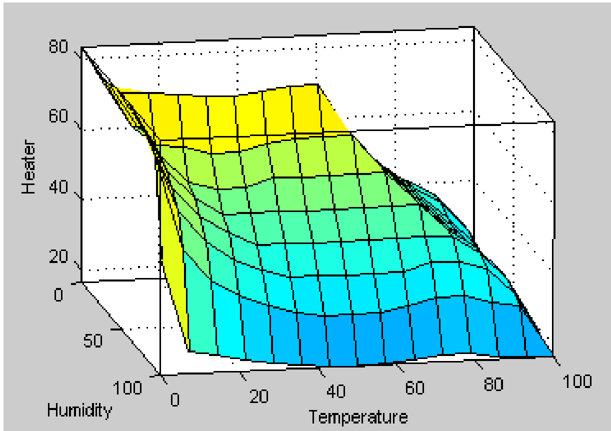

Fig. 11. Relationship among humidity, temperature and heater

This shows that if temperature is low and humidity is high, then the heater must be at high level.

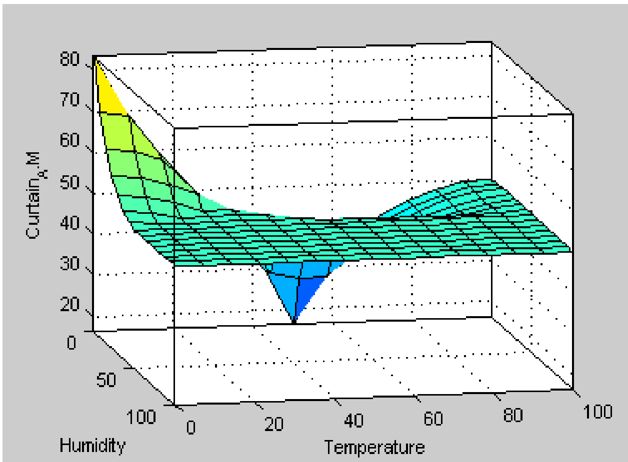

Fig. 12. Relationship between inputs electric motor, tube well and area

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This shows that for low Humidity and medium Temperature, Curtain should be at high level.

III. Mathematical Calculation

For mathematical calculation we have designed the algorithm based on fuzzy logic controller with the % age value of the input and output parameters. These values are:

Temperature= 24.5
Humidity= 41.5
Light = 71.3
Air Conditioner= 34
Heater = 65.1
Exhaust= 49
Curtain = 46.2

The value of the Temperature (24.5) lies in region 1 as shown in the Fig. 13. Membership functions for region 1 are Low (L) and Medium (M). The MFs mf1 and mf2 for these values are:

mf1 = 50 – 24.5/50 = 0.51
mf2 = 1- mf1 = 1- 0.51 = 0.49

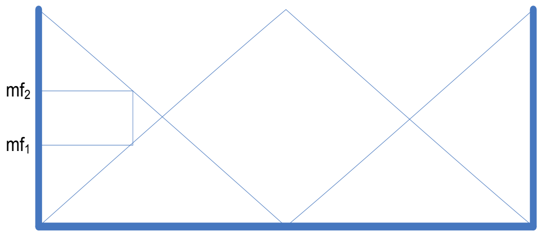

Fig. 13. MFs for temperature

For Humidity (41.5) values lies in the region 1 as shown in the Fig. 14. Membership functions for region 1 are Less (Le) and Normal (N). The MFs mf3 mf4 for these values are:

mf3 = 50 – 41.5/50 = 0.17
mf4 = 1 - mf3 = 1- 0.17= 0.83

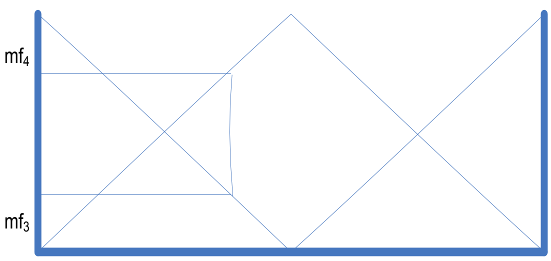

Fig. 14. MFs for humidity

For Light (71.3) value lies in region as shown in fig. 11. Membership functions for region 2 are Normal (N) and Intense (I). The MFs mf5 and mf6 for these values are:

mf5 = 100 – 71.3/50 = 0.574
mf6 = 1 - mf5 = 1- 0.574 = 0.426

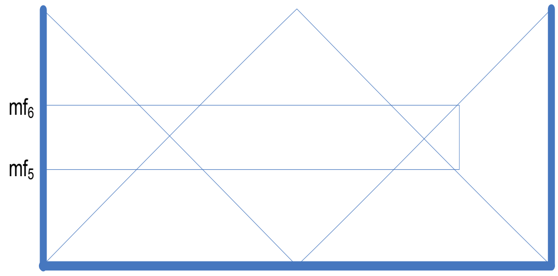

Fig. 15. MFs for light

The rules for fuzzy logic controller were selected according to value of input parameters like Temperature = 24.5, Humidity = 41.5, Light = 71.3. These are listed in Table III.

TABLE III Eight selected rules according to input parameters

Rules	Temperature	Hunidity	Light	Air Conditioner	Heater	Exhaust	Curtain
R_1	L	Le	N	L	M	L	M
R_2	L	Le	I	L	M	L	L
R_3	L	N	N	L	M	M	M
R_4	L	N	I	L	M	M	L
R_5	M	Le	N	M	L	L	M
R_6	M	Le	I	M	L	L	L
R_7	M	N	N	M	L	M	M
R_8	M	N	I	M	L	M	L

Membership functions related rule is given in Table IV.

TABLE IV MFs related to each Rule

Rule No.	Membership Function
R_1	$mf_1 \wedge mf_3 \wedge mf_5$
R_2	$mf_1 \wedge mf_3 \wedge mf_6$
R_3	$mf_1 \wedge mf_4 \wedge mf_5$
R_4	$mf_1 \wedge mf_4 \wedge mf_6$
R_5	$mf_2 \wedge mf_3 \wedge mf_5$
R_6	$mf_2 \wedge mf_3 \wedge mf_6$
R_7	$mf_2 \wedge mf_4 \wedge mf_5$
R_8	$mf_2 \wedge mf_4 \wedge mf_6$

Mamdani's model has been used for calculation of crisp value for fuzzy logic controller. Fuzzy logic based adopted control system has been proposed for automatic electrical control sheds. This system contains FLC with temperature, humidity and light as input parameters. The heater, air conditioner, exhaust and curtains are considered as output parameters. Mamdani's model is used for this system and results for this model are discussed here. The values of inputs and output for fuzzy logic controller of this design are temperature= 24.5, humidity = 41.5, light = 71.3, air conditioner = 34, exhaust fan = 49, heater = 65.1 and moveable auto curtains = 46.2.

For inference engine three MFs has been used for each rule. Table V consists of membership functions corresponding to each rule. As AND logic has been used so membership function with smallest value is selected for

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each rule.

TABLE IV MFs related to each rule with values

Rule No.	Membership Function
R_1	$mf_1 \wedge mf_3 \wedge mf_5 = 0.51 \wedge 0.17 \wedge 0.574 = 0.17$
R_2	$mf_1 \wedge mf_3 \wedge mf_6 = 0.51 \wedge 0.17 \wedge 0.426 = 0.17$
R_3	$mf_1 \wedge mf_4 \wedge mf_5 = 0.51 \wedge 0.83 \wedge 0.574 = 0.51$
R_4	$mf_1 \wedge mf_4 \wedge mf_6 = 0.51 \wedge 0.83 \wedge 0.426 = 0.426$
R_5	$mf_2 \wedge mf_3 \wedge mf_5 = 0.49 \wedge 0.17 \wedge 0.574 = 0.17$
R_6	$mf_2 \wedge mf_3 \wedge mf_6 = 0.49 \wedge 0.17 \wedge 0.426 = 0.17$
R_7	$mf_2 \wedge mf_4 \wedge mf_5 = 0.49 \wedge 0.83 \wedge 0.574 = 0.49$
R_8	$mf_2 \wedge mf_4 \wedge mf_6 = 0.49 \wedge 0.83 \wedge 0.426 = 0.426$

Formula used to calculate the outputs are given below.

$$\text{Output} = [\Sigma\, G_j \times R_j / \Sigma\, R_j] \times 100 \quad (1)$$

Where, Rj = Rules used, Gj = Singleton values

The mathematical formula that was used to express exact value of a variable is called singleton value. In the current design output has three values like low, medium and high. If output is high, then singleton value is 1, for Medium 0.5 and for low value is 0.

So,

$\Sigma G_j \times R_J = 0.17\times0+0.17\times0+0.51\times0+0.426\times0+0.17\times0.5+0.17\times0.5+0.49\times0.5+0.426\times0.5$
$= 0.628$

$\Sigma\, R_j = 0.17+0.17+0.51+0.426+0.17+0.17+0.49+0.426$
$= 2.532$

According to the above mentioned formula the output power of FLECS.

$= [\Sigma\, G_j \times R_j / \Sigma\, R_j]$
$= 0.248$

Table V compares the results of MATLAB simulation and design values calculated from Mamdami's Model.

TABLE V Comparison Between simulated and calculated values

Sr. No.	Observation	Results
1	Value from MATLAB Simulation	0.268
2	Value from Mamdani's Model	0.245
3	Difference	0.023

The percentage error has been calculated for all values of fuzzy logic controller

.

$\%\ \text{Error} = [\text{Difference}/\ \text{Actual Value}] \times 100$
$= 0.023/24.5\times100$
$= 0.09\ \%$

Table V shows that results from simulation and design values are very close with only difference of 0.023 for air conditioner. Similarly, we have calculated values for other outputs such as for heater 0.4, 0.12 for exhaust and for curtain 0.197.

The % error for air conditioner is 0.09 %, for heater is 0.61 %, for exhaust is 0 .25 % and for curtain is 0.42 % which is very small. Hence the conclusion has been drawn from above research that the proposed system is efficient and effective for outputs heater, air conditioner, exhaust and curtain from FLECS.

IV. CONCLUSION

Three inputs temperature, humidity and light were considered for analysis. Each input variables is labeled by three fuzzy characteristics sets. Similarly, the output variables heater, air conditioner, exhaust and curtain are expressed as a set of three fuzzy sets. The response of outputs was analyzed. Three membership function of each input and output were defined. Various combinations of rules were define in rule editor and AND logic was used for simulation. Twenty seven fuzzy rules for fuzzy inferring system were used. Fuzzy logic controller is comprises of three inputs with three membership functions and four outputs also with three memberships functions. Simulation results are compared with mathematical calculations by using Mamdani's model. Results are efficient and lesser error as calculated percentage error is only 0.61 % for heater, 0.09 % for air conditioner, 0.25 % for exhaust and 0.42 for curtain. Therefore, the simulated and theoretical results are close agreement that verified the system performance.

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