Simulation and Analysis of Irrigation Controller based on Fuzzy Logic

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

***Abstract* – Agriculture is one of the leading factor that has momentous impact on the GDP growth of the country. It provides the food and fibers for domestic and international industry. About 65 % of total earnings in Pakistan come from export of cotton, rice, and cotton based goods. The irrigation system of Pakistan is one of the best system in the world but still there is entire needs to improve the conventional methods of irrigation system. Significant amount of energy can be saved by using automatic irrigation system through tube wells and electric motors with hybrid power system (Solar & Grid). Hence, large area can be irrigated in less time. Here, authors have presented design and simulation of automatic irrigation control system. MATLAB based fuzzy logic tool has been used for analysis. Tube well and electric motor with hybrid setup have been considered for Inputs and water level, time and area have been considered for outputs to evaluate the efficiency of controller. Simulated and mathematical results were compared and 0.23% error was found. By adopting this technique a large area can be irrigated and crop production will increase. Through hybrid electric power system also useful to reduce the operation costs.**

***Index Terms* – Control System, Fuzzy logic, Simulation, Irrigation.**

I. INTRODUCTION

For the control of automatic irrigation system, various constraints have to been considered and monitored like water level, temperature, humidity, speed of wind and sunshine. The most operative ways to maintain the irrigation system are to decrease the water wastage, lessen the pollution from excess and over irrigation and progress the growth and strength of plants/crops by controlling the above mentioned constraints. Various techniques have been implemented for automatic irrigation control system. One of them is fuzzy logic based controller for automatic monitoring of irrigation system. A fuzzy logic based irrigation control system has been presented based on field programmable gate array (FPGA) for the control of fertigation in greenhouse [1]. A low cost irrigation controller has been presented which integrates with economical and easily accessible electronic constituents, controller and sensor that required requiring trifling human communication [2]. The fuzzy logic based intelligent irrigation control system has been presented by using wireless sensor networks (WSN) precision agriculture (PA). The water flow of the pump has been controlled to provide the required level of moisturizer to the soil of agricultural place [3]. A novel approach has been presented for estimating the working of irrigation systems based on the implementation of fuzzy logic [4]. The design and development of a controller has been presented for the improvements of various factors like energy, heat and water utilization based on fuzzy logic [5]. An automatic irrigation control system has been presented based on the factor of soil moisture by employing wireless sensor network (WSN) [6].

A fuzzy logic based system has been developed capable of regulating the amount of water mandatory for the plants by accumulating the facts from environmental circumstances [7]. The design of an intelligent irrigation system has been presented using wireless sensor networks and fuzzy logic control. The proposed system primarily comprises of WSN and the monitoring center [8]. The Mamdani and Sugeno fuzzy logic based genetic methods have been employed for the modeling of reference evapotranspiration [9]. An automatic irrigation control system has been presented based on global system for mobile communication (GSM) for proficient usage of means and crop development [10]. A number of fuzzy coefficients have been used for four diverse models for efficient approximation of the water steadiness constituents [11]. A fuzzy logic based decision support system has been developed for irrigation and water preservation in cultivation [12]. To decrease the cracking of tomato, a fuzzy logic based controller has been developed to control the environment of greenhouse by considering various factors like substrate temperature, solar radiation and shade temperature [13]. The fuzzy logic based control system has been presented for the control of environmental constraints of the greenhouse. The heating and cooling factors have been employed to confirm the particular assortment of temperature and humidity constraints [14]. Fuzzy logic has been implemented to design a controller to moderate water usage through controlling the factors like soil moisture and temperature of the air in greenhouse [15]. The fuzzy logic based automatic control system has been presented to monitor and control the covering and irrigation procedure [16]. The fuzzy logic controller based irrigation system has been designed. The sensors of moisture from soil and temperature provided the inputs for the controller while the output (on/off) signal was provided to motor and valves to provide the water required by the plants [17]. A controller has been designed for the sensing system of plants using image evaluation for the conciliation of changing ambient brightness [18]. The fuzzy logic based controller has been described to monitor the endangered cultivation. The key linguistic variables have been employed for the subsystems of sensor and actuator [19]. To standardize the growth of plants, a multi stage controller has been designed based on fuzzy logic. Various basic environmental factors compulsory for the normal growth of plants like temperature, water and

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light were evaluated and analyzed [20]. In this work authors present the simulation and mathematical verification of fuzzy logic based controller for automatic irrigation.

II. SIMULATION

Fuzzy logic tool is used in MATLAB for simulation. FLC comprises of two input parameters for automatic irrigation control system. These input parameters are diesel engine and electric motor with hybrid function (Solar and grid). Each input variable is labeled by a set of three fuzzy characteristics sets as follow.

Diesel engine = {Slow, Medium, Fast} = {S, M, F}
Electric motor = {Main, Solar, Hybrid} = {M, S, H}

Similarly the three outputs variables water level, time and area can also be written as a set of three fuzzy sets values as.

Water level = {Low, Medium, High} = {L, M, H}
Time = {Short, Long, Very Long} = {S, L, V}
Area = {Small, Medium, Large} = {S, M, L}

The inputs (diesel engine, electric motor) and outputs (water level, time and area) with mamdani model is shown in Fig. 1.

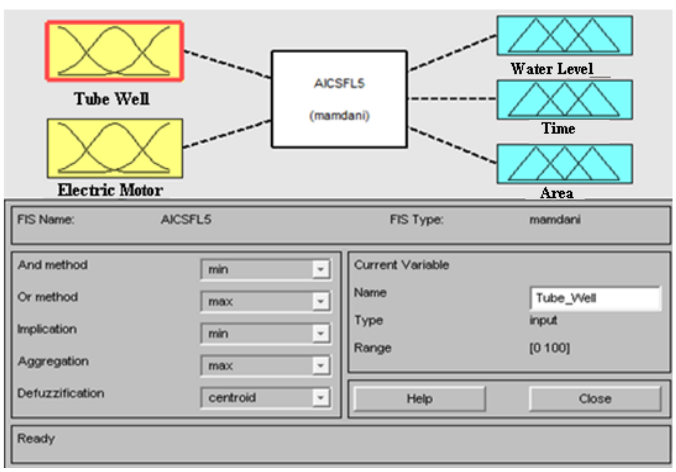

Fig. 1. FIS Editor for automatic irrigation control system

The inputs membership functions are shown in Fig. 2 and Fig. 3. 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), FIS has been used.

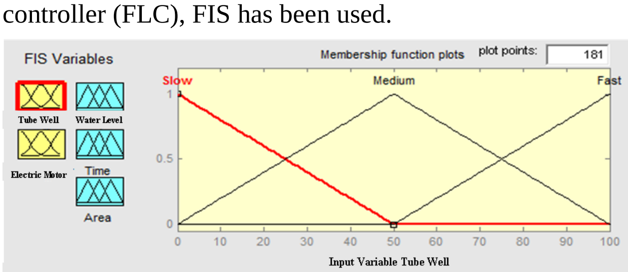

Fig. 2. MFs graph for Input Variable "Tube Well"

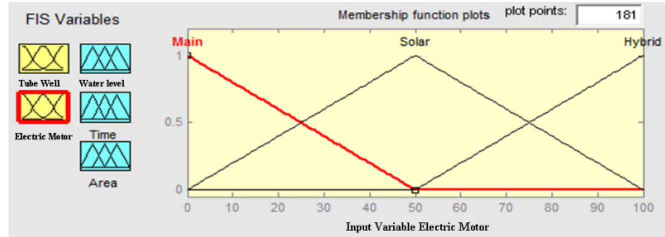

Fig. 3. MFs graph for Input Variable "Electric Motor"

The outputs membership functions are shown in Fig. 4, Fig. 5 and Fig. 6.

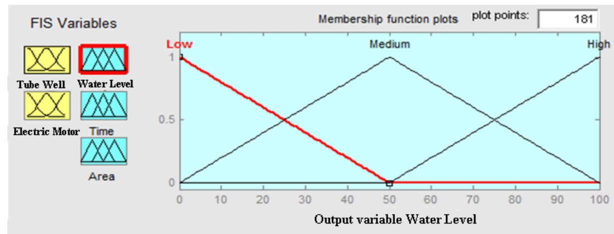

Fig. 4. MFs graphs for the Output Variable "Water Level"

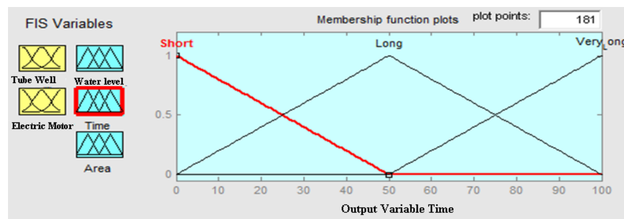

Fig. 5. MFs graphs for the Output Variable "Time"

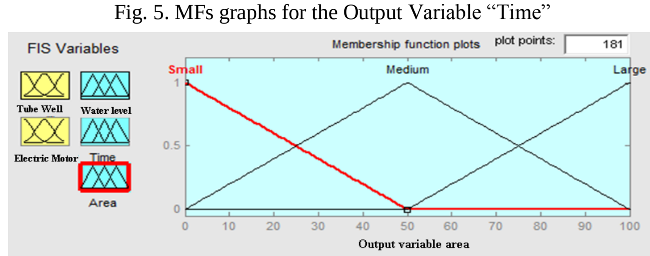

Fig. 6. MFs graphs for the Output variable "Area"

Membership functions of inputs and outputs along with their ranges are shown in Table I. We have used ranges of membership functions as: for MF1 range is 0-50, for MF2 range is 0-100 and for MF3 range is 50-100.

TABLE I MFS OF INPUTS AND OUTPUTS ALONG WITH RANGES

MFs	Ranges	Diesel Engine	Electric Motor	Water Level	Time	Area
MF1	0-50%	Slow (S)	Main (M)	Low (L)	Short (S)	Small (S)
MF2	0-100%	Medium (M)	Solar (N)	Medium (M)	Long (L)	Medium (M)
MF3	50-100%	Fast (F)	Hybrid (H)	High (H)	Very Long (L)	Large (L)

Nine fuzzy rules have been used for FIS by using "X^n" formula where X is number of fuzzy sets and n is number of inputs.

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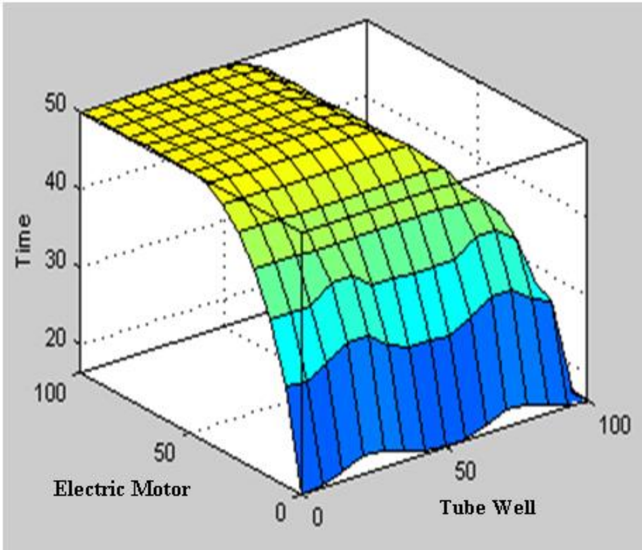

Fig. 7. Nine fuzzy rules

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

TABLE II OBSERVATION

IF		THEN		
Diesel Engine	Electric Motor	Water Level	Time	Area
S	M	H	S	L
S	S	L	L	S
S	H	L	L	S
M	M	H	S	L
M	S	M	L	S
M	H	M	L	S
F	M	H	S	L
F	S	M	S	M
F	H	M	S	M

FLC surface viewer with various inputs and outputs are shown in Fig. 7, Fig. 8 and Fig. 9. From the simulated results it is clear from Fig. 7 that if electric motor is driven by main supply then high water will be available for irrigation but if diesel engine runs slowly or medium then it will be able to provide a low level of water for irrigation.

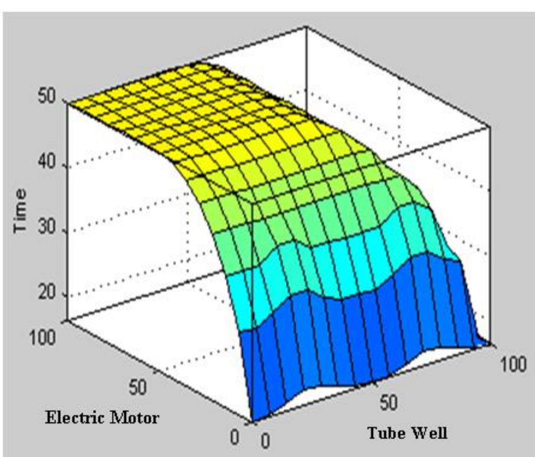

Fig. 8. Relationship between inputs electric motor, tube well and water level

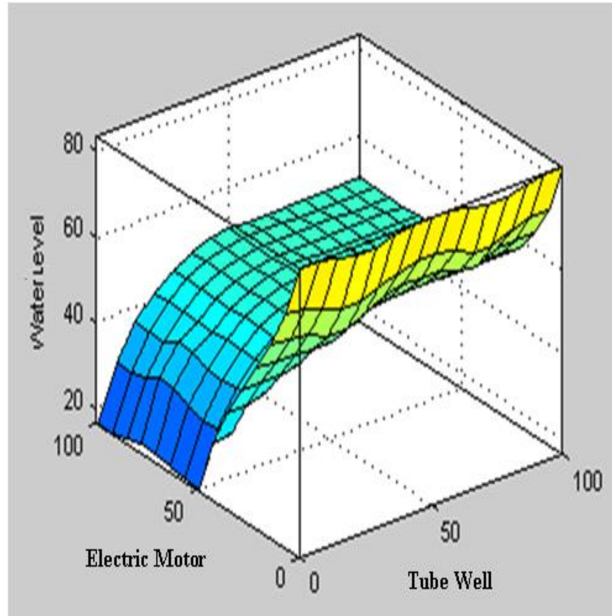

Fig. 9. Relationship between inputs electric motor, tube well and time

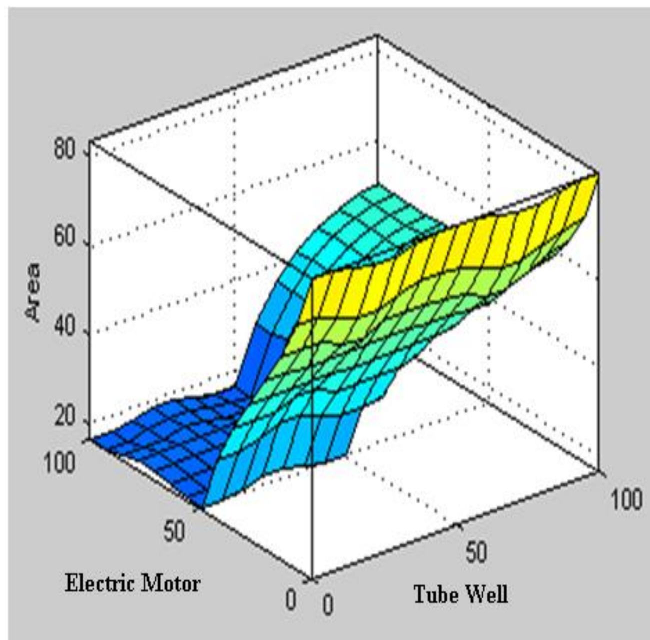

Fig. 10. Relationship between inputs electric motor, tube well and area

Fig.8 shows the relationships between inputs diesel engine, electric motor and output Time. This shows that if electric motor is driven by main then it will be able to take short time for irrigation but when it is driven by solar power or by any other source then it will take long time for irrigation. Similarly, if diesel engine slow or medium it will take long time for irrigation but when it runs fast then it will take short time for irrigation. Fig.9 shows the relationship between inputs diesel engine, electric motor and output area. This shows that if electric motor is driven by solar or by any other source, then the area prepared for irrigation will be small but if the diesel engine runs slowly, medium or fast then every time it will be able to prepare large area for irrigation.

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III. DESIGN ALGORITHM

For design algorithm, we have selected values of inputs and outputs that are shown in Fig. 11.

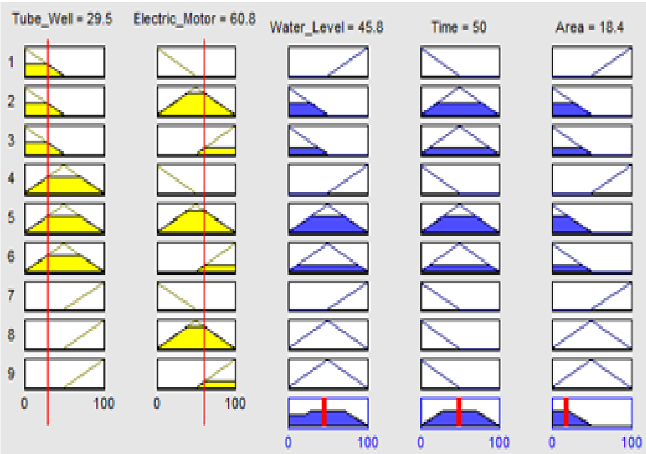

Fig. 11. Selected values for design algorithm

The values for inputs and outputs parameters are given below that have been used for design algorithm of fuzzy logic controller.

Diesel Engine = 29.5
Electric Motor = 60.8
Water Level = 45.8
Time = 50
Area = 18.4

The value of the diesel engine (29.5) lies in region 1 is shown in the Fig. 11. Membership functions for region 1 are Slowl (S) and Medium (M). The MFs mf1 and mf2 for these values are:

mf1 = 50-29.5/50 =0.41
mf2 = 1 - mf1 = 1-0.41 =0.59

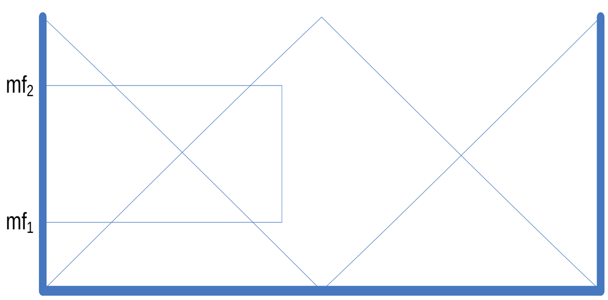

Fig. 12. MFs for diesel engine

For Electric Motor values lies in the region 2 as shown in the Fig. 12. Membership functions for region 2 are Solar (S) and Hybrid (H). The MFs mf3 and mf4 for these values are

mf3 = 100 – 60.8/50 = 0.784
mf4 = 1 – mf3 =1- 0.5= 0.216

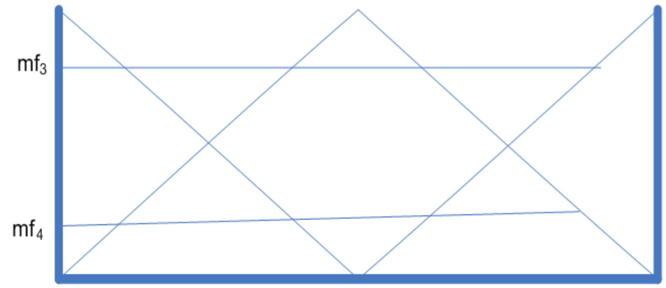

Fig. 13. MFs for electric motor

Selected rules for fuzzy logic controller according to value of input parameters are listed in Table III.

TABLE III RULES ACCORDING TO INPUT PARAMETERS

Rules	Diesel Engine	Electric Motor	Water Level	Time	Area	Singleton Value
R_1	S	S	L	L	S	0.5
R_2	S	H	L	L	S	0.5
R3	M	S	M	L	S	0.5
R_4	M	H	M	L	S	0.5

Membership functions related to each rule is given in Table IV.

TABLE IV MFS RELATED TO EACH RULE

Rule No.	**Membership Function**
R_1	$mf_1 \wedge mf_3$
R_2	$mf_1 \wedge mf_4$
R_3	$mf_2 \wedge mf_3$
R_4	$mf_2 \wedge mf_4$

We have used Mamdani's model to calculate crisp value for FLC.

Output = [Σ Gj × Rj / Σ Rj] × 100
RJ = Selected Rules
Gj = Singleton Values
j = 1, 2,…4

IV. DISCUSSION

Adopted control system based on fuzzy logic has been proposed for ACISFLS. This system contains FLC with diesel engine and electric motor as input parameters and water level, time and area as output parameters. Mamdani's model is used for this system and results for this model are discussed below. The values of inputs and output for fuzzy logic controller of this design are: diesel engine = 29.5, electric motor = 60.8, eater level = 45.8, Time = 50 and area = 18.4. For inference engine three MFs has been used for each rule. Membership functions corresponding to each rule with values is shown in Table V. As AND logic has been used so membership function with smallest value is selected for each rule.

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TABLE V MFS RELATED TO EACH RULE WITH VALUES

Rule No.	Membership Function
R_1	$mf_1 \wedge mf_3 = 0.41 \wedge 0.784 = 0.41$
R_2	$mf_1 \wedge mf_4 = 0.41 \wedge 0.216 = 0.216$
R_3	$mf_2 \wedge mf_3 = 0.59 \wedge 0.784 = 0.59$
R_4	$mf_2 \wedge mf_4 = 0.59 \wedge 0.216 = 0.216$

Following formula has been used to calculate output:

Output = [Σ Gj × Rj /Σ Rj] ×100

Where

Rj = Rules used

Gj = Singleton values

Mathematical term that is used to represent exact value of a variable or object is called singleton value. In this design output has three values for each output like water level, time and area. If output is large, then singleton value is 1, for intermediate 0.5 and for small value is 0.

Hence,

Σ Gj × Rj = 0.5 ×0.41 + 0.5 × 0.216 + 0.5 ×0.59 + 0.5 ×0.216

= 0.205+0.108+0.295+0.108

= 0.716

Σ Rj = 0.5 +0.5 +0.5+ 0.5

= 2

According to the above mentioned formula the output power of MEMSEH

= [Σ Gj ×Rj /Σ Rj]

= 0.716/ 2

= 0.35

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

TABLE VI COMPARISON BETWEEN SIMULATED AND CALCULATED VALUES

Sr. No.	Observation	Results
1	Value from MATLAB Simulation	0.458
2	Value from Mamdani's Model	0.35
3	Difference	0.108

% Error = [Difference/ Actual Value] × 100

= 0.108/45.8×100

= 0.23 %

Table V shows that results from simulation and design values are very close and with only difference of 0.108. The % error is 0.23 % which is very small. Therefore, the above discussion shows that the proposed system is efficient and effective for output water level from AICSFLS.

V. CONCLUSION

Agriculture is back bone of economic growth of Pakistan. It is leading industry that has momentous impact on the GDP growth of the country. The irrigation system of Pakistan needs improvement. Significant amount of energy can be saved by using automatic irrigation system. Hybrid power system (Solar & Grid) can be used for electric motor and tube well. Large area can be irrigated in less time by supplying water continuously. In this study authors have presented design and simulation of automatic irrigation control system. Fuzzy logic tool has been used for analysis. Tube well and electric motor (with hybrid setup) have been considered as inputs and water level, time and area as outputs. Simulated and mathematical results were compared and 0.23% error was found. By implementing this method a large area can be irrigated and crop production will increase. Through hybrid electric power system also useful to reduce the operation costs.

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