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Fuzzy Logic Based Hydro-Electric Power Dam Control System

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Abstract — This research paper presents the construction design of Hydro-Electric Power Dam Control System using Fuzzy Logic. In this design two input parameters: water level and flow rate and two output parameters: release valve control and drain valve control are used. This proposed system uses a simplified algorithmic design approach with wide range of input and output membership functions. The hardware of control system for fuzzifiers and defuzzifiers is designed according to the need of system. The proposed simplified algorithmic design is verified using MATLAB simulation and results are found in agreement to the calculated values according to the Mamdani Model of the Fuzzy Logic Control System.

Index Terms—Fuzzy Logic Control, Hydro-Electric Power Plant, Inference Engine, Rule Selection.

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1 INTRODUCTION

THE modern-day technologies in the areas of information storage and retrieval, web search, image processing, control, pattern recognition, bio-information and computational biology, e-markets, autonomous navigation, and guidance are benefited using fuzzy sets. An integrated framework sustaining a variety of facets of human-centric computing is developed by means of fuzzy sets. The current trends of information technology have proved that the increasing level of intelligence, autonomy and required flexibility comes true with the increased human centricity of resulting results. The holistic view covers concepts, design methodologies, and algorithms with interpretation, analysis, and engineering knowledge. The computing systems are based on predefined models of two-valued logic and human information processing, concerned with two distinct words. In order to communicate between these two words we need to develop an interface. This is the key motivation behind the emergence of human-centric systems and human-centric computing [1].

The construction of a dam is necessary for the electric power generation, flood control, irrigation system, metropolitan and industrial water supply. Different kind of methods have been introduced and implemented to control the hydro-electric power dam due to non-deterministic behavior of water parameters such as flow rate and release etc. [2].

Fuzzy Set Theory along with its membership functions was implemented to the Fairbairn reservoir in Emerald, Central Queensland, Australia where fuzzy rules were generated with explicit recognition of storage volume non-specificity in the discrete Stochastic Dynamic Programming (SPD) [3].

Fuzzy dynamic programming model was used for Hirakud dam in the State of Orissa in India in which irrigation; hydropower generation and flood control were considered as fuzzy variables [4].

The neural network and fuzzy systems were also adopted for dam control in which a comparison was made between reservoir operations using the fuzzy and neural network systems and actual one by operator, using examples of floods during flood and non-flood seasons [5].

Reports show that hydroelectric dams produce 20 percent of the world's total production of electrical energy. The development of a hydro-electric power dam control system based on fuzzy logic with two inputs and two outputs. Using water level and flow rate measuring devices for feedback control, and two control elements for draining and valve controlling (release), and formulated fuzzy rules for water level and flow rate has been achieved.

To control the water release, the controller reads the water level and flow rate after every sampling period. This proposed design work of Hydro-Electric Power Dam System is the application of fuzzy logic control system consisting of two input variables: water level and flow rate, and two output variables: Drain valve and (Releasing) Valve control used in a reservoir plant of Hydro-Electric Power Dam to monitor the system of Dam.

The basic structure of the proposed model is described in Section 2. Section 3 gives the simplified design algorithm

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of fuzzy logic for Hydro-Electric Power Dam System. Section 4 describes the simulation results of this system. Conclusion and future work is given in Section 5.

2. BASIC STRUCTURE OF THE PROPOSED HYDRO-ELECTRIC POWER DAM

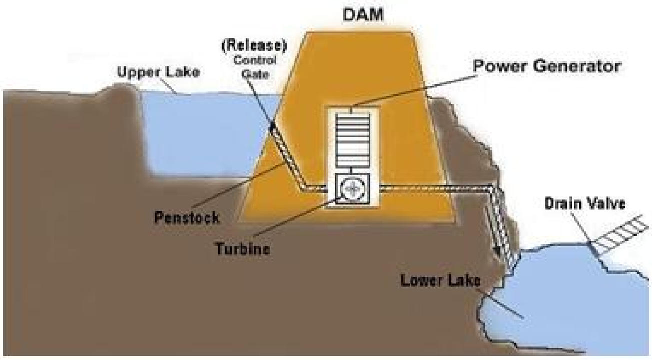

Fig.1 Arrangement of proposed hydro–electric power system

The main parts of the proposed hydro-electric power plant are shown in Fig. 1. Upper lake where water is stored presents the water level. The greater the vertical distance b/w the upper and lower lakes, the more is the generation of electricity. In order to release or block water, a control valve is used according to the need. Water on releasing from the dam gets to the blades of the turbine all the way through the penstock. Its slope and thickness determines the efficiency of the dam. Turbine produces electrical energy and water released from the turbine is released to lower lake where the drainage system is brought into action according to the requirements [6].

The schematic diagram of the proposed hydro-electric power plant is shown in Fig. 2. Water level and flow rate devices are used to monitor the status of water in the plant which is connected with the two fuzzifiers of the fuzzy logic control system after suitable amplification and voltage adjustment unit. Two outputs of defuzzifiers are the releasing control valve and drainage valve.

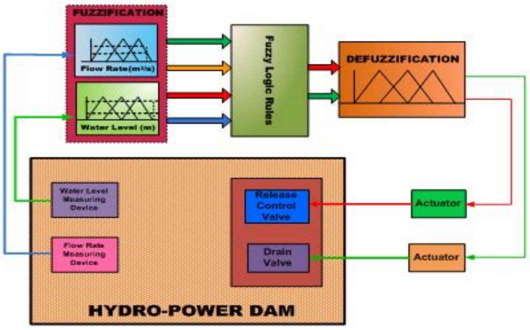

Fig. 2 Block Diagram of Hydro-Electric Power Dam fuzzy control system

3. DESIGN ALGORITHM

The algorithm designed for this system consists of two fuzzy input variables. Five triangular membership functions are equally determined over a scale range of 0 m to 20 m for the water level and 0(m^3s^{-1}) to100000(m^3s^{-1}) for flow rate inputs. The five fuzzy membership functions for water level input are termed as: very low 0-5 m, low 0-10 m, below danger5-15 m, danger10-20 m and above danger15-20 m. The five fuzzy membership functions for flow rate input are: very slow 0m^3s^{-1} -25000m^3s^{-1}, slow 0m^3s^{-1}-50000m^3s^{-1}, normal 25000m^3s^{-1}-75000m^3s^{-1}, fast 50000m^3s^{-1}-100000m^3s^{-1}, and very fast 75000m^3s^{-1}-100000m^3s^{-1}.Two outputs of this proposed system are: (release) control valve and drainage valve. The control valves for release and drainage output variables consist of five membership functions: fully closed 0-5, 25% Opened 0-50, 50% Opened 40-60, 75% Opened 50-90 and Fully Opened 70-100.

3.1. Fuzzifier

The input crisp values are compared by the fuzzifier with certain levels and generate linguistic values of each input variable for inference engine. The inference engine simulates human decision with fuzzy concepts, implication and rules of inference in fuzzy logic [7]. The occupied region description, membership functions and range for two input variables are given in Table 1 and Table 2.

TABLE 1
MEMBERSHIP FUNCTIONS AND RANGES OF INPUT VARIABLE WATER LEVEL (m)

Membership Function (MF)	Ranges	Region Occupied
Very Low	0-5	1
Low	0-10	1-2
Below Danger	5-15	2-3
Danger	10-20	3-4
Above Danger	15-20	4

TABLE 2
MEMBERSHIP FUNCTIONS AND RANGES OF INPUT VARIABLE FLOW RATE (m^3/s)

Membership Function (MF)	Ranges	Region Occupied
Very Slow	0 -25000	1
Slow	0-50000	1-2
Normal	25000-75000	2-3
Fast	50000-100000	3-4
Very Fast	75000-100000	4

For each input variable, five membership functions are used as shown in Fig. 2 and in Fig. 3.

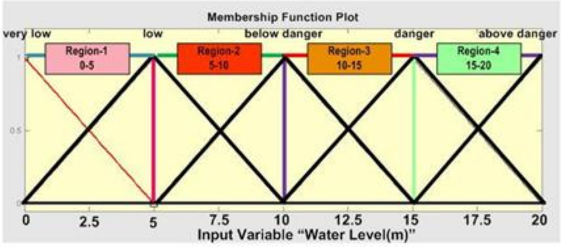

Fig.3 Plot of membership functions for input variable, "WATER LEVEL"

The five membership functions, "very low", "low", "below danger", "danger" and "above danger" are used to show the various ranges of input fuzzy variable "WATER LEVEL" in a plot consisting of four regions as shown in Fig. 2.

The five membership functions, "very slow", "slow", "normal", "fast" and "very fast" are used to show the various ranges of input fuzzy variable "FLOW RATE" in a plot also consisting of four regions as shown in Fig. 3.

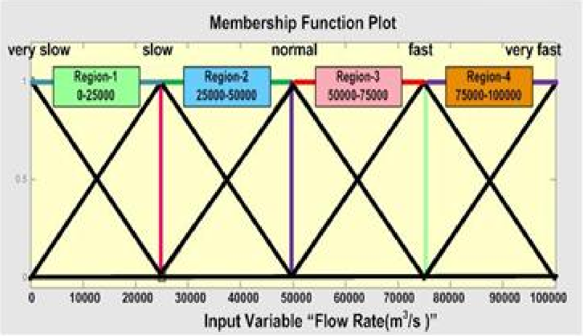

Fig. 4 Plot of membership functions for input variable, "FLOW RATE"

The linguistic values are the mapping values of the fuzzy input variables with the membership functions occupied in the regions. As we are using two variables, therefore four linguistic values are shown in Fig.4. The mapping of input fuzzy variables with the functions in four regions is listed in Table 3.

TABLE 3
LINGUISTIC VALUES OF FUZZIFIERS OUTPUTS IN ALL REGIONS

Input Variables	Linguistic Fuzzifiers Outputs	Region 1	Region 2	Region 3	Region 4
Water Level	f_1	$f_1[1]$	$f_1[2]$	$f_1[3]$	$f_1[4]$
	f_2	$f_1[2]$	$f_1[3]$	$f_1[4]$	$f_1[5]$
Flow Rate	f_3	$f_2[1]$	$f_2[2]$	$f_2[3]$	$f_2[4]$
	f_4	$f_2[2]$	$f_2[3]$	$f_2[4]$	$f_2[5]$

TABLE 4
RULE MAPPING FOR REGIONS OCCUPIED

Case No.	Regions Occupied		Rules $f_n[m]$= Membership value, where n=No. of input variable, m=No. of membership function MF occupied
	Water Level Input variable 1	Flow Rate Input variable 2	
1.	1	1	$R_1 = f_1 \wedge f_3 = f_1[1] \wedge f_2[1]$ $R_2 = f_1 \wedge f_4 = f_1[1] \wedge f_2[2]$ $R_3 = f_2 \wedge f_3 = f_1[2] \wedge f_2[1]$ $R_4 = f_2 \wedge f_4 = f_1[2] \wedge f_2[2]$
2.	1	2	$R_1 = f_1 \wedge f_3 = f_1[1] \wedge f_2[2]$ $R_2 = f_1 \wedge f_4 = f_1[1] \wedge f_2[3]$ $R_3 = f_2 \wedge f_3 = f_1[2] \wedge f_2[2]$ $R_4 = f_2 \wedge f_4 = f_1[2] \wedge f_2[3]$
3.	1	3	$R_1 = f_1 \wedge f_3 = f_1[1] \wedge f_2[3]$ $R_2 = f_1 \wedge f_4 = f_1[1] \wedge f_2[4]$ $R_3 = f_2 \wedge f_3 = f_1[2] \wedge f_2[3]$ $R_4 = f_2 \wedge f_4 = f_1[2] \wedge f_2[4]$
4.	1	4	$R_1 = f_1 \wedge f_3 = f_1[1] \wedge f_2[4]$ $R_2 = f_1 \wedge f_4 = f_1[1] \wedge f_2[5]$ $R_3 = f_2 \wedge f_3 = f_1[2] \wedge f_2[4]$ $R_4 = f_2 \wedge f_4 = f_1[2] \wedge f_2[5]$
5.	2	1	$R_1 = f_1 \wedge f_3 = f_1[2] \wedge f_2[1]$ $R_2 = f_1 \wedge f_4 = f_1[2] \wedge f_2[2]$ $R_3 = f_2 \wedge f_3 = f_1[3] \wedge f_2[1]$ $R_4 = f_2 \wedge f_4 = f_1[3] \wedge f_2[2]$
6.	2	2	$R_1 = f_1 \wedge f_3 = f_1[2] \wedge f_2[2]$ $R_2 = f_1 \wedge f_4 = f_1[2] \wedge f_2[3]$ $R_3 = f_2 \wedge f_3 = f_1[3] \wedge f_2[2]$ $R_4 = f_2 \wedge f_4 = f_1[3] \wedge f_2[3]$
7.	2	3	$R_1 = f_1 \wedge f_3 = f_1[2] \wedge f_2[3]$ $R_2 = f_1 \wedge f_4 = f_1[2] \wedge f_2[4]$ $R_3 = f_2 \wedge f_3 = f_1[3] \wedge f_2[3]$ $R_4 = f_2 \wedge f_4 = f_1[3] \wedge f_2[4]$
8.	2	4	$R_1 = f_1 \wedge f_3 = f_1[2] \wedge f_2[4]$ $R_2 = f_1 \wedge f_4 = f_1[2] \wedge f_2[5]$ $R_3 = f_2 \wedge f_3 = f_1[3] \wedge f_2[4]$ $R_4 = f_2 \wedge f_4 = f_1[3] \wedge f_2[5]$
9.	3	1	$R_1 = f_1 \wedge f_3 = f_1[3] \wedge f_2[1]$ $R_2 = f_1 \wedge f_4 = f_1[3] \wedge f_2[2]$ $R_3 = f_2 \wedge f_3 = f_1[4] \wedge f_2[1]$ $R_4 = f_2 \wedge f_4 = f_1[4] \wedge f_2[2]$
10.	3	2	$R_1 = f_1 \wedge f_3 = f_1[3] \wedge f_2[2]$ $R_2 = f_1 \wedge f_4 = f_1[3] \wedge f_2[3]$ $R_3 = f_2 \wedge f_3 = f_1[4] \wedge f_2[2]$ $R_4 = f_2 \wedge f_4 = f_1[4] \wedge f_2[3]$
11.	3	3	$R_1 = f_1 \wedge f_3 = f_1[3] \wedge f_2[3]$ $R_2 = f_1 \wedge f_4 = f_1[3] \wedge f_2[4]$ $R_3 = f_2 \wedge f_3 = f_1[4] \wedge f_2[3]$ $R_4 = f_2 \wedge f_4 = f_1[4] \wedge f_2[4]$

Case No.	Regions Occupied		Rules $f_n[m]$= Membership value, where n=No. of input variable, m=No. of membership function MF occupied
	Water Level Input variable 1	Flow Rate Input variable 2	
12.	3	4	$R_1 = f_1 \wedge f_3 = f_1[3] \wedge f_2[4]$ $R_2 = f_1 \wedge f_4 = f_1[3] \wedge f_2[5]$ $R_3 = f_2 \wedge f_3 = f_1[4] \wedge f_2[4]$ $R_4 = f_2 \wedge f_4 = f_1[4] \wedge f_2[5]$
13.	4	1	$R_1 = f_1 \wedge f_3 = f_1[4] \wedge f_2[1]$ $R_2 = f_1 \wedge f_4 = f_1[4] \wedge f_2[2]$ $R_3 = f_2 \wedge f_3 = f_1[5] \wedge f_2[1]$ $R_4 = f_2 \wedge f_4 = f_1[5] \wedge f_2[2]$
14.	4	2	$R_1 = f_1 \wedge f_3 = f_1[4] \wedge f_2[2]$ $R_2 = f_1 \wedge f_4 = f_1[4] \wedge f_2[3]$ $R_3 = f_2 \wedge f_3 = f_1[5] \wedge f_2[2]$ $R_4 = f_2 \wedge f_4 =f_1[5] \wedge f_2[3]$
15.	4	3	$R_1 = f_1 \wedge f_3 = f_1[4] \wedge f_2[3]$ $R_2 = f_1 \wedge f_4 = f_1[4] \wedge f_2[4]$ $R_3 = f_2 \wedge f_3 = f_1[5] \wedge f_2[3]$ $R_4 = f_2 \wedge f_4 = f_1[5] \wedge f_2[4]$
16.	4	4	$R_1 = f_1 \wedge f_3 = f_1[4] \wedge f_2[4]$ $R_2 = f_1 \wedge f_4 = f_1[4] \wedge f_2[5]$ $R_3 = f_2 \wedge f_3 = f_1[5] \wedge f_2[4]$ $R_4 = f_2 \wedge f_4 = f_1[5] \wedge f_2[5]$

Fuzzification process for two input variables need two separate fuzzifiers. Each fuzzifier consists of: input voltage to crisp value converter, operational region for a crisp value detector, fuzzy set membership value mapping and selection arrangements [8]. The design of such a fuzzifier is shown in Fig. 5.

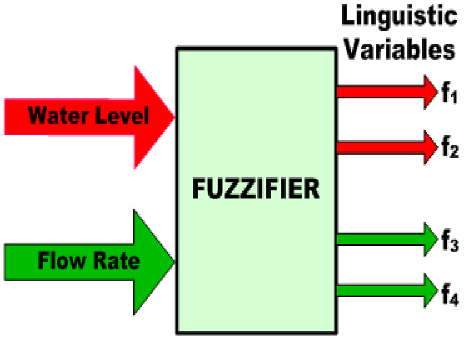

Fig. 5 Fuzzifier Block

Table 5 gives the working results of two fuzzifiers using the given values of input variables. These results are achieved using the fuzzifier design for water level and flow rate inputs shown in Fig. 6 (a) and Fig. 6 (b) [9].

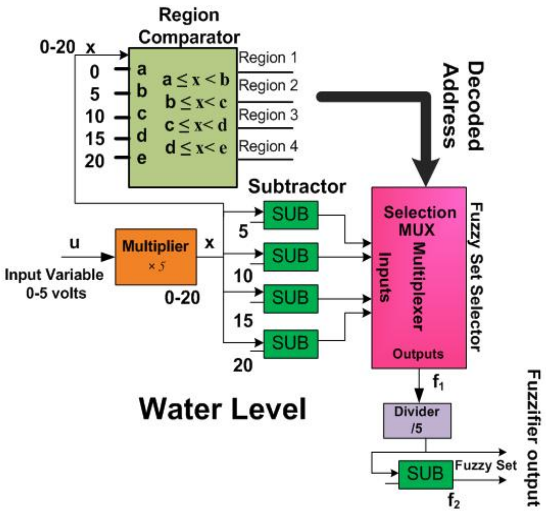

Fig. 6 (a) Design of fuzzifier for Water Level Input

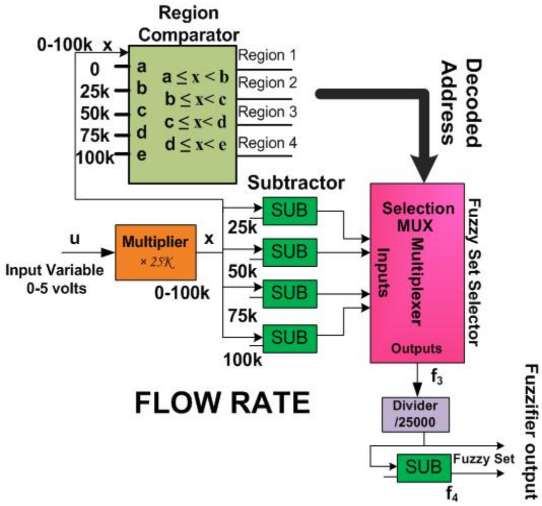

Fig. 6 (b) Design of fuzzifier for Flow Rate Input

TABLE 5
RESULTS OF FUZZIFICATION

Input Variables	Values	Region Selection	Fuzzy Set Calculation
Water Level	x=13	10≤x<15 Region-3	f_1=(15-13) / 5=0.4 f_2=1-f_1=1-0.4=0.6
Flow Rate	x=95000	75000≤x<100000 Region-4	f_3=(100000-95000) / 25000=0.2 f_4=1-f_3=1-0.2=0.8

3.2. Inference Engine

The inference engine contains four AND operators that select minimum value input for the output. This inference engine accepts four inputs from fuzzifier and applies the min-max composition to obtain the output R values. The min-max inference method uses min-AND operation between the four inputs. Fig. 7 shows this type of inference process.

Number of active rules = m^n, where m = maximum number of overlapped fuzzy sets and n= number of inputs. For this design, m = 5 and n = 2, so the total number of active rules are 25.The total number of rules is equal to the product of number of functions accompanied by the input variables in their working range [10]. The two input variables described here consisted of five membership functions. Thus, 5 x 5 = 25 rules were required which are shown in Table 6.

TABLE 6
TOTAL NUMBER OF RULES

INPUTS		OUTPUTS	
Water Level (m)	Flow Rate (m^3/s)	Out-flow (Valve)	Drain Valve
Very Low	Very Slow	Fully closed	Fully closed
Very Low	Slow	Fully closed	Fully closed
Very Low	Normal	Fully closed	Fully closed
Very Low	Fast	Fully closed	Fully closed
Very Low	Very Fast	Fully closed	Fully closed
Low	Very Slow	Fully closed	Fully closed
Low	Slow	Fully closed	Fully closed
Low	Normal	Fully closed	Fully closed
Low	Fast	Fully closed	Fully closed
Low	Very Fast	Fully closed	Fully closed
Below Danger	Very Slow	Fully closed	25% opened
Below Danger	Slow	25% opened	25% opened
Below Danger	Normal	25% opened	25% opened
Below Danger	Fast	50% opened	50% opened
Below Danger	Very Fast	50% opened	75% opened
Danger	Very Slow	50% opened	50% opened
Danger	Slow	50% opened	50% opened
Danger	Normal	75% opened	Fully opened
Danger	Fast	75% opened	Fully opened
Danger	Very Fast	75% opened	Fully opened
Above Danger	Very Slow	75% opened	75% opened
Above Danger	Slow	75% opened	Fully opened
Above Danger	Normal	Fully opened	Fully opened
Above Danger	Fast	Fully opened	Fully opened
Above Danger	Very Fast	Fully opened	Fully opened

In this case only 4 rules are required for the particular values of two variables because each value of two variables in a region corresponds to mapping of two functions. The corresponding mapping values of f_1 [3], f_1 [4], f_2[2], f_2[3] were used to establish the 4 rules. Here f_1 [3] means the corresponding mapping value of membership function "Below Danger" of water level in region-3 and the similar definitions are for the others.

$R_1 = f_1 \wedge f_3 = f_1[3] \wedge f_2[4] = 0.4 \wedge 0.2 = 0.2$
$R_2 = f_1 \wedge f_4 = f_1[3] \wedge f_2[5] = 0.4 \wedge 0.8 = 0.4$
$R_3 = f_2 \wedge f_3 = f_1[4] \wedge f_2[4] = 0.6 \wedge 0.2 = 0.2$
$R_4 = f_2 \wedge f_4 = f_1[4] \wedge f_2[5] = 0.6 \wedge 0.8 = 0.6$

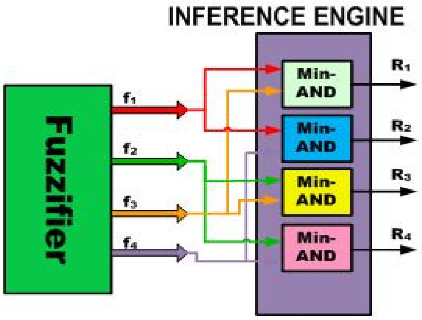

Fig. 7 Block Diagram of Inference Engine

3.3. Rule Selector

The rule selector receives two crisp values of water level and flow rate. It gives singleton values of output functions under algorithm rules applied on design model. For two variables, four rules are needed to find the corresponding singleton values S_1, S_2, S_3 and S_4 for each variable according to these rules are listed in Table 7.

TABLE 7
ILLUSTRATION OF RULES APPLIED MODEL

Rule No.	INPUTS		SINGLETON VALUES OF OUTPUTS		Singleton Values
	Water Level	Flow Rate	Release Control Valve	Drainage Valve	
1	Below Danger	Fast	0.50 =50% opened	50% opened =0.50	S_1
2	Below Danger	Very Fast	0.50 =50% opened	75% opened =0.75	S_2
3	Danger	Fast	0.75 =75% opened	Fully Opened =1.0	S_3
4	Danger	Very Fast	0.75 =75% opened	Fully Opened =1.0	S_4

The rule base accepts two crisp input values, distributes the universe of discourse into regions with each region containing two fuzzy variables, fires the rules, and gives the output singleton values corresponding to each output variable. Fig. 8 shows the main block diagram of the Rule Base.

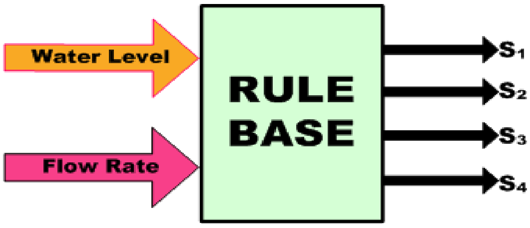

Fig. 8 Rule Base

3.4. Deffuzifier

In this system, two defuzzifiers control the actuators; Release (Valve Control and Drainage Valve. The membership functions of the two output variables are shown in Fig. 7 to Fig.9, and the detail of each plot is given in Table 8.

TABLE 8
OUTPUT VARIABLES MEMBERSHIP FUNCTIONS

MFs	Range	Release(Valve)	Drain Valve
MF1	0-5	Fully Closed	Fully Closed
MF2	0-50	25% Opened	25% Opened
MF3	40-60	50% Opened	50% Opened
MF4	50-90	75% Opened	75% Opened
MF5	70-100	Fully Opened	Fully Opened

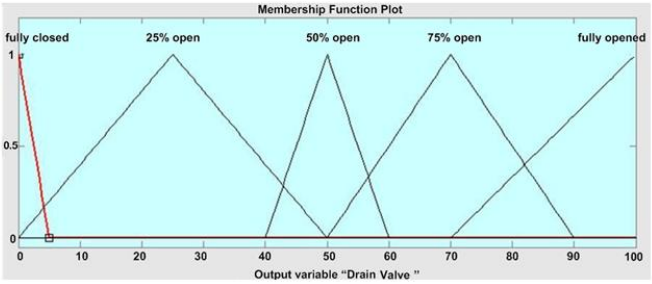

Fig. 9 Plot of Membership Functions for Output Variable, "Drain Valve"

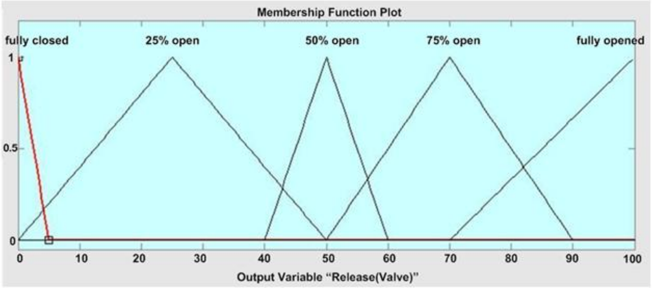

Fig. 10 Plot of Membership Functions for Output Variable, "Release (Valve Control)"

The defuzzification process provides the crisp value outputs after estimating its inputs [11]. In this system 8 inputs are given to each of the two defuzzifiers. Four values of R_1, R_2, R_3, R_4 from the outputs of inference engine and four values S_1, S_2, S_3, and S4 from the rule selector are shown in Fig. 10. Each defuzzifier estimates the crisp value output according to the center of average (C.O.A) method using the mathematical expression, $\mathbf{\Sigma S_i} * R_i / \mathbf{\Sigma} R_i$, where $i = 1$ to 4. Each output variable membership function plot consists of five functions with the same range values for simplification.

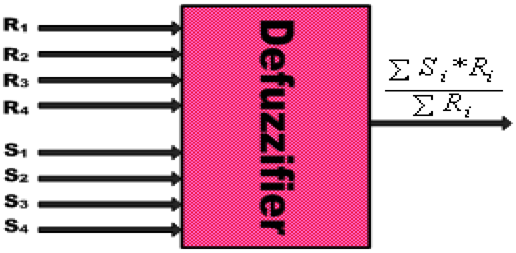

Fig. 11 Defuzzifier Block

Fig. 11 shows the design arrangement of a defuzzifier. One defuzzifier consists of: one adder for $\mathbf{\Sigma} R_i$, four multipliers for the product of $S_i * R_i$, one adder for $\mathbf{\Sigma S_i} * R_i$, and one divider for $\mathbf{\Sigma S_i} * R_i / \mathbf{\Sigma} R_i$. Finally a defuzzifier gives the estimated crisp value output.

4. RESULTS AND DISCUSSION

The designed values for two outputs; Release (Valve Control) and Drain Valve are given in the Table 9 and Table 10. According to the results of inference engine
$\Sigma R_i = R_1+R_2+R_3+R_4 = 0.2+0.4 +0.2 +0.6 = 1.4$

TABLE 9
DESIGNED VALUE FOR CONTROL VALVE (RELEASE)

i	R_i	S_i	$R_i * S_i$
1	0.2	0.50	0.10
2	0.4	0.50	0.20
3	0.2	0.75	0.15
4	0.6	0.75	0.45

$\mathbf{\Sigma S_i} * R_i = 0.90$

$\mathbf{\Sigma S_i} * R_i / \mathbf{\Sigma} R_i = 0.90 / 1.4 = 0.6428 = 64.28\%$ of the Valve will be Opened.

TABLE 10
DESIGNED VALUE FOR DRAIN VALVE

i	R_i	S_i	$R_i * S_i$
1	0.2	0.50	0.1
2	0.4	0.75	0.3
3	0.2	1.0	0.2
4	0.6	1.0	0.6

$\mathbf{\Sigma S_i} * R_i = 1.2$
$\mathbf{\Sigma S_i} * R_i / \mathbf{\Sigma} R_i = 1.2 / 1.4 = 0.8571 = 85.71$ % of Drain Valve.

Using mathematical expression $\Sigma S_i * R_i / \Sigma R_i$ the crisp values for output variables were determined and the results were found according to the MATLAB simulation as shown in Fig. 12. These results are compared in Table 12 and found correct according to the design model. MATLAB simulation was adapted according to the arrangement of membership functions for four rules as given in Table 11.

TABLE 11
ARRANGEMENT OF MEMBERSHIP FUNCTIONS FOR SIMULATION

Rule No.	INPUTS		OUTPUTS	
	Water Level	Flow Rate	Release(Valve)	Drain Valve
1	Below Danger	Fast	50% opened	50% opened
2	Below Danger	Very Fast	50% opened	75% opened
3	Danger	Fast	75% opened	Fully Opened
4	Danger	Very Fast	75% opened	Fully Opened

In Fig. 12 the same values of input variables, Water Level = 13, and Flow Rate = 95000 are shown. Various values of input and output variables match the dependency scheme of the system design. The simulated values were checked using MATLAB-Rule viewer as shown in Fig. 12.

The correctness of results shows the validity of the simplified design work for processing system using control system.

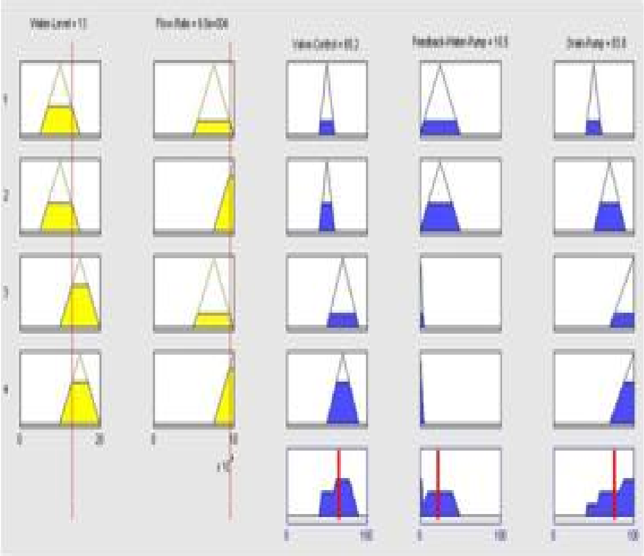

Fig. 12 MATLAB-Rule Viewer

TABLE 12
COMPARISON OF SIMULATED AND CALCULATED RESULT

Result	Release (Control Valve)	Drain Valve
Design Values	64.2	85.7
MATLAB Simulation	65.2	83.8
% error	1.55	2.21

4.1. Simulation Graphs Discussion

This system was simulated for the given range of input variables. The given value of: Water Level = 13 lies in region 3 of the range 10-15 and Flow Rate = 95000 lies in region 4 of the range 75000-100000. The four rules were applied for MATLAB simulation according to this range scheme. In this design model, the release and drain control valves depends upon the selected values of water level and flow rate. The simulated and calculated results are according to the dependence scheme.

Fig. 13(a) shows that the control valve is directly proportional to water level and it does not depend upon the flow rate. Fig. 13(b) shows that the drain valve system is directly proportional to flow rate.

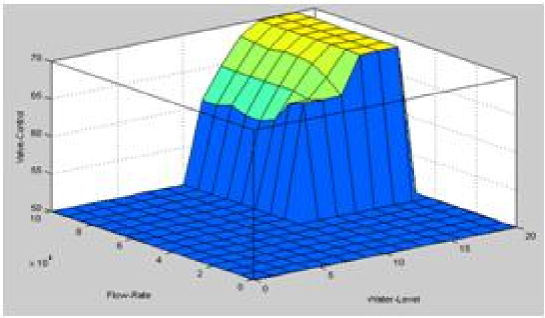

Fig. 13(a) Plot between Water Level - Flow Rate Release Valve Opened/Closed

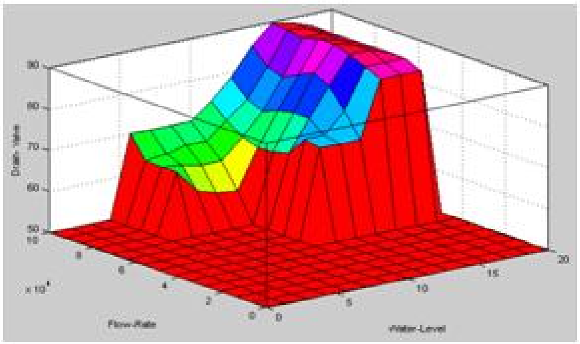

Fig. 14 Plot between Water Level and Flow Rate Drain Valve

5. CONCLUSION

Both the design model and simulation results are same. The designed system can be extended for any number of inputs and outputs. The drain valve control output can be utilized further for land irrigation according to the need and water release control valve for electric generation to fulfill the dire need of this system in automation.

The design work is being carried out to design state of the art fuzzy logic Hydro-Electric control system in future using FPGAs.

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