CONSTANT WATER LEVEL CONTROLLER USING FUZZY LOGIC

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ABSTRACT

Water level controller is one of the most important control system used in mechanical and high power industries as water is the main coolant used in these industries. It is necessary to build a constant water level system as the failure of the same may even lead to emergency shutdown of those industries. PID controllers are commonly employed for this purpose but they are not dependable in case of feedback failure. Also, designing of such controllers are complex. Hence a dependable solution needs to be built. A rather new logic, namely Fuzzy Logic may be used for designing the same controller. Fuzzy logic water controller introduces the most cost-effective and reliable water level controller for nonlinear as well as complex systems. Fuzzy logic can be considered as a powerful tool for solving automation tasks. This paper focuses on the software implementation of constant water level controller using Mamdani type fuzzy logic controller and testing the system for various inputs using the FIS Toolbox included in MATLAB.

Keywords: - *Constant Water Level System, MATLAB, Fuzzy Logic, and Mamdani System etc….*

1. INTRODUCTION

Water level controller is a complex system with its application ranging from domestic to highly important industrial functions. Controlling of water level by setting a desired value or by controlling the incoming and outgoing flow rate are the generic methods used. In most of the industrial applications, the liquid level control is highly important, especially in petrochemical industries, and nuclear power plants. The quality of the final product in such industries depends on the accuracy of the water level controller. Since PID Controllers fails to control satisfactorily for low power applications and become difficult to design for complex and nonlinear systems, we opt for fuzzy logic controller which flexibly fit into all complex systems. Fuzzy logic resembles human decision making [1] and relates input to output in linguistic terms. It is also resilient against disturbances than PID [2]. Moreover, it can be easily combined with conventional and allied control techniques [3].

2. FUZZY LOGIC

Fuzzy Logic is a multivalued logic [4] which uses the whole interval between False (0) and True (1) is capable of handling concepts of partial truth and partial false in addition to logical truth and logical false. It was first proposed by Lotfi Zadeh, who is now called the Father of Fuzzy Logic. Also, works by other scientists, prominently Mamdani, Takagi and Sugeno has made it quite popular among the logicians.

Fuzzy Logic has emerged as a very powerful tool to address complex problems. The main advantage of this is that it uses human common sense and linguistic variables when it comes to solving problems. Hence, from a human point of view it is easier to work with and make some changes when necessary and it can produce the required output even when there is vague information [5].

2.1 Fuzzy System

A system which uses Fuzzy Logic for its working is called a Fuzzy System. A fuzzy system takes any number of fuzzy inputs, processes it according to the rules given and produces any number of fuzzy outputs. But the major problem that it needs to handle is that anything and everything available is crisp in nature. Also, we need crisp values at output. Hence we make use of a block namely Fuzzifier. Fuzzifier converts the crisp value(s) available to a fuzzy value(s) so that the fuzzy system can handle it. Also, at output of the fuzzy system, a block namely Defuzzifier is used to convert the fuzzy output(s) to crisp output(s) so that it will be of use later.

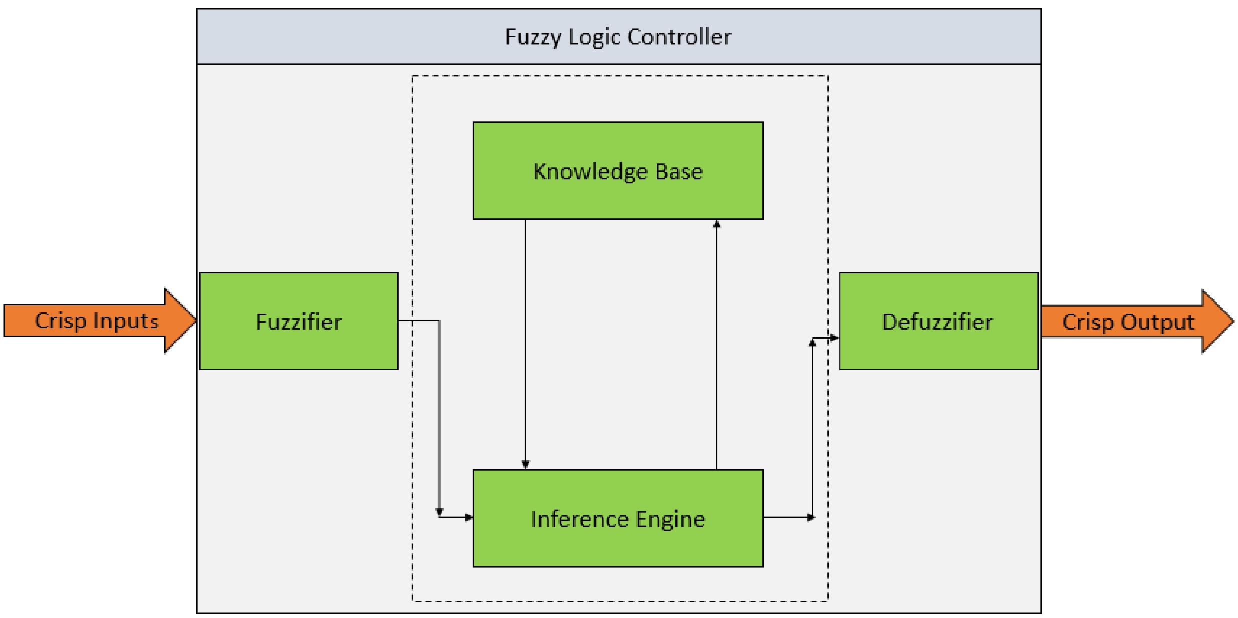

Fig -1: Fuzzy Interference System

2.1 Constant Water Level Controller

A constant water level is a controller which maintains constant water in a tank. This system is of great important in Nuclear Power Plant industries and other mechanical industries which require water for cooling purpose. We use transistor circuit to sense the different water levels and use the output of controller to control the solenoid valve which is used to control the water flow from surge tank to the tank whose water level needs to be maintained at a constant level. This system works as explained below:

- Desired constant Water Level is taken as 90% of capacity of tank.
- Transistor circuits/ other sensors may be employed to sense current level.
- Rate of Level Change is calculated as,

$$\text{Rate} = \frac{\text{Desired Level} - \text{Current Level}}{\text{Desired Level}}$$

- Current Level and Rate is given as inputs to the controller.
- Controller produces an output voltage which is given to a solenoid valve placed in between surge tank and the Main tank.
- When output of controller is varied, the valve opens and closes according to magnitude of output, thus filling the main tank using water from surge tank, if required.
- Thus, a constant water level is maintained.

2.2 Fuzzy System Design

There are mainly three steps in designing of a Fuzzy System.

1. Pick the nouns or variables for inputs and output

This system requires two inputs, namely Level and Rate of Level Change and one Output namely (State of) Valve.

2. Define subsets of inputs and outputs

The first input Level may be divided into five levels namely Very Low, Low, Medium, High and Very High.
The second input may be classified into three levels namely negative, zero, and positive.
Finally, Sudden Open, Open Fast, Open Medium, Open Slow, Sudden Close may be considered as the subset of Output

3. Set the fuzzy rules

First we form a rule matrix which has all combinations of inputs

Level → ↓ Rate	Very High	High	Medium	Low	Very Low
+ve	Sudden Close	Open Medium	Open Medium	Open Fast	Sudden Open
Zero	Sudden Close	Sudden Close	Open Medium	Open Fast	Sudden Open
-ve	Sudden Close	Sudden Close	X	X	X

Table -1: Rule Matrix

Now, we can formulate the following rules to be followed by the controller from the rule matrix.

i. If Level is Very High , then (State of) Valve is Sudden Close
ii. If Level is High and Rate is Positive, then (State of) Valve is Open Medium
iii. If Level is High and Rate is Zero, then (State of) Valve is Sudden Close
iv. If Level is High and Rate is Negative, then (State of) Valve is Sudden Close
v. If Level is Medium, then (State of) Valve is Open Medium
vi. If Level is Low, then (State of) Valve is Open Fast
vii. If Level is Very Low, then (State of) Valve is Sudden Open

2.2.1. Fuzzification

Fuzzification is the process of converting crisp inputs to fuzzy inputs. This system uses Singleton Method for Fuzzification of inputs. Inputs are represented using support and grade sets. In Singleton method, the membership value of crisp input is taken as the fuzzified value.

2.2.2. Defuzzification

Defuzzification is the process of converting fuzzy outputs to crisp outputs. This system uses the centroid method for defuzzification of fuzzy value. In this method, output crisp value may be calculated as,

$$z^* = \frac{\int x \, . \, \mu(x) \, dx}{\int \mu(x) \, dx}$$

where x represents value of variable μ(x) denotes membership function corresponding to x.

3. MATLAB

MATLAB is the abbreviation for MATrix LABoratory. It is world's commonly used programming language used to demonstrate the technical computing. Developed by MathWorks, MATLAB is a combination of modern high performance language with data structures, built in editing and debugging tools and a platform that is integrated with Simulink which is capable of graphical simulation and model-based design for embedded systems. MATLAB also encloses a tool named FIS editor for the easy designing and simulation of fuzzy logic system.

3.1. FIS Editor

Fuzzy Inference System Editor or simply FIS editor is a tool which can be used to create a fuzzy system. It can be used to select type of fuzzy system, inputs, outputs, rules, defuzzification methods etc. It has membership function editor in which the designer may select the type of membership function as per his requirement. It also includes a rule viewer for simulating different outputs according to different inputs and also a surface viewer, which is used to plot 3 dimensional view of relation between inputs and outputs. In this case, we use the fuzzy system as described by Mamdani [6].

3.2. Fuzzy Set Characterizing Input

Inputs taken to the fuzzy controller are level and rate of change of level.

3.2.1. Level

This input indicates the current water level of the system. Range of the input is taken as 0 to 1. Thus the obtained input value is normalized in between 0 and 1. Five input variables are assigned.

Range: (0 to 1)

Fuzzy variables	Membership function	Crisp input range
Very low	Z MF	[0.048 0.36]
Low	Trapezoidal MF	[0.176 0.24 0.4 0.48]
Medium	Trapezoidal MF	[0.4384 0.4752 0.647 0.6832]
High	Trapezoidal MF	[0.664 0.672 0.7949 0.808]
Very high	Pi MF	[0.788 0.98 1.06 1.38]

Table -2: Membership Function parameters of input 'Level'

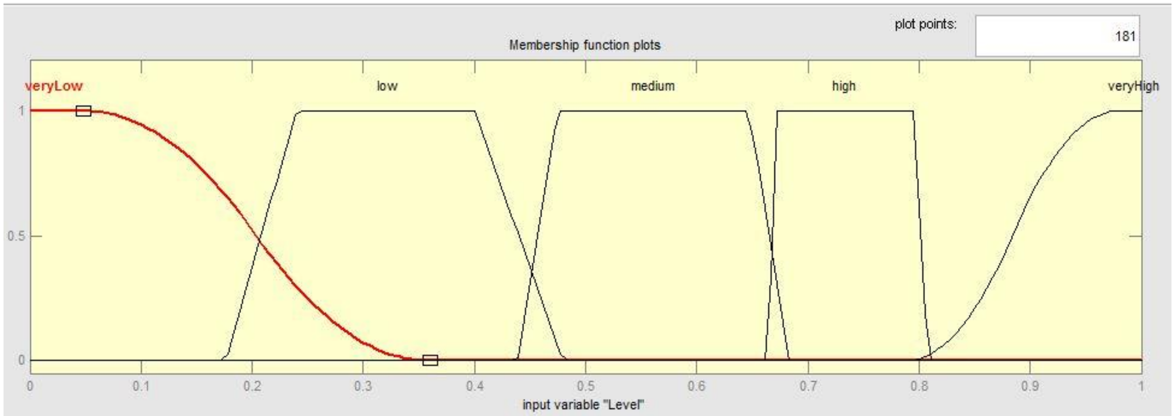

Fig -2: Membership Function parameters of **i**nput 'Level'

3.2.2 Rate of change

It is the rate of change of water level of the system which is calculated with respect to the desired level. Range of this input is taken from -1 to +1. Three input variables are assigned. Negative values of the input are considered as variable '-ve' and positive values as variable '+ve'. If the deviation from the desired output is very low then it is considered under the variable 'zero'.

Range: (-1 to +1)

Fuzzy variables	Membership function	Crisp input range
-ve	Z MF	[-0.2 -0.01]
Zero	Triangular MF	[-0.262 0.0316 0.209]
+ve	S MF	[0.0879 0.463]

Table-3: Membership Function parameters of **i**nput 'Rate'

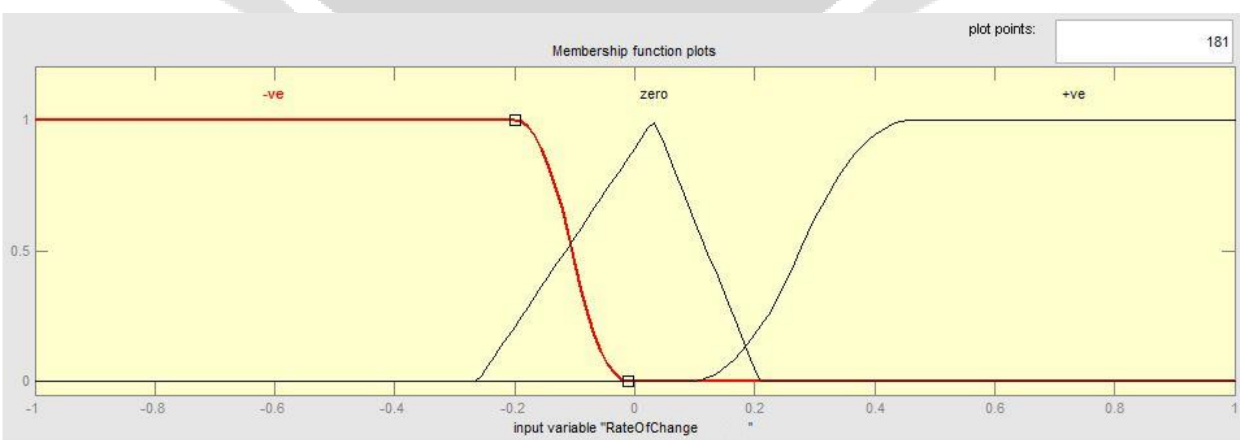

Fig -3: Membership Function parameters of **i**nput 'Rate'

3.3. Fuzzy Set Characterizing Output

Single output '(state of) valve' is taken. Five variables are chosen. Range of the output is taken from 0 to 1.

Range: (0 to 1)

Fuzzy variables	Membership function	Crisp input range
Sudden close	Z MF	[0 0.1]
Open slow	Trapezoidal MF	[0.07011 0.161 0.396 0.459]
Open medium	Trapezoidal MF	[0.3 0.375 0.6997 0.8]
Open fast	Trapezoidal MF	[0.7474 0.779 0.968 1.05]
Sudden open	S MF	[0.95 0.96]

Table-4: Membership Function parameters of **i**nput 'Rate'

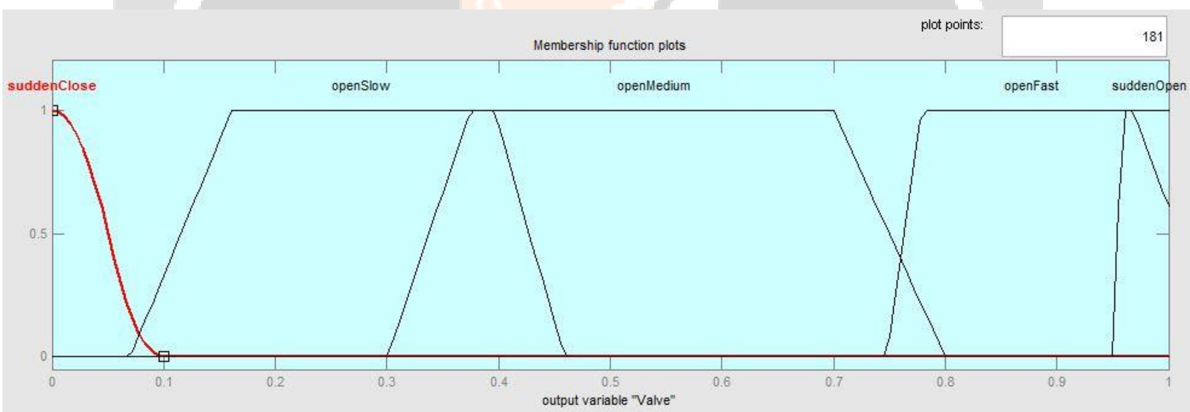

Fig -4: Membership Function parameters of output '(state of) valve'

3.4. Rule editor

Based on the rule matrix designed rules are written using IF and THEN. Rule editor allows to build rule statements automatically by clicking and selecting.

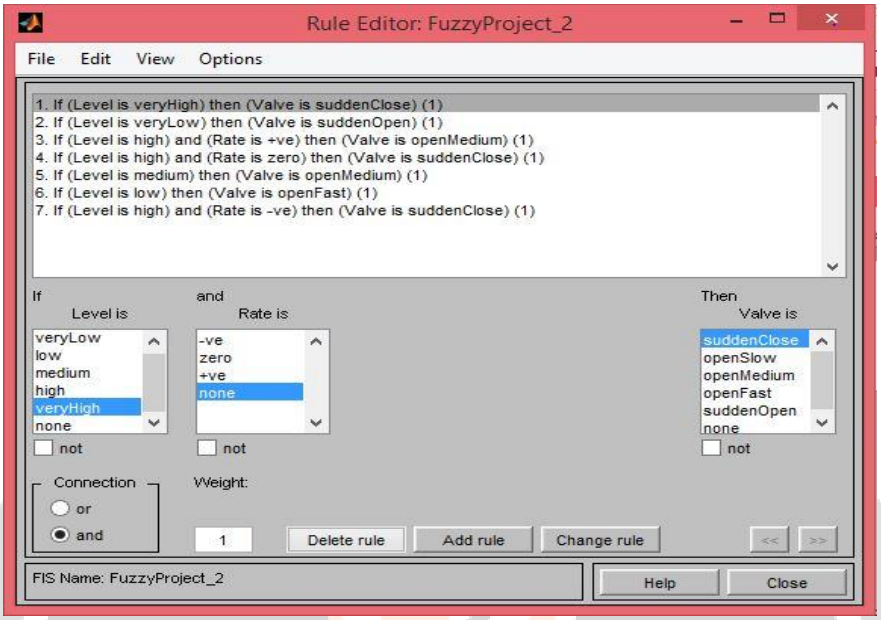

Fig -5: Rule Editor of FIS Editor

3.4. Response of Fuzzy Logic Controller using Rule Viewer

Rule viewer helps to interpret the fuzzy system. It also helps to analyse the rules written in the rule editor. It gives the crisp output value for given inputs.

1) When level is Very Low and rate can have any value

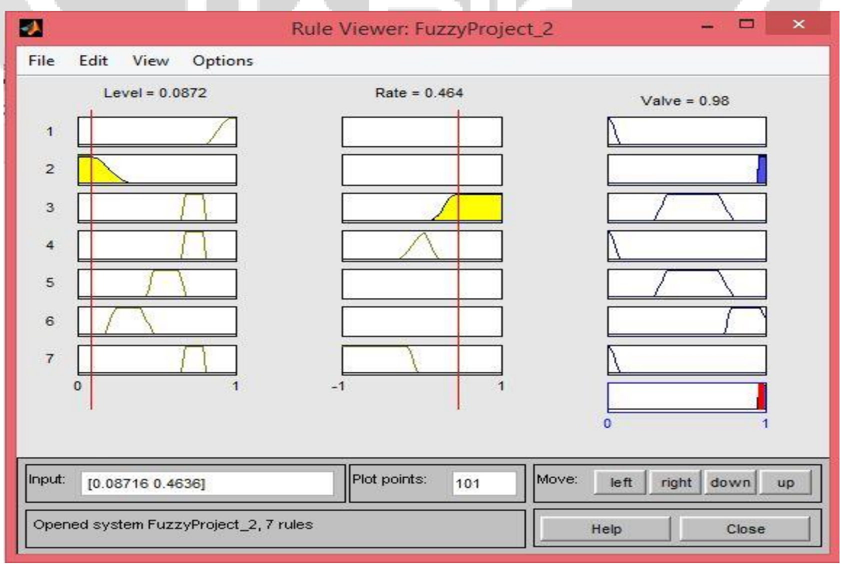

Fig -6: Response when Level is Very Low

2) When Level is Low and Rate can have any value

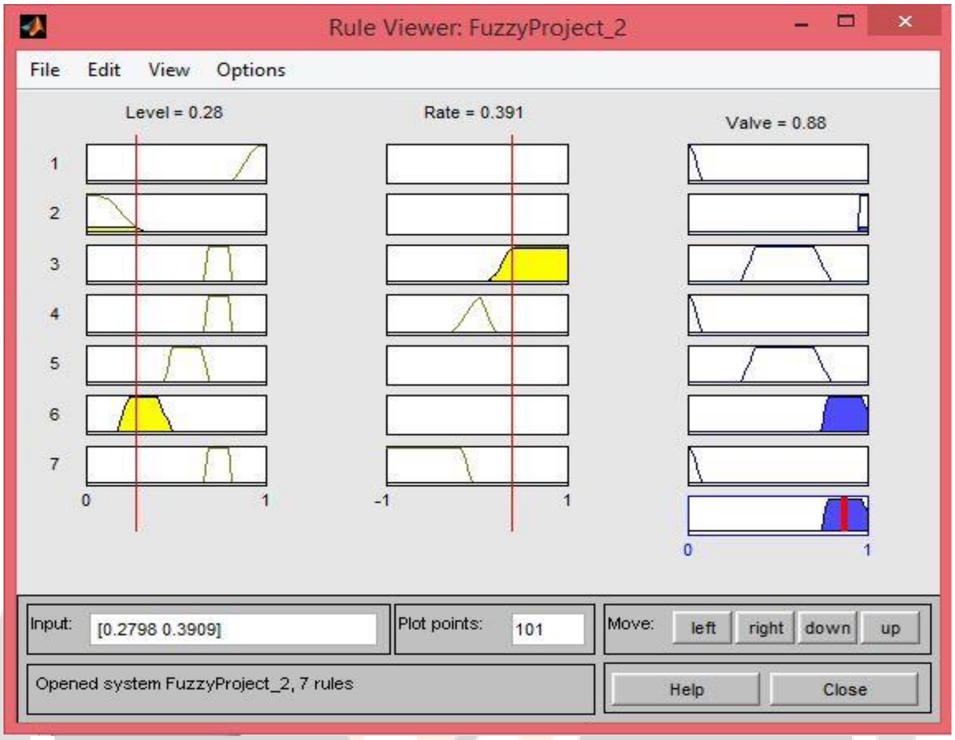

Fig -7: Response when level is Low

3) When Level is Medium and Rate can have any value

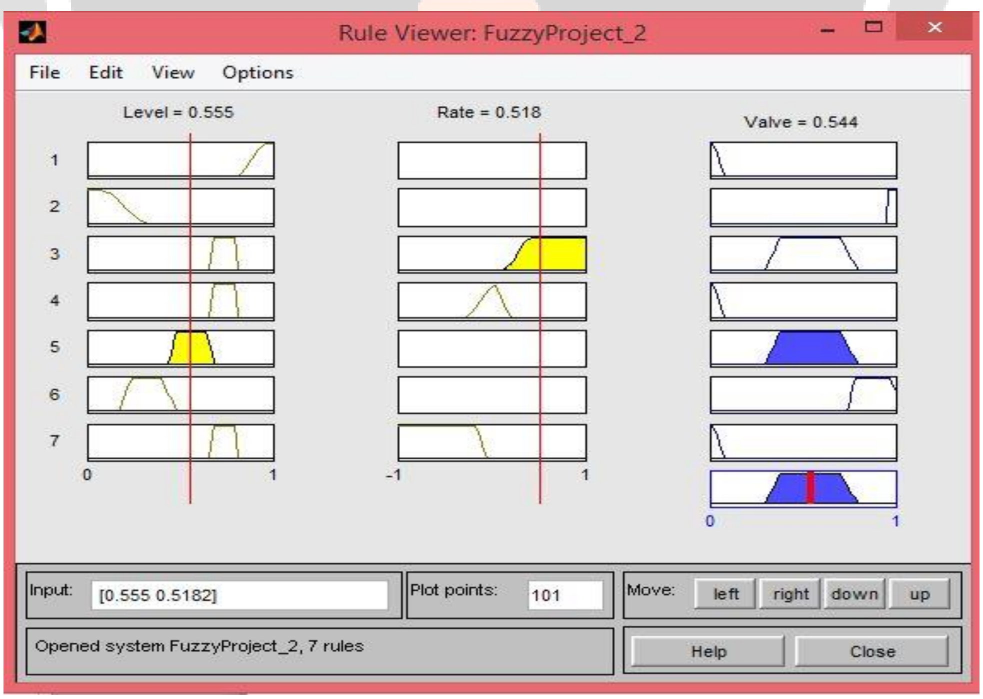

Fig -8: Response when Level is Medium

4) When Level is High and Rate is (close to)Zero

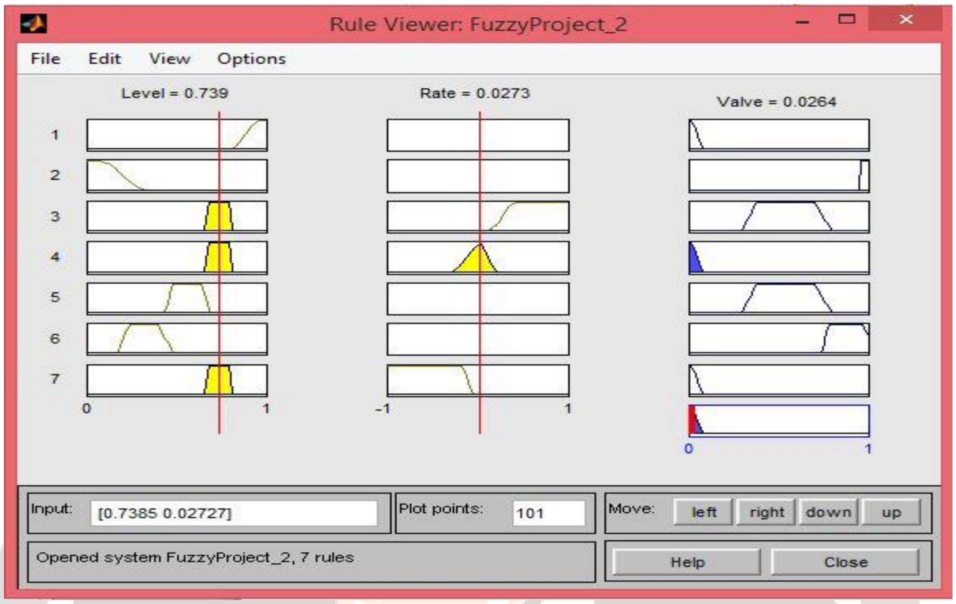

Fig -9: Response when Level is High and Rate is (close to) Zero

5) When Level is High and Rate is Negative

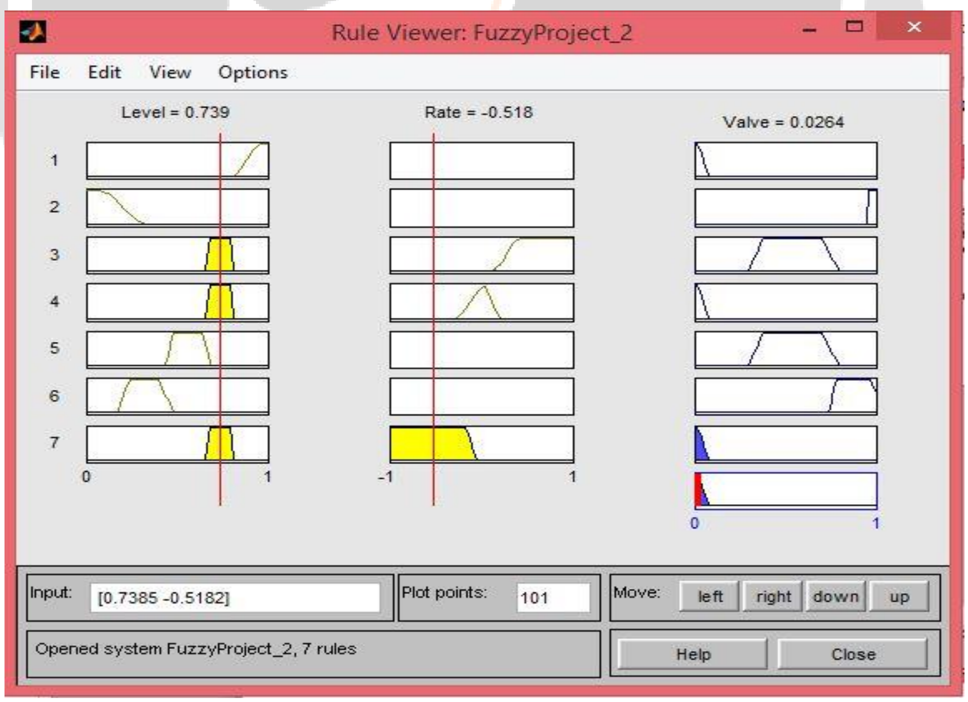

Fig -10: Response when Level is High and Rate is Negative

6) When Level is High and Rate is Positive

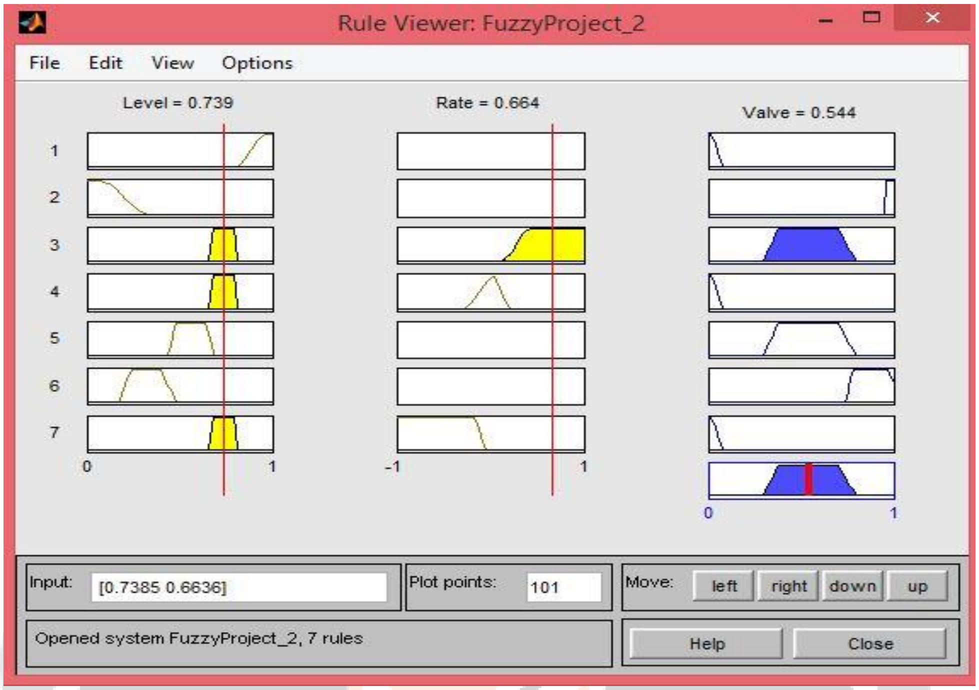

Fig -11: Response when Level is High and Rate is Positive

7) When Level is Very High and Rate is Negative

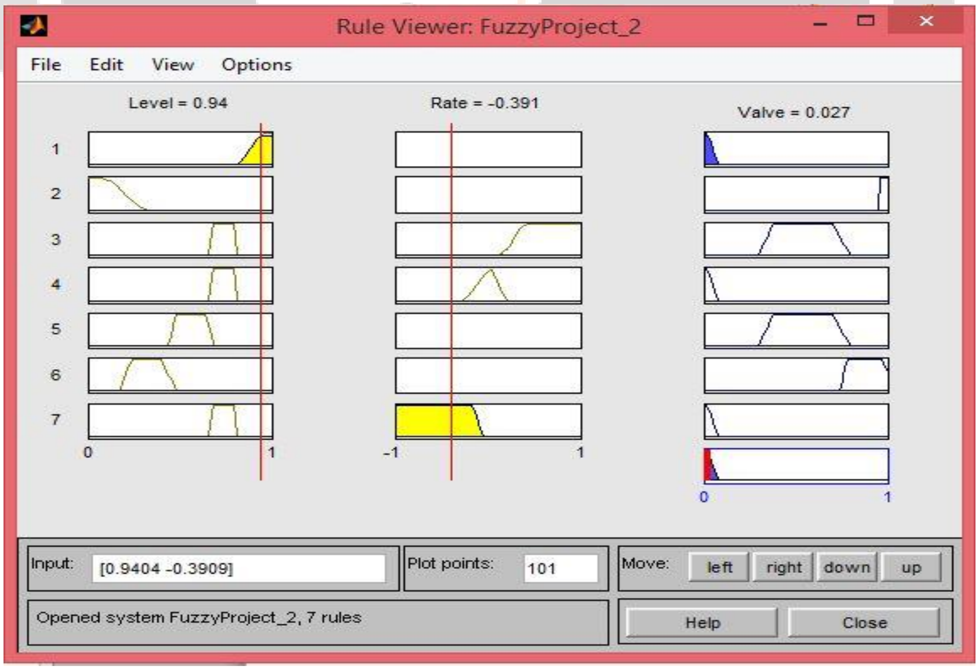

Fig -12: Response when Level is Very High and Rate is Negative

3.4. Response of Fuzzy Logic Controller using Surface Viewer

Surface viewer gives a 3 dimensional view of relation between inputs and output.

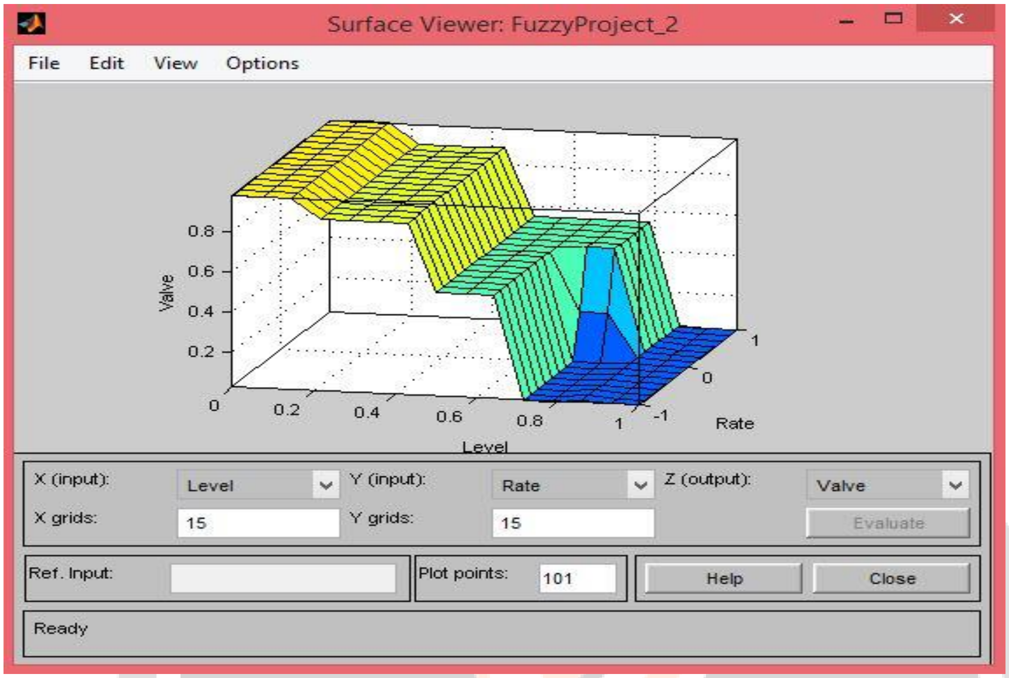

Fig -13: Response using Surface Viewer

4. CONCLUSIONS

Fuzzy logic system is an excellent choice for many control application since it mimics human control logic. It is very useful in converting real life time problems into linguistic variables. Constant water level was effectively achieved using fuzzy logic toolbox in MATLAB. Desired outputs were obtained during simulation for various inputs. Designing of fuzzy controller is simple and less time consuming so it can be widely used in all types of control applications. Thus fuzzy logic controller is conceived as a good solution for constant water level controlling application.

5. REFERENCES

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