Scientific Journal Impact Factor (SJIF): 1.711
International Journal of Modern Trends in Engineering and Research
IJMTER
ISSN (ONLINE) : 2349 - 9745
ISSN (PRINT) : 2393 - 8161

Designing of FLC for Controlling of Liquid Level In Couple Tank System

Ashish Singh Thakur[1], Himmat Singh[2], Sulochana Wadhwani[3]

[1] Electrical Engineering Department, MITS, Gwalior
[2]Electrical Engineering Department, MITS, Gwalior
[3]Electrical Engineering Department, MITS, Gwalior

Abstract - The industrial application of Coupled Tank System (CTS) are widely used especially in chemical process industry. The overall process require liquid to be pump, stored in the tank and pumped again to a different tank for certain desired level. However, the level of liquid in tank need to be controlled and flow between two tanks must be regulated. This paper presents the fuzzy controller for adjustment of liquid level in the tank and presents the theoretical concepts of triangular fuzzy statistics. The dynamic of nonlinear processes can be easily controlled by using Fuzzy Logic Controller. In this paper we investigated the usage of Fuzzy Logic Controller (FLC) in controlling the liquid level in the second tank of Coupled-Tanks system through variable manipulation of liquid pump in the first tank. System modeling involves developing a mathematical model by applying the fundamental physical laws of science and engineering. This simulation studies are then conducted based on the developed model using Matlab Simulink. The behavior of the system is studied in terms of time response (e.g., steady state error, rise-time, settling time) and compare FLC adverse PID controller. It found that the performance of the fuzzy logic based controller is better than the classical PID controller.

Keywords — PID Controller, Fuzzy Logic Controller, Rule Viewer, Fuzzy Interface System, Graphical User Interface, Coupled Tank System, Matlab Simulation.

I. INTRODUCTION

PID controllers are designed for linear systems and they provide a preferable advantage. However, the presence of nonlinear property limits their performance. Fuzzy controllers are effectively applied to non-linear system because of their knowledge based nonlinear structural characteristics [1]. Chemical process & petroleum refineries present many challenging control problems due to their nonlinearity, uncertainty and time varying behavior of parameters, undesirable interaction among manipulated and controlled variables, input and measurements dead time. To overcome these difficulties inherent in controlling a system that is both nonlinear and time dependent parameters, a controller based on fuzzy logic was implemented. Fuzzy controllers are known for their ability to provide very good control of this type of system.

Usually, level control exists in some of the control loops of a process control system [2]. Mixing reactant method is a very common method in chemical process industries and food processing industries [3]. Many other industrial applications are concerned with level control. It may be a single loop level control or sometimes it may be a multi-loop level control. Hence, level control is one of the control system variables which are very important in process industries [4-5]. The above mentioned industries are the vital industries where liquid level and flow control are essential [6-7]. Most of the time the liquid will be processed by chemical or mixing treatment process in the tank. In the tanks fluid level has to be controlled, and the flow among tanks must be regulated. In tanks Level and flow control is the heart of all chemical engineering systems.

II. COUPLE - TANK SYSTEM

Two interacting tanks in series with outlet flow rate being function of the square root of tank height [8] shown Fig.1. Liquid is flowing into a tank at some rate Q_{in} and out of the tank at some rate Q_{out}. The liquid in the tank at some height or level h_1 & h_2 it is known as output flow rate varies as the square root of the height, so the higher the level, faster the water flow out. If the output flow rate is greater than the input flow rate, the level will drop or if the output flow rate is less than the input flow rate, the level will rise [9]. This process is known as self-regulation. This means that at some input water flow rate, the water height will rise until it reaches a height for which the output flow rate matches the input flow rate.

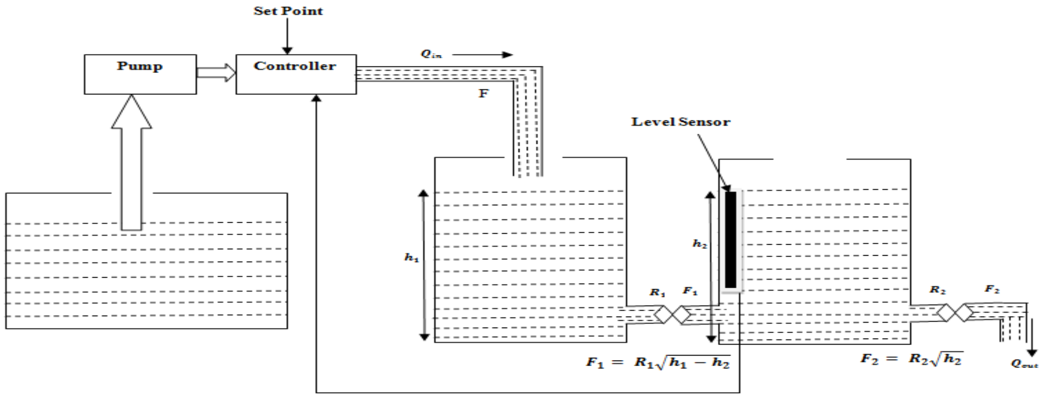

Figure 1 Schematic diagram for coupled tank system

A self regulating structure does not offer regulation of a variable to any particular reference value. In this example, the liquid level will accept some value for which input and output flow rate are the same, and there it will stay. But if the input flow rate changed, then the level would modify also. So it is not synchronized to a reference value. Suppose we want to keep the level at some particular value 'h1 & h2' as shown in Figure1 regardless of the input flow rate then something more than self-regulation is needed. Water enters a tank from the top and leaves through an orifice in its base. The voltage applied to the pump is directly proportional to the rate of water enters into the tank. The rate at which water leaves is directly proportional to the square root of the height of water in the tank.

2.1 Couple tank equations

The equation for the height of liquid in the tank 'h_1 & h_2' and flow out is given as

$$\frac{d}{dt}h_1 = \frac{F}{A_1} - \frac{R_1}{A_1}\sqrt{h_1 - h_2} \qquad (1)$$

$$\frac{d}{dt}h_2 = \frac{R_1}{A_2}\sqrt{h_1 - h_2} - \frac{R_2}{A_2} \qquad (2)$$

$$F_1 = R_1\sqrt{h_1 - h_2} \qquad (3)$$

$$F_2 = R_2\sqrt{h_2} \qquad (4)$$

Where

F = Steady-state liquid flow rate, cm^3/sec.

F_1 = Out flow rate from first tank, cm^3/sec.

F_2 = Out flow rate from second tank, cm3/sec.

R_1 and R_2 = Coefficients, $cm^{2.5}$/sec.

h_1 = Level first tank, cm.

h_2 = Level second tank, cm.
A_1 = Cross sectional area for first tank, cm^2.
A_2 = Cross sectional area for second tank, cm^2.

The values of the parameters in the present research work are as F=5 cm^3/sec., A_1=10 cm^2, A_2=10 cm^2, R_1=2 $cm^{2.5}$/sec., and R_2=2 $cm^{2.5}$/sec. These equations describe the water height as a function of time, due to the difference between flows rates into and out of the tank. It is nonlinear due to its dependence on the square-root of height of the liquid level. Linearizing the model, using Simulation Control Design, simplifies the analysis of this model [10].

III. DESIGNING OF FUZZY LOGIC CONTROLLER

3.1 Fuzzy interface system editor

We have defined two inputs and one output for the fuzzy logic controller may be shown as Fig.2. One is error that range of the liquid in the second tank denoted as "Error" that represented

$$Error = h_{reference} - h_2 \qquad (5)$$

If $h_{reference}$ is the set point for level that control on it and the next one is the ratio of change of liquid in the second tank denoted as "Rate". Both these inputs are applied to the Rule Editor [11]. According to the Rules written in the Rule Editor the controller takes the action and gives the running of the pump which is the output of the controller and is denoted by "Pump".

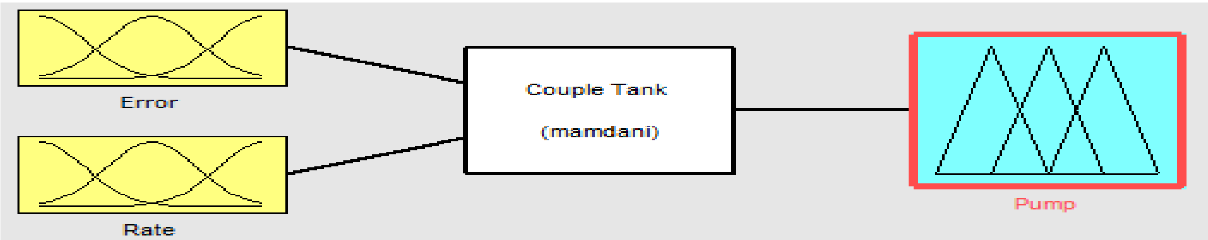

Figure 2 Mamdani type fuzzy controllers

3.2 Membership function editor

The membership function Editor is the tool that displays and edits all of the membership functions associated with all of the input and output variables for the entire fuzzy inference system [12-13]. When the membership function Editor is opened to work on a fuzzy inference system that does not already exist in the workspace, there is no membership functions associated with the variables that is just defined with the FIS Editor.

3.2.1 Fuzzy set characterizing input

3.2.1.1 Error

In this research work the triangular membership functions are taken for the "Error" input. First, set the Range (and the Display Range) to (-13 to 13), to cover the input range. The input "Error" is divided into three membership functions are "Low", "Ok" and "High".

Table 1 Crisp range table for "Error"

Fuzzy Variable	MF Used	Crisp Input Range
Low	Triangular MF	[-15, -13, 0]
Ok	Triangular MF	[-9, 0, 9]
High	Triangular MF	[0, 13, 15]

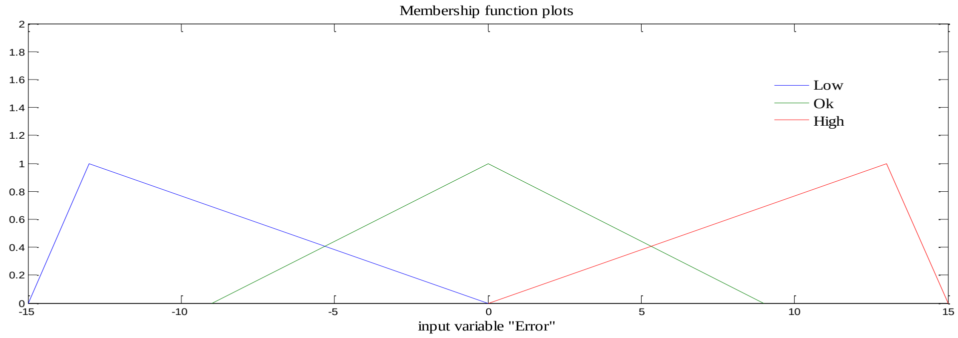

Figure 3 Membership function fuzzy set characterize input

3.2.1.2 Rate

In this research work the triangular membership functions are taken for the "Rate" input. First, set the Range (and the Display Range) to (-0.2 to 0.2), to cover the input range. The input "Rate" is divided into three membership functions are "Negative", "None" and "Positive".

Table 2 Crisp range table for "Rate"

Fuzzy Variable	MF Used	Crisp Input Range
Negative	Triangular MF	[-0.4, -0.2, 0]
None	Triangular MF	[-0.14, 0, 0.14]
Positive	Triangular MF	[0, 0.2, 0.4]

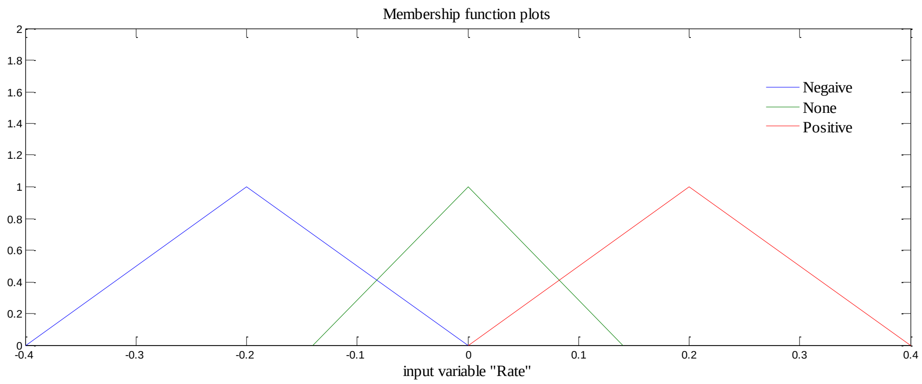

Figure 4 Membership function fuzzy set characterize output

3.2.2 Fuzzy set characterizing output

In this research work the triangular membership functions are taken for the “Pump” output. First, set the Range (and the Display Range) to (-100 to 100), to cover the output range.

3.2.2.1 Pump

The output “Pump” is divided into five triangular membership functions "close fast", "close slow" "no change", "open slow" and "open fast".

Table 3 Crisp range table for “Pump”

Fuzzy Variable	MF Used	Crisp Input Range
Close Fast	Triangular MF	[-100, -90, -80]
Close Slow	Triangular MF	[-60, -50, -40]
No Change	Triangular MF	[-10, 0, 10]
Open Slow	Triangular MF	[20, 30, 40]
Open Fast	Triangular MF	[80, 90, 100]

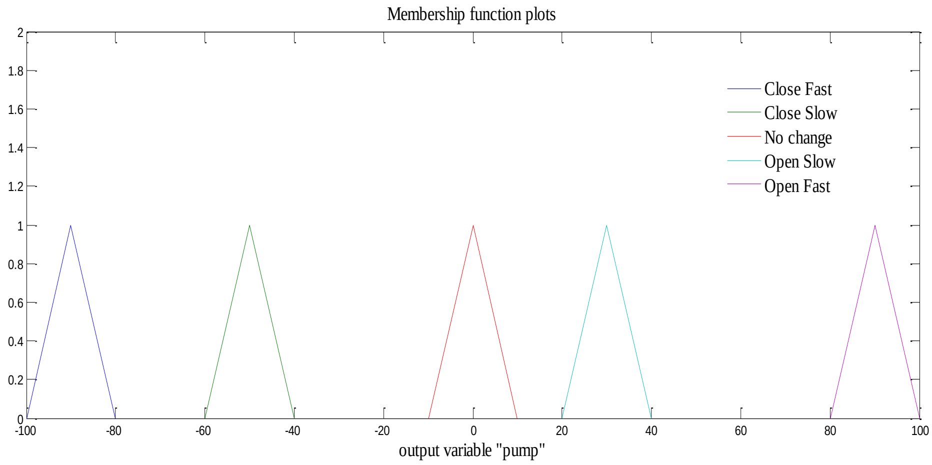

Figure 5 Triangular membership function output

3.3 The rule editor

Constructing rules using the graphical Rule Editor interface is fairly self-evident. Based on the input and output variables defined with the FIS Editor, the Rule Editor allows you to create the rule statement automatically.

1. If (Error is ok) then (Pump is no change) (1).
2. If (Error is High) then (Pump is Open Fast) (1).
3. If (Error is Low) then (Pump is Close Fast) (1).
4. If (Error is ok) and (Rate is Positive) then (Pump is Close Slow) (1).
5. If (Error is ok) and (Rate is Negative) then (Pump is Open Slow) (1).

3.4 Response of fuzzy logic controller using rule viewer

When the value of the Error is 0.5 and the Rate is -0.2 then the value of Pump is 17.5

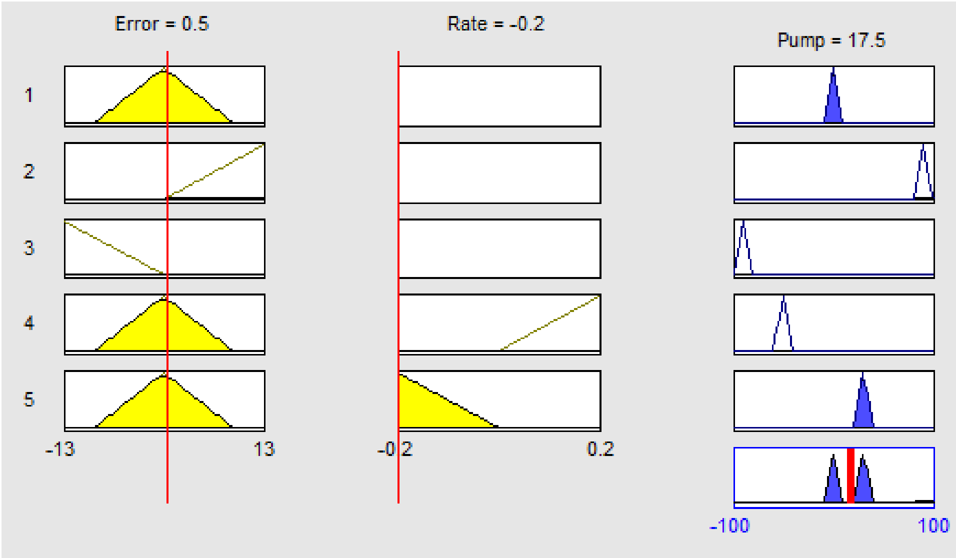

Figure 6 Fuzzy Logic Controller using Rule Viewer

3.5 The surface viewer

Surface view of the Rule bases for couple tank system

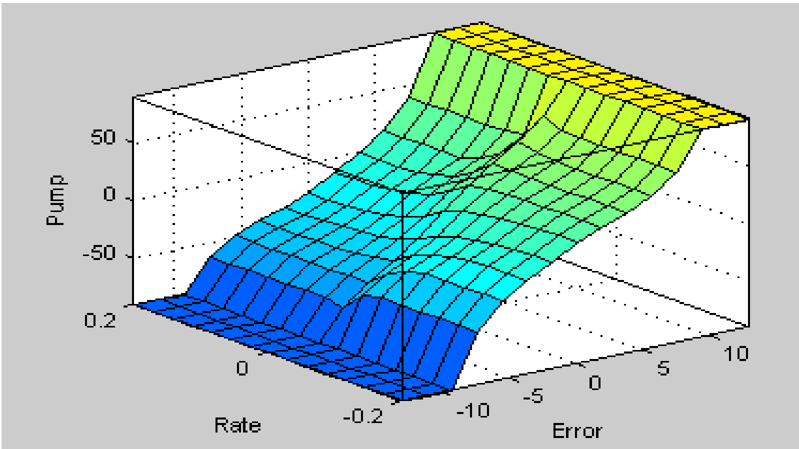

Figure 7 Fuzzy Logic Controller using Surface Viewer

IV. SIMULATION BLOCK DIAGRAM

4.1 Simulation model of couple tank subsystem is given

Simulation model of couple tank subsystem for liquid level controlling is shown in figure 8. The simulation model of the couple tank subsystem is design by using couple tank equation. In the couple tank subsystem the input flow in is directly connected PID & Fuzzy Logic Controller for the controlling of liquid level. At the output of the couple tank subsystem we observe the liquid flow out, water level and over flow.

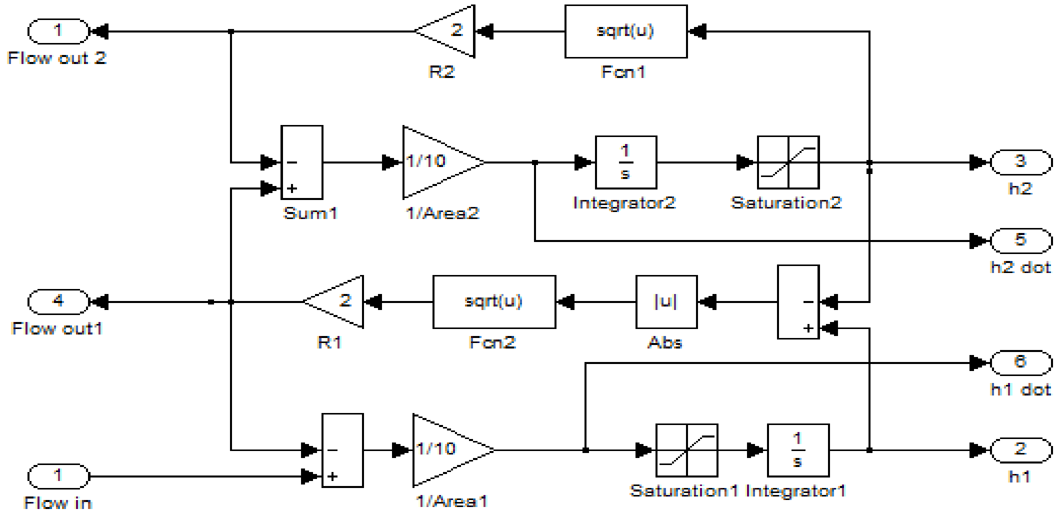

Fig. 8:- Simulation model of Couple tank

4.2 Simulation model of couple tank using PID controller

Simulation model of PID controller for couple tank is shown in figure 9. In this we control the water level of the system with the help of PID controller in the MATLAB simulation. In this simulation model the step is taken as a reference signal. The PID controller is directly connected with the input of the couple tank subsystem.

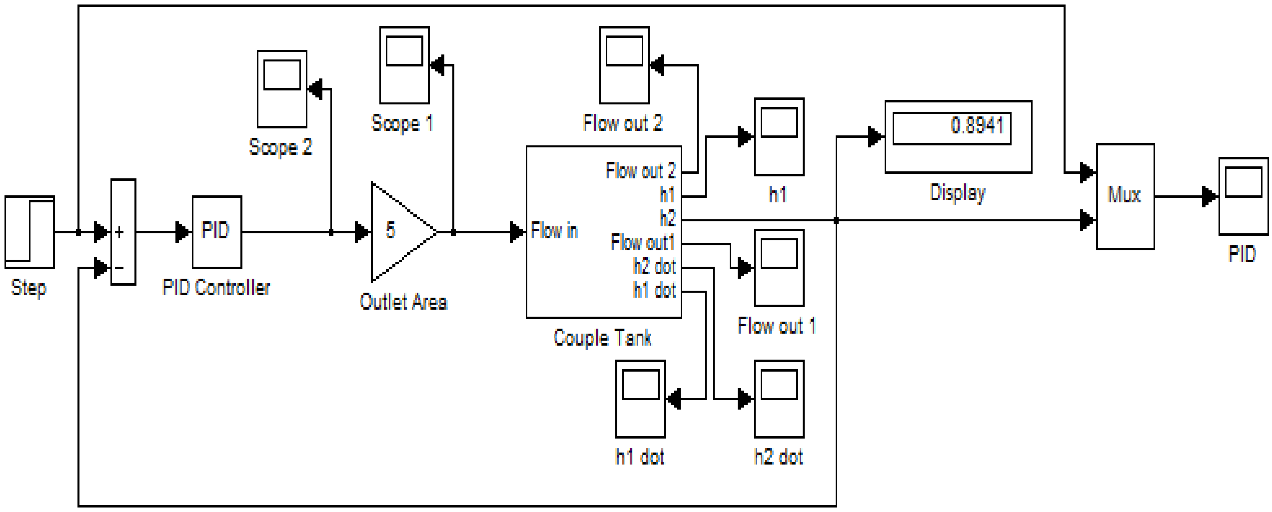

Fig. 9:- Simulation model by using PID controller

4.3 Simulation model of couple tank using fuzzy logic controller

Simulation model of Fuzzy Logic Controller for couple tank is shown in figure 10. In this we control the water level of the system with the help of Fuzzy Logic Controller in the MATLAB simulation. In this simulation model the step is taken as a reference signal. The Fuzzy Logic Controller is directly connected with the input of the couple tank subsystem.

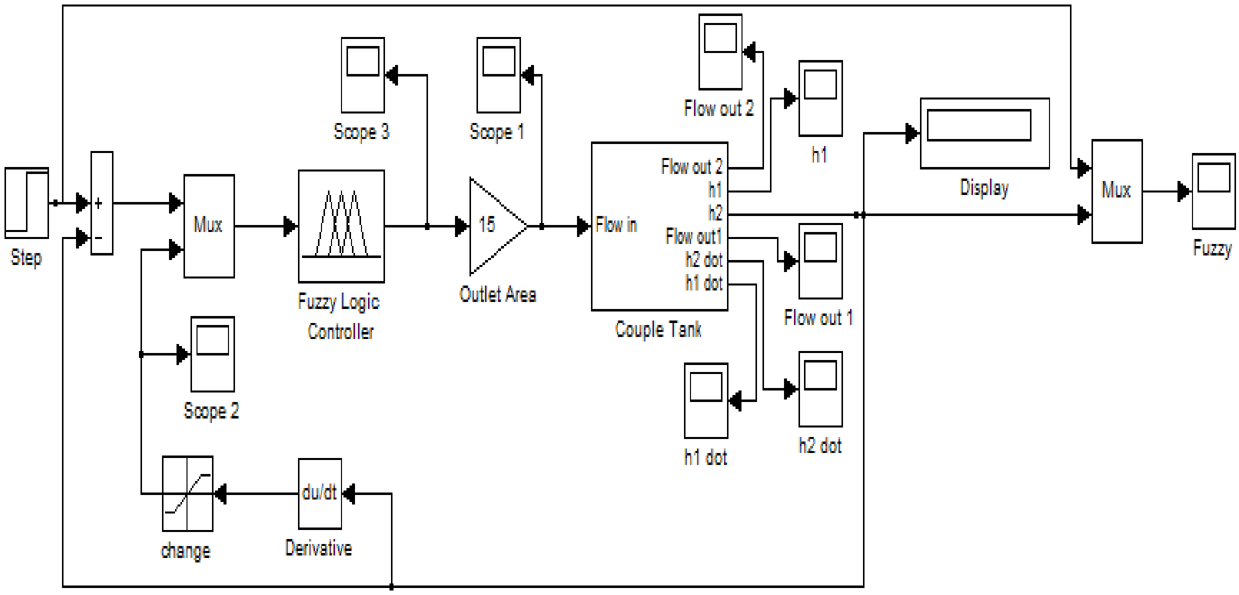

Fig. 10:- Simulation model by using fuzzy logic controller

V. SIMULATION RESULTS & DISCUSSION

5.1 Simulation result of couple tank using PID controller

The simulation result of PID controller shown in figure 11. This simulation result shows that the output of the couple tank is not matched with the reference signal.

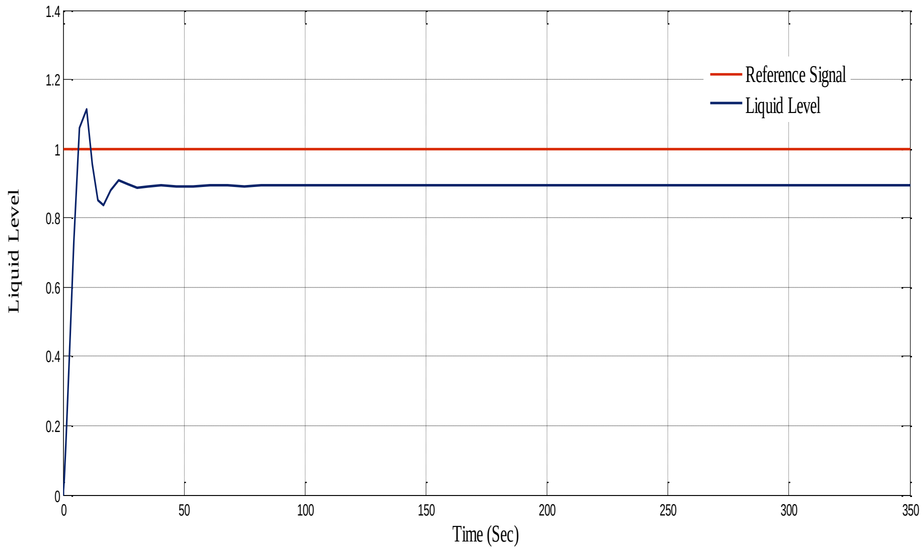

Fig. 11:- Simulation result using PID controller

5.2 Simulation result of couple tank using fuzzy logic controller

The simulation result of Fuzzy Logic Controller shown in figure 12. This simulation result shows that the output of the couple tank is exactly matched with the reference signal.

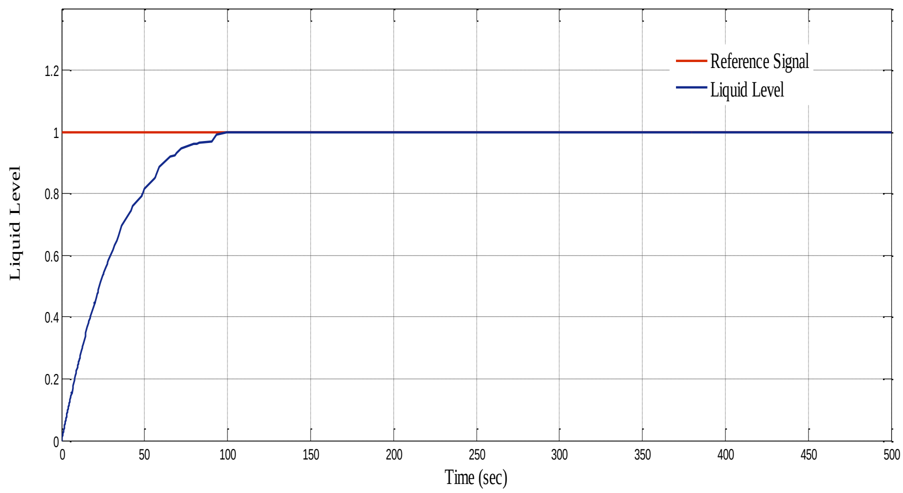

Fig. 12:- Simulation result using fuzzy logic controller

From figure 12 Fuzzy Logic Controller provide good performance in terms of oscillations and overshoot in the absence of a prediction mechanism.

5.3 Discussion

For comparison purposes, simulation plots include a conventional PID controller, and the fuzzy algorithm. It can be seen that the Fuzzy Logic Controller provide good and satisfactory time domain response performance in terms of oscillations and overshoot are quite absence due to prediction mechanism. The Fuzzy Logic Controller algorithm adapts quickly to longer time delays and provides a stable response while the PID controllers may drive the system unstable due to mismatch error generated by the inaccurate time delay parameter used in the plant model.

To strictly limit the overshoot, a Fuzzy Controller can accomplish a great control effect. In this paper, we take the water level tank , and use Matlab to design a Fuzzy Controller. Then we examine the control effect and compare it with the effect of PID controller. After comparision the Fuzzy Logic Controller is better then the PID controller. Specially, it can give more attention to various parameters, such as the response time, the error of steadying and overshoot. After comparison we find that the fuzzy logic controller significantly reduced overshoot and steady state error. Comparison results of PID and Fuzzy Logic Controller are shown in Table 4.

Table 4 Comparison table of PID & FLC

Parameters	**PID Controller**	**Fuzzy Logic Controller**
Overshoot	Present	Not Present
Settling Time	More	Less
Transient	Present	Not Present
Rise Time	Less	More
Steady State Error	Present	Not Present

VI. CONCLUSIONS

The proposed approach for designing Fuzzy controller in this paper gives valid results. The conventional PID with fixed gain parameters cannot satisfy this kind of requirements. Fuzzy controller which can self-tune the values of the gain parameters has been successfully presented in this paper for the step response of two tank liquid level system. Using the same rule base for two tank system with change of gain parameters range for the system self-tuning mechanism can be implemented. The simulation results show that the Fuzzy control system has a faster response, a lower transient overshooting, and a better dynamic performance than the conventional PID controller.

The simulation results also conclude that the proposed Fuzzy Controllers can also be replaced with conventional PID controller. Fuzzy Logic Controller is easy to implement than PID controller. Additionally, the Fuzzy Logic Controller can be easily programmed into many currently available industrial process controllers. The Fuzzy Logic Controller on a level control problem with promising results can be applied to an entirely different industrial level controlling apparatus.

VII. FUTURE WORK

As a future work we can develop design of a Fuzzy Logic Controller for three or four level tank system as adaptive Fuzzy Logic Controller like PID algorithm, which gives high performance for system and high intelligence. We can also develop design of this couple tank system by using other evolutionary computing methods such as genetic algorithm etc.

REFERENCES

[1] S.N.Sianandam, S.Sumathi and S.N.Deepa, “Introduction to Fuzzy Logic using MATLAB(Springer,2007)”.
[2] Abdul Rasyid, Bin Mohammd Ali,"Optimization of Controller Parameters for A Couple Tanks System using Metamodelling Technique", University Technology Malaysia, 2009,147 pp.
[3] Carlos A. Smith, P.E. & Armando B. Corripio, "Principles and Practice of Automatic Process Control" Second Edition, 1997,783pp.
[4] Dharamniwas , Aziz Ahmad , Varun Redhu and Umesh Gupta," Liquid Level Control by using Fuzzy Logic Controller", International Journal of Advances in Engineering & Technology, Vol. 4, Issue 1, pp. 537-549, July 2012.
[5] Elke Laubwald, " Coupled Tanks Systems”, Visiting Scientist, control systems principles.co.uk.
[6] P. Berk, D. Stajnko, P. Vindis, B. Mursec, M. Lakota, "Synthesis water level control by fuzzy logic", International OCSCO World Press, Volume 45,Issue 2, pp.204-210,April 2011.
[7] G.Sakthivel & T.S.Anandhi & S.P.Natarajan," Design of Fuzzy Logic Controller for a Spherical tank system and Its Real Time Implementation",G.Sakthivel,T.S.Anandhi,S.P.Natarajan/ International Journal of Engineering Research and Applications (IJERA), Vol. 1, Issue 3, pp.934-940.
[8] Katsuhiko Ogata, “Modern Control Engineering“, Fifth Edition, 905pp, 2010.
[9] Q. Li, Y. Fang, J. Song, J. Wang, "The application of fuzzy control in liquid level system", “IEEE/ICMTMA”, Vol.3, pp.776-778, Mar 2010.
[10] Z. Zhi, H. Lisheng, "Performance assessment for the water level control system in steam generator of the nuclear power plant",“IEEE/CCC”pp. 5842-5847, July 2011.
[11] E.H. Mamdani, “Advances in the linguistic synthesis of fuzzy controllers”, International Journal of Man Machine Studies, 669-678, 8 (1976).
[12] E.H. Mamdani, “Applications of fuzzy logic to approximate reasoning using linguistic synthesis”, IEEE Transactions on Computers, 1182-1191, 26/12 (1977).
[13] P. J. King, and E. H. Mamdani, “The application of Fuzzy logic control systems to industrial processes,” Automated v11, p235-212,1997.