COMPARATIVE ANALYISIS OF P, PI, PID AND FUZZY LOGIC CONTROLLER FOR TANK WATER LEVEL CONTROL SYSTEM

Sumit Kumar[1], Mrs. Pooja Nagpal[2]

[1]*JCDM College of Engineering, Haryana, India, Sirsa*

[2]*Associate Professor, JCDM college of Engineering, Haryana, India*

Abstract - *The objectives of this paper are to design and comparatively analyze the P, PI, PID and Fuzzy Logic controller for coupled tank liquid level system. Simulink model for coupled tank system is designed within MATLAB/Simulink. Tuning of parameters for PID controller is done using signal constraint block in MATLAB/simulink. Simulated results were compared to verify the performance of the control system in terms of rise time, steady state error, settling time and overshoot. A simulated result of the controllers in coupled tank system indicates that fuzzy logic controller gives better results as compared to other controllers.*

Key Words: *Coupled tank system, PID controller, Fuzzy Logic controller, MATLAB/Simulink, Signal constraint.*

1. INTRODUCTION

Accuracy in level and flow control of the tanks is highly important application for the chemical process industries [1]. Mostly PID controller is used in industries for control process due to its simple structure and easiness in implementation [2, 7] Conventional P controller can reduce the adjusting time it can eliminate the present error only and PID controller use mathematical model of the system as it is difficult to find proper gain so it is not good for highly non linear system [3]. In this work coupled tank system is used which is a non linear system and dynamic behavior of tanks affect each other as inflow between the tanks depends on the level of both tanks. Where PI controller is suitable for low order process where accuracy does not the prime factor but for higher accuracy it is not suitable [4]. It is also difficult to get desired result by using conventional PI controller as it gives poor performance for higher order process [4]. Fuzzy logic control system does not use mathematical model of the process so fuzzy logic controller can be used where PID controller is difficult to apply [5].FLC system use human reasoning so it is flexible and can be understood easily. It is suitable for the requirement of industrial applications it may be a reason behind the wide use of FLC system [6]. So in this paper a comparative analysis of P, PI, PID and FLC has done for coupled tank system in terms of rise time, setting time, overshoot and steady state error. The simulated results are compared and verified in MATLAB/Simulink and find that fuzzy logic control system gives better performance than other control systems.

2. MATHEMATICAL MODELLING OF COUPLED TANK SYSTEM

Let us consider a coupled tank system used in industrial application as shown in fig.1 the mathematical model for this coupled tank system is nonlinear as shown by equation 1.1 and 1.2.

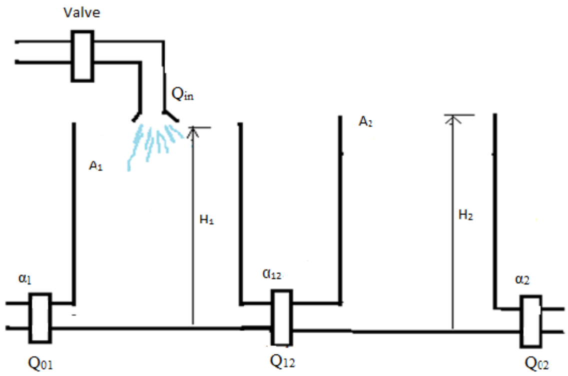

Fig.1: Schematic diagram of coupled tank system

Q_{in}, Q_{01}, Q_{12} and Q_{02} are quantity of liquid flow in the tanks, quantity of liquid flow out from tank1, quantity of liquid flow in between the tanks and quantity of liquid flow out from tank2.

H_1, H_2 are the height of the liquid in the tanks, respectively

A_1, A_2 are the cross sectional area of the tanks, respectively

α_1, α_2 and α_{12} are the cross sectional area of output pipe tank1, tank2 and in between tanks.

Equation for tank 1:-

$$(A_1)\,\frac{dH_1}{dt} = Q_{in} - \alpha_1\left(\sqrt{H_1}\right) - \alpha_{12}\left(\sqrt{H_1 - H_2}\right) \qquad 1.1$$

Equation for tank 2:

$$(A_2)\,\frac{dH_2}{dt} = \alpha_{12}\left(\sqrt{H_1 - H_2}\right) - \alpha_2\left(\sqrt{H_2}\right) \qquad 1.2$$

Using these two equations a simulink model for the coupled tank has been designed.

A linearization method is applied to get linear equation and transfer function for the coupled tank system.

Transfer function will be as shown below:

$$\frac{(K_{21})(K_1)}{(T_1)(T_2)s^2 + (T_1 + T_2)s + 1 - (K_{12})(K_{21})}$$

Where T_1= 2.6085, T_2= 2.5839 are the time constants and K_1 = 0.081516, K_{12}=0.8934 and K_{21}= 0.8850 are the gains for the coupled tank system. Transfer function of the coupled tank model is as below.

$$\frac{0.07212}{6.7401s^2 + 5.1924s + 0.2093}$$

The analysis of this mathematical model is done using MATLAB/Simulink toolbox for P, PI, and PID controllers.

3. CONTROLLER DESIGN FOR COUPLED TANK SYSTEM

3.1 PID controller design for the system

A simulated model for PID control system is as shown fig.3 the difference of set point and measured variable goes to the controller. PID controller combines the control action of Proportional, Integral and derivative controller where Proportional controller reduces the rise time, integral controller eliminates steady state error and derivative controller reduces overshoots of the system. PID controller involves three tuning parameters K_p, K_i and K_d. In this paper parameters are tuned within MATLAB/Simulink block signal constraint. This tool helps in optimization of parameters very fast. In this tool we used 0 to infinity tolerance for finding optimal solution or feasible solution. Parameters values found for P, PI and PID controller which is shown below.

Proportional controller- K_p=328.34 not found any feasible solution

Proportional plus Integral controller- K_p = 67.4043, K_i=1.1154 found a feasible solution

Proportional plus Integral plus Derivative controller- K_p=67.3394, K_i=1.1552, K_d=10.7037 found a feasible solution

This optimization method gives fast response.

3.2 Fuzzy logic controller design for the system

FLC consist of fuzzification, fuzzy rules and defuzzification. Where fuzzification converts the crisp inputs into fuzzy inputs. We used rate and level as an input and valve as an output for this application. Fuzzification next step is selection of membership function for input and output variables. Triangular membership function is used for both input and output variables. In the next step range of subset for variables is selected within the display range variables. Here we have used low, high and ok subsets for error variable and negative, zero, positive subsets for rate of change variable and OF, OS, CF, CS, NC subsets for valve variable. Ranges of these subsets are selected within the variables membership function range. After the selection of range for each subset these subsets are used for the designing of rules in rule editor tool box. Response of the controller depends upon the rules. Nine rules are designed for this application which is shown in matrix form. Response of the designed rules can be viewed in surface viewer tool box. When a control rule generates from the FIS it must be defuzzified from fuzzy value to crisp value center of gravity rule method is used for defuzzification.

The rules shown in the rule matrix are expressed as shown below.

IF the level is low AND rate is zero THEN open fast valve.

Table-1: rule matrix

Level / Rate	Low	Okay	High
Negative	OF	OS	CF
Zero	OF	NC	CF
Positive	OF	CS	CF

Where
OF – open fast
OS – open slowly
CF – close fast
CS – close slowly
NC – no change

4. SIMULINK RESULTS AND COMPARISON

The simulink model for coupled tank, PID controller and fuzzy logic control system and their simulated response to find rise time, setting time overshoot and steady state error of the controllers are shown below.

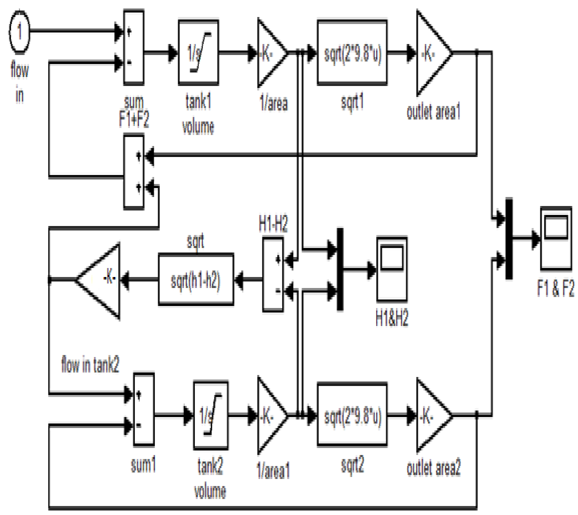

Fig.2: Simulink model for coupled tank

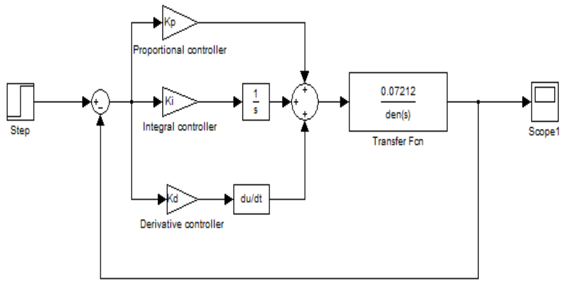

Fig.3: Simulink model for PID control system

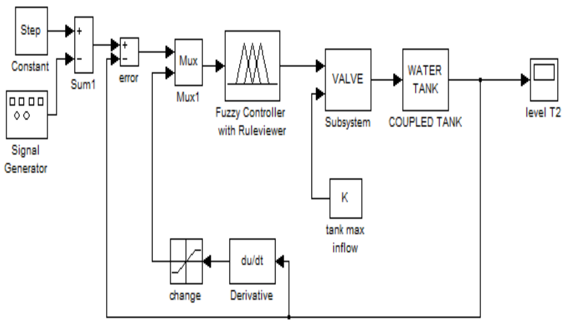

Fig.4: simulink model for fuzzy logic control system

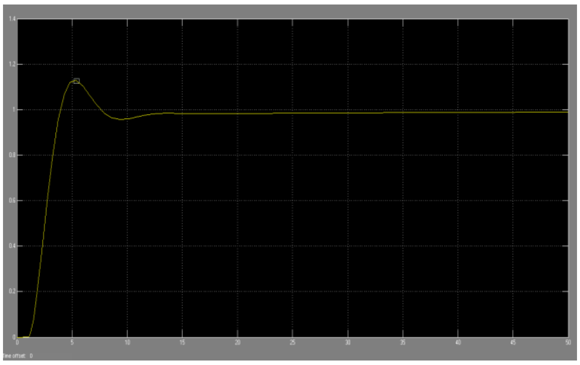

Fig.5: Simulink response of PID controller

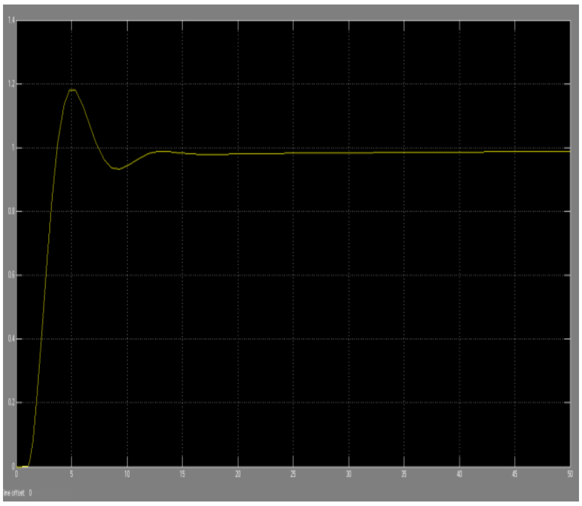

Fig.6: Simulink response of PI controller

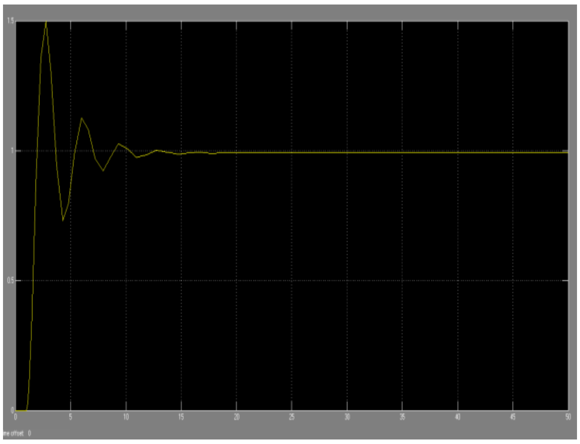

Fig.7: Simulink response of P controller

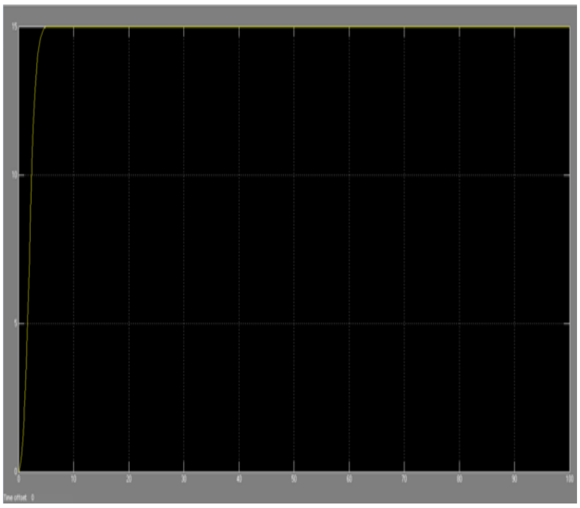

Fig.8: simulink response of fuzzy logic controller

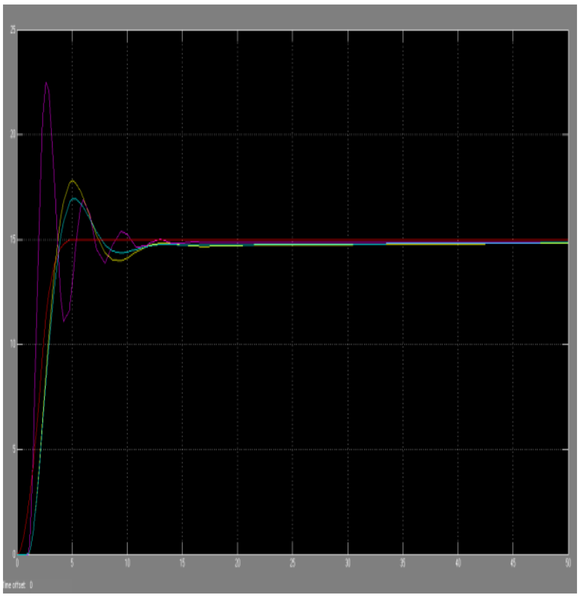

Fig.9: Comparative Simulink response of P, PI, PID and fuzzy logic controller for parameters

Table-2 Comparative evaluation of controllers in tabular form

Controllers	Rise time	Steady state error	Peak overshoot	Setting time
P	1.9sec	0.9%	50%	20sec
PI	3.41sec	1.6%	18%	16sec
PID	3.56sec	1.6%	13%	12sec
FLC	3.25sec	0	0	5sec

5 CONCLUSIONS

In this paper, we developed the mathematical model of coupled tank system and design a simulink model for coupled tank, PID controller and fuzzy logic control system. Designed model are simulated within MATLAB/Simulink and comparatively analyzed in terms of rise time, steady state error, peak overshoot and setting time. From the analysis we concluded that coupled tank system with fuzzy logic controller gives better performance. The simulated results shows that fuzzy logic controller is a better option for real world applications as we can see in the results shown in table 2.

REFERENCES

[1] S.Shamily, Parveena and Bhuvaneswar, "Intelligent control and Adaptive control for Interacting system", proceedings of IEEE International conference on technological innovations in ICT for agriculture and rural development, pp 116-121, 2015.
[2] Qu Qingly, Zhao Pingrong, Wu Yangxi, "Control system of the Boiler water level based on Normalized PID", proceedings of the 3rd IEEE International conference on computer science and network technology, 1251-1254, 2013.
[3] S.A.Mali, C.B Kadu, B.J Parvat, "Design of fuzzy adaptive PI controller for SISO system", proceedings of IEEE International conference on energy system and applications, pp 234-238, 2015.
[4] Michail Petrov, Ganchev Albena Taneva, "Fuzzy PID control of nonlinear plants", 1st international IEEE symposium on intelligent system, vol.1, pp 30-35, 2002.
[5] Muhammad Abid, "Fuzzy logic control of coupled liquid tank system", IEEE transaction on process control, pp144-147, 2005.
[6] Sayed Kamaleddin Mousavi Mashidi, "Design fuzzy controller for synthesis water level", Journal of Mathematics and Computer Science, pp 300-313, 2014.
[7] S.Nithya, Abhay Singh Gour, "Intelligent Controller Implementation in Real time for a non linear process", IEEE transaction on process controller, pp 2508-2513, 2008.
[8] Meng Quinsong, Wang Qi, Wei Hongling, "Design of fuzzy controller for liquid level control system based on MATLAB/RTW", proceedings of the 2nd IEEE International conference on measurement, information and control, Harbin, China, vol.2, pp 1090-1094, 2013.
[9] Lian Li, Wengkuan Ding, "Optimization control strategy of Boiler water level based on fuzzy PID", proceedings of the 28th IEEE Chinese control and decision conference, China, pp 5893-5896, 2016.