Middle-East Journal of Scientific Research 23 (Sensing, Signal Processing and Security): 232-238, 2015
ISSN 1990-9233

DOI: 10.5829/idosi.mejsr.2015.23.ssps.58

Real Time Implementation of Advanced Control Scheme (Fuzzy Logic Controller) for Three Tank Interacting System

S. Shri Shankari, Mohitha Gireeshan, V. Azhagan and D. Kalpana

Department of Instrumentation, MIT, Anna University, India

Abstract: In an industrial system, liquid level control has its own significance especially in petrochemical pharmaceutical industries. Thus a three tank interacting system has been considered for our work. The system is of a higher order which can be modeled into a First Order plus Dead Time System. The conventional control algorithm (PID) is initially used to control the system. However it is difficult to reach required control quality with more strict restrictions on overshoot. Thus an advanced control scheme: Fuzzy Logic controller has been used to control the system, with the error and change in error values obtained from PID controller. Both the controllers have been simulated and implemented in real time. Finally, a comparison of the conventional PID model, fuzzy model has been presented. It has been established that Fuzzy gives a better performance over the conventional PID.

Key words: Fuzzy Logic · PID Controller · Tuning Methods · Three Tank System

INTRODUCTION

Fuzzy logic idea is similar to the human being's feeling and inference process. Unlike classical control strategy, which is a point-to-point control, fuzzy logic control is a range-to-point or range-to-range control. To implement fuzzy logic technique to a real application requires the following three steps: 1. Fuzzification – convert classical data or crisp data into fuzzy data or Membership Functions (MFs). 2. Fuzzy Inference Process – combine membership functions with the control rules to derive the fuzzy output. 3. Defuzzification – use different methods to calculate each associated output and put them into a table: the lookup table. Pick up the output from the lookup table based on the current input during an application.

Fuzzification: All machines can process crisp or classical data such as either '0' or '1'. In order to enable machines to handle vague language input such as 'Somehow Satisfied', the crisp input and output must be converted to linguistic variables with fuzzy components fuzzification involves two processes: derive the membership functions for input and output variables and represent them with linguistic variables. This process is equivalent to converting or mapping classical set to fuzzy set to varying degrees. Membership functions can have multiple different types, such as the triangular waveform, trapezoidal waveform, Gaussian waveform, bell-shaped waveform, sigmoidal waveform and S-curve waveform.

Fuzzy Inference Process: In the second step, to begin the fuzzy inference process, one need combine the Membership Functions with the control rules to derive the control output and arrange those outputs into a table called the lookup table. The control rule is the core of the fuzzy inference process and those rules are directly related to a human being's intuition and feeling.. Different methods such as Center of Gravity (COG) or Mean of Maximum (MOM) are utilized to calculate the associated control output and each control output should be arranged into a table called lookup table. The fuzzy rule is represented by a sequence of the form IFTHEN, leading to algorithms describing what action or output should be taken in terms of the currently observed information.

Defuzzification: During an actual application, a control output should be selected from the lookup table developed from the last step based on the current input. Furthermore, that control output should be converted from the linguistic variable back to the crisp variable and output to the control operator. This process is called Defuzzification.

Corresponding Autor: S. Shri Shankari, Department of Instrumentation, MIT, Anna University, India.

Mathematical Modelling of Three Tank Interacting System

Mathematical Equations: According to fluid dynamics, there is linear relationship between the liquid level and flow in the turbulence situation. Through linear processing, the tank equations are given by equations 1, 2 and 3:

$$Fin - b2\sqrt{(h_1 - h_2)} = A.\frac{dh_1}{dt} \tag{1}$$

$$b1\sqrt{(h_1 - h_2)} - b2\sqrt{(h_2 - h_3)} = A.\frac{dh_2}{dt} \tag{2}$$

$$b2\sqrt{(h_2 - h_3)} - b3\sqrt{h_3} = A.\frac{dh_3}{dt} \tag{3}$$

Fig. 1: Laboratory setup of the three tank interacting system

For the laboratory setup, $b_1=b_2=b_3= 0.003125$, D= diameter of the tank=15cm, A=Area of the tank=Capacitance of the process = $\frac{\pi}{4}D^2$ =0.01767 m^2

Open Loop Response: The Open Loop response is obtained in Real Time by interfacing and accessing the setup with PC through LABVIEW software. The experimental set up is adjusted such that the interacting valves are kept completely open.The drain valve of tank 3 is kept 25% open. The output from level transmitter is connected to I/V converter which in turn connected to DAQ.The output from DAQ is connected to V/I converter which is connected to the control valve.

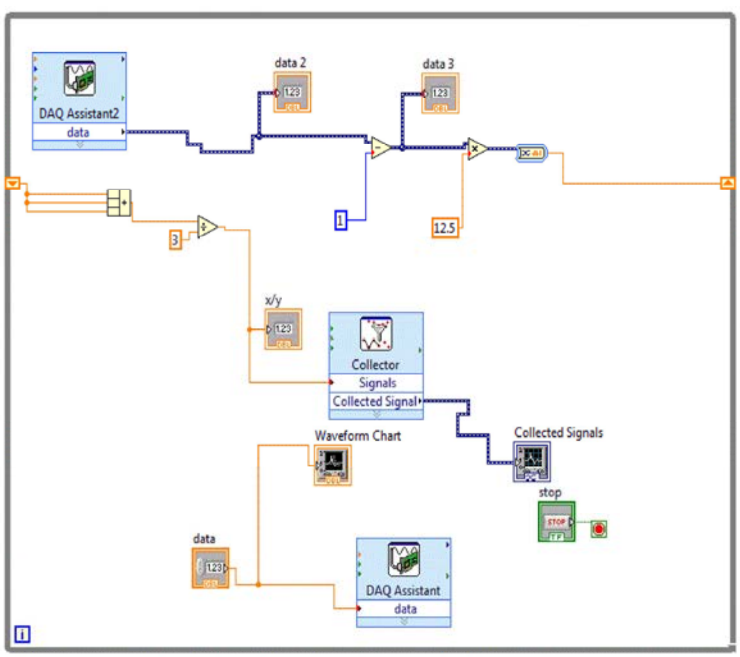

Fig. 2: Block diagram for open loop response in LABVIEW

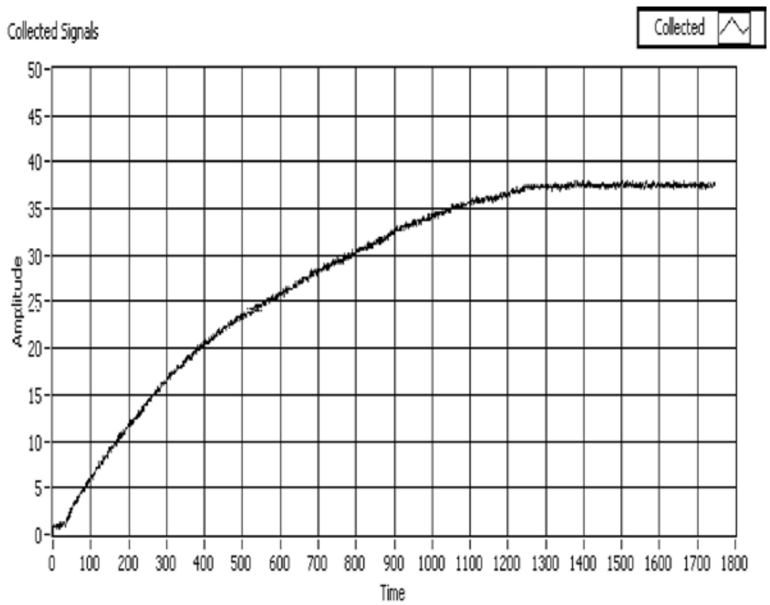

Fig. 3: Open loop response curve

Table 1: Gain values for PID Controller: ZN Open loop method

K_p	K_i	K_d
0.2955	0.255	0.969

From the response obtained, the values of K, τ_d andτ are obtained using Sundaresan technique:

$$\tau_d=1.3*t_{35.3}-0.29*t_{85.3} \quad (4)$$

$$\tau=0.67*(t_{35.3}-t_{85.3}) \quad (5)$$

The transfer function thus obtained is

$$\frac{h_3(s)}{F_{in}} = \frac{18.69*e^{-39.38s}}{434.14s+1} \quad (6)$$

Design of Pid Controller

Controller Tuning Using Zn Open Loop Method: The controller parameters using ZN open loop method are shown in Table 1.

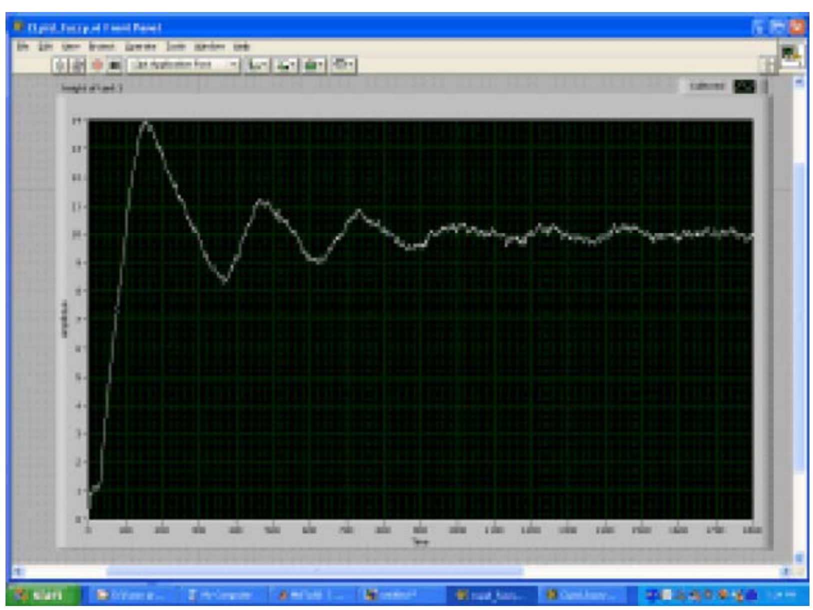

Fig. 4: Closed loop response (ZN Open loop)

Controller Tuning Using Direct Synthesis Method: The controller parameters using Direct Synthesis method are shown in Table 2.

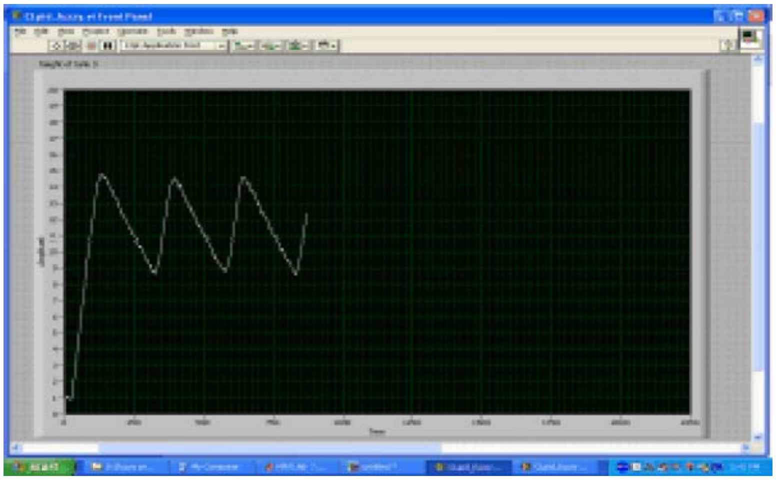

Fig. 5: Closed Loop Response (Direct Synthesis)

Controller Tuning Using Cohencoon Method: The controller parameters using Cohencoon method are shown in Table 3.

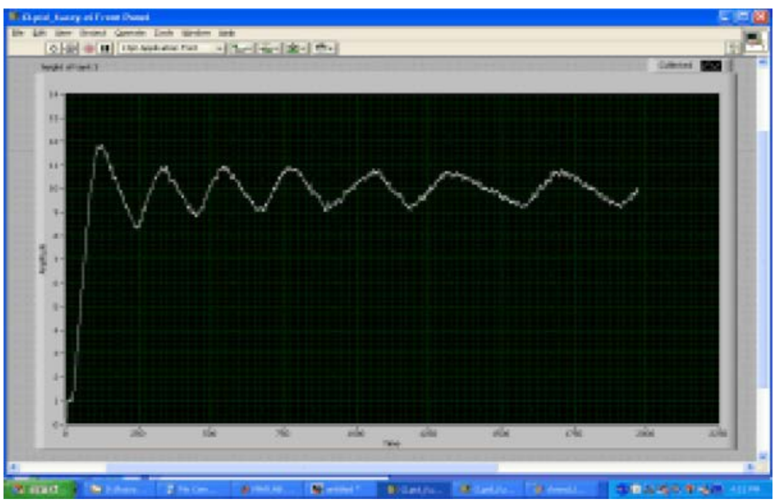

Fig. 6: Closed loop response (Cohencoon)

Table 2: Gain values for PID Controller: Direct Synthesis method

K_p	K_i	K_d
0.0267	0.00371	0.1918

Table 3: Gain values for PID Controller: Cohencoon method

K_p	K_i	K_d
0.3999	0.8595	0.0129

Comparison of PID Tuning Techniques: The performances of PID controller tuned by ZN open loop, Cohencoon and direct synthesis methods are shown in Table 4.

Table 4: Comparison of PID Tuning techniques

	ZN Open Loop	Cohencoon	Direct Synthesis
Peak Value (SP=10cm)	14	11.8	14.6
Peak time	160s	140s	130s
% Overshoot	40	18	46
Rise time	97s	98s	110s
2% Settling time	1600s	-	-

From Table 4, it is evident that, amongst all the tuning techniques, ZN Open Loop gives a better performance. Thus the error and change in error values of ZN Open Loop method has been used as membership functions for the Fuzzy Logic Controller.

Table 5: Membership functions and their ranges

Error	NB	-75	-50	-20
	N	-22	-11	2
	ZO	-3.7107	0	3.743
	P	-2	10	22
	PB	20	50	75
Del Error	NB	-50	-1	-0.7
	N	-0.8	-0.5	-0.2
	ZO	-0.24	0	0.24
	P	0.2	0.5	0.8
	PB	0.7	1	50
Controller Output	NB	-1	0	0.7
	N	0.5	1.25	2
	ZO	1.875	2.5	3.125
	P	3	3.75	4.5
	PB	4.375	5.0134	5.5

Design of Fuzzy Logic Controller: Fuzzy Logic Controller (FLC) is implemented using LABVIEW with the existing transfer function. Based on the obtained values of error and change in error, the fuzzy logic membership functions are formed and rules are designed. The rules can be checked in the test engine.

Formation of Membership Functions

Design of Rule Base: The rule base has been deigned from the ranges of error and change in error of Table 5. He rules have further been simulated and modified using trial and error method

Implementation of Fuzzy Logic Controller: Fuzzy Logic Controller has been implemented in LABVIEW with the error and change in error values obtained in ZN OPEN loop Method.

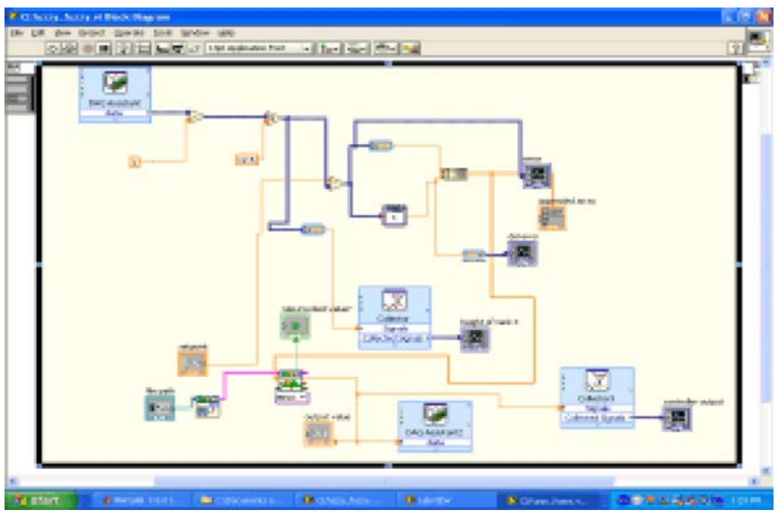

Fig. 9: LABVIEWBlock Diagram - Implementation of Fuzzy Logic Controller

Response of Fuzzy Logic Controller:

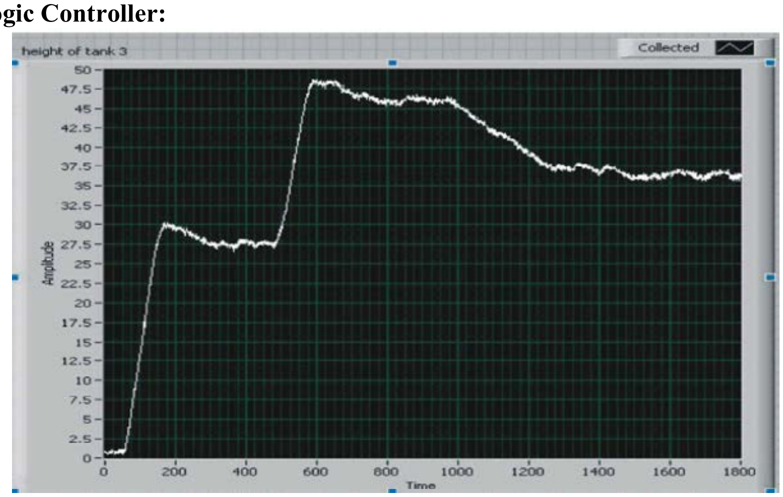

Fig. 10: Closed Loop Response (FLC)

Comparison of Pid Controller and Fuzzy Logic Controller: The set point is given as a multiple step with values being 25, 35 and 45. The response is shown as follows:

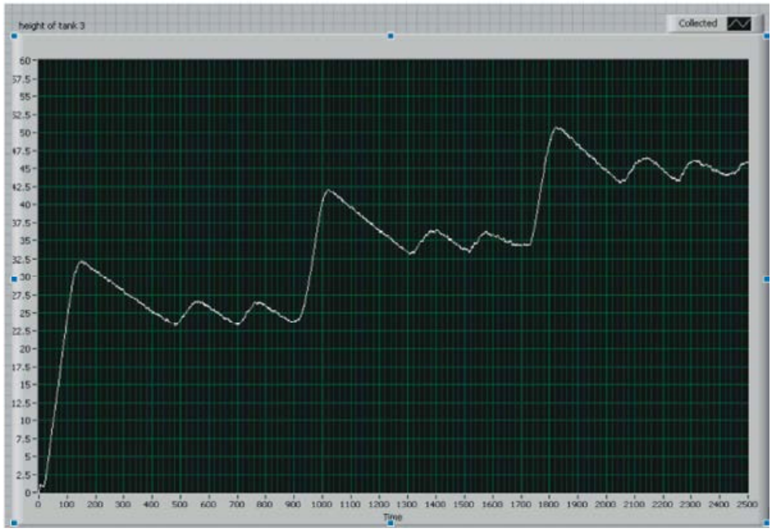

Fig. 11: Response of Closed Loop controlled by PID controller

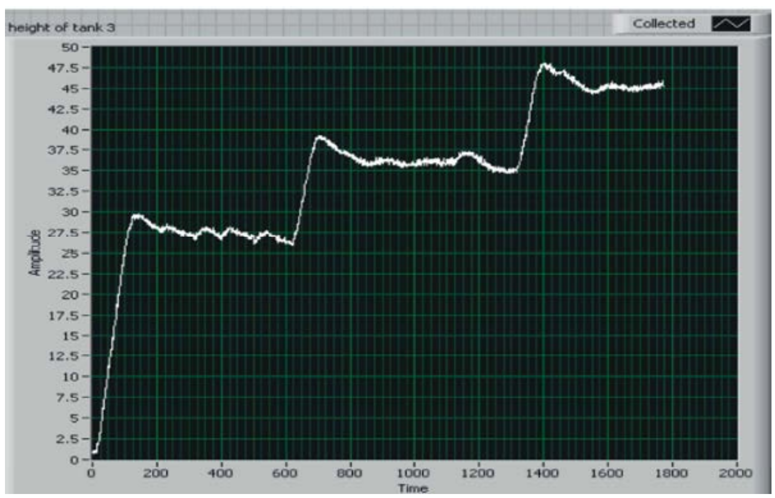

Fig. 12: Response of Closed Loop controlled by FLC

Table 6: Rule Base for Fuzzy logic Controller

	Del Error				
Error	NB	N	ZO	P	PB
NB	NB	NB	NB	NB	NB
N	NB	NB	NB	N	PB
ZO	N	N	NB	N	P
P	ZO	ZO	P	ZO	PB
PB	PB	PB	PB	PB	PB

Table 7: Comparison of PID controller and Fuzzy Logic Controller

Parameters	PID	FLC
Overshoot (%)	21.42	11.248
Rise Time (s)	75	60
Peak Time (s)	150	120
5% Settling Time (s)	675	260

The comparison of PID and Fuzzy Controllers with respect to parameters such as overshoot, rise time, peak time and 5% settling time are shown in Table 7.

CONCLUSION

Fuzzy Logic Controller has been designed for the Three Tank Interacting System.. Both PID and fuzzy Controllers have been implemented in real time and their performances have been compared. Fuzzy Controller is found to have better transient parameters than its PID counterpart.

REFERENCES

1. Sharad Kumar Tiwari and Gagandeep Kaur, 2011. Analysis of Fuzzy PID and Immune PID Controller for Three Tank Liquid Level Control, International Journal of Soft Computing and Engineering (IJSCE) ISSN: 2231-2307, Volume-1, Issue-4, September 2011
2. Maruthai Suresh, Gunna Jeersamy Srinivasan and Ranganathan Rani Hemamalini, 2009. Integrated Fuzzy Logic Based Intelligent Control of Three Tank System, Serbian Journal of Electrical Engineering, 6(1): 1-14.
3. Fundamentals of Fuzzy Logic Control – Fuzzy Sets, Fuzzy Rules and Defuzzifications by Ying Bai and Dali Wang
4. Wang, L.X. and J.M. Mendel, 1992. Generating fuzzy rules by learning from examples, IEEE Trans. Fuzzy Syst., Man, Cybern., 22(6): 1414-1427.
5. Bansal, R.K., A.K. Goel and M.K. Sharma, XXXX. Matlab and its applications in engineering,
6. Zhang, J. and S. Lang, 1989. Explicit self-tuning control for a class of nonlinear systems, Automatica, 25(4): 593-596.
7. Li, Q., Y. Fang, J. Song and J. Wang, 2010. The application of fuzzy control in liquid level system, IEEE/ICMTMA, 3: 776-778.
8. Lee, C.C., 1990. Fuzzy logic in control systems: Fuzzy logic controller- part 1, IEEE trans. Syst., Man, Cybern., 20: 404-418.
9. Antsaklis, 1997. Intelligent Controls, Department of Electrical Engineering University of Notre Dame Notre Dame, IN 46556 USA written for the Encyclopedia of electrical and Electronics Engineering John Wiley & Sons, Inc. 1997.
10. Ari Ingimundarson and Tore Hagglund, 2002. Performance comparision between PID and Deadtime compensating controller, Journal in Process Control, 9(11): 1163-1175.