International Journal of Advanced Technology in Engineering and Science
Vol. No.3, Special Issue No. 01, September 2015
www.ijates.com
ijates
ISSN 2348 - 7550

DETERMINATION OF THE PERFORMANCE OF NEURAL PID, FUZZY PID AND CONVENTIONAL PID CONTROLLERS ON TANK LIQUID LEVEL CONTROL SYSTEMS

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ABSTRACT

In modern industrial control systems, the liquid level is one of the important factors as the control action for level control in tanks containing different chemicals or mixtures of liquids is concern. From the various controllers available one would find it difficult to identify the most appropriate one for excellent performance. Comparative studies of the performances of the conventional PID, Fuzzy PID and Neural PID controllers on systems of tanks are conducted in this work. The simulation results show that Fuzzy PID has smaller settling time in single, four and five tank while conventional PID has smaller settling time in couple and three tank control system.

Keywords: Liquid Level Control; PID; Fuzzy Logic; Neural.

I. INTRODUCTION

In industrial applications, liquid level control is a typical representation of process control and is widely used in storage tanks in oil/gas industries, dairy, pharmaceutical industries, filtration, food processing industry and water purification systems. The typical actuators used in liquid level control systems include pumps, motorized valves , on-off valves and level sensors such as displacement float and capacitance probe. Pressure sensor provides liquid level measurement for feedback control purpose so that as per the process requirements the fluids could be controlled. The aim of the controller in the level control is to maintain a level set point at a given value and be able to accept new set point values dynamically [2]. The control quality directly affects the performance and efficiency as well as the quality of products and safety of equipments.

[3] Conducted an analysis on Conventional PID, Fuzzy PID and Immune PID controllers for three tank liquid level control from which new immune PID controller shows smaller overshoot and also improves the settling time of the process. The PID controller may be the one which is the most extensively applied. However, in the past, the control gain parameters adopted in PID controller were usually determined based on the experience of the operator, trial and error or experiments [4]. Although PID controllers have strong abilities they are not suitable for the control of long time-delay systems, in which the P, I, and D parameters are difficult to chose [5]. Whether the inlet or outlet flow is controlled may vary depending on the particular application [6]. Very often a

PID controller is used for liquid level control in most applications and is commonly utilized in controlling the level, but the parameter is not enough for efficient control. Conventional PID controller is probably the most used feedback control design and has been used to control about 90% industrial processes worldwide [2] and [7]. Due to its qualities, robustness, non-linearity and disturbance inclusion fuzzy logic could be a suitable option to adjust parameters of PID controllers considering that liquid level tank control is a field where non-linearity and change of conditions or transients are usual and PID is quite inflexible to these characteristics [7]. By [8] basic design mode and extended design mode of PID controller were carried out and extended design mode of PID controller proves smaller overshoot. The fact that the available controllers have different values of these parameters; one would find it difficult to identify the most suitable one for a given.

In this work, we investigated the performance of the conventional PID, Fuzzy PID and Neural PID controllers on liquid level control systemsfrom which would enable one quickly to decide on the appropriate controller provided the transfer function of the system is developed.

II. METHODOLOGY

The transfer function of the system is modelled mathematically and simulated using Matlab Simulink.

- **Mathematical Modelling of Liquid Level Control System**

In this paper, the liquid level control system of a container water tank system is discussed. A single, couple, three, four and five – container water tank is usually connected by first-order non periodic inertia links in series, and the structure of single, couple and three tank system can be schematically shown in Fig.1, 2 & 3.

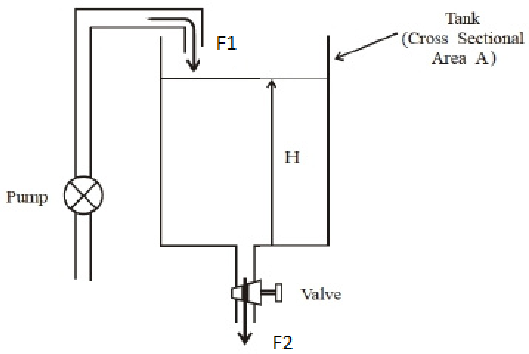

Fig.1 Single Tank Liquid Level Control Structure

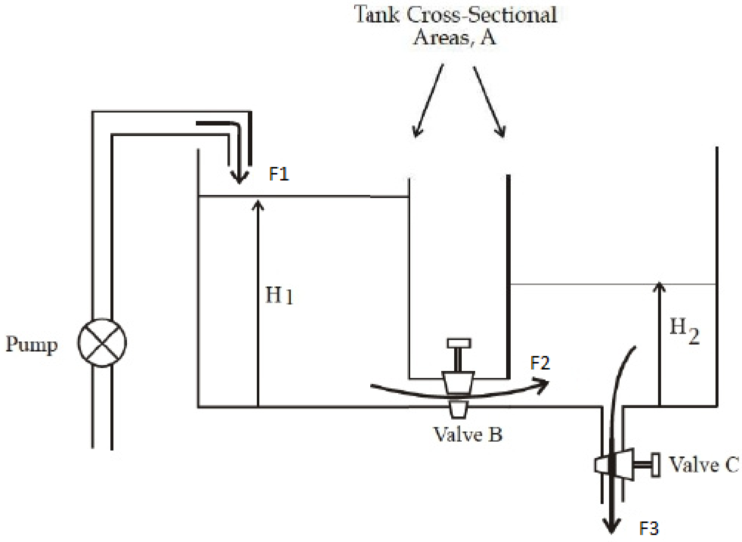

Fig.2 Couple Tank Liquid Level Control Structure

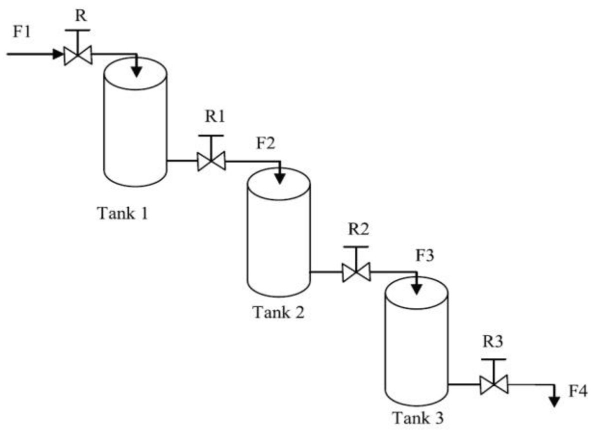

Fig.3 Three Tank Liquid Level Control Structure

Mathematical modeling:-

For Tank 1

$$F_1(t) - F_2(t) = A_1\frac{dh_1}{dt} \quad (1)$$

Where$F_1(t)$ = tank 1 in flowing liquid (m^3/s),$F_2(t)$= tank 1 out flowing liquid (m^3/s), A_1= Area of tank 1 (m^2), h_1 = liquid level in tank 1(m)

For Tank 2

$$F_2(t) - F_3(t) = A_2\frac{dh_2}{dt} \quad (2)$$

WhereF_2 = tank 2 in flowing liquid (m^3/s),$F_3(t)$= tank 2 out flowing liquid (m^3/s), A_2= Area of tank 2 (m^2), h_2 = liquid level in tank 2(m)

For Tank 3

$$F_3(t) - F_4(t) = A_3\frac{dh_3}{dt} \quad (3)$$

Where$F_3(t)$ = tank 3 in flowing liquid (m^3/s),$F_4(t)$= tank 3 out flowing liquid (m^3/s), A_3= Area of tank 3 (m^2),h_3= liquid level in tank 3(m)

Same applies for Tank 4 and Tank 5

$F_2(t) = {}^{h_1}/_{R_1}$, $F_3(t) = {}^{h_2}/_{R_2}$, $F_4(t) = {}^{h_3}/_{R_3}$, $F_5 = {}^{h_4}/_{R_4}$, $F_6 = {}^{h_5}/_{R_5}$

Where R1, R2, R3, R4 and R5 are linear resistance of Tank 1, 2, 3, 4 & 5 (m/m^3/s)

The overall transfer functions of the tanks are as follows:

For Single Tank

$$\frac{H_1(s)}{q_1(s)} = \frac{R_1}{R_1A_1s+1} \tag{4}$$

For Couple Tank

$$\frac{H_2(s)}{q_1(s)} = \left[\frac{R_1}{R_1A_1s+1}\right]\left[\frac{R_2/R_1}{R_2A_2s+1}\right] \tag{5}$$

For Three Tank

$$\frac{H_3}{q_1(s)} = \left[\frac{R_1}{R_1A_1s+1}\right]\left[\frac{R_2/R_1}{R_2A_2s+1}\right]\left[\frac{R_3/R_2}{R_3A_3s+1}\right] \tag{6}$$

For Four Tank

$$\frac{H_4(s)}{q_1} = \left[\frac{R_1}{R_1A_1s+1}\right]\left[\frac{R_2/R_1}{R_2A_2s+1}\right]\left[\frac{R_3/R_2}{R_3A_3s+1}\right]\left[\frac{R_4/R_3}{R_4A_4s+1}\right] \tag{7}$$

For Five Tank

$$\frac{H_5(s)}{q_1} = \left[\frac{R_1}{R_1A_1s+1}\right]\left[\frac{R_2/R_1}{R_2A_2s+1}\right]\left[\frac{R_3/R_2}{R_3A_3s+1}\right]\left[\frac{R_4/R_3}{R_4A_4s+1}\right]\left[\frac{R_5/R4}{R_5A_5s+1}\right] \tag{8}$$

By considering

A1=A2=1m^2, A3=A4=A5=0.5m^2, R1=R2=2(m/cm^3/s), R3=R4=R5=4(m/cm^3/s)

$$\frac{H_1(s)}{q_1(s)} = \frac{2}{2s+1} \tag{9}$$

$$\frac{H_2(s)}{q_1(s)} = \frac{4}{4s^2+4s+1} \tag{10}$$

$$\frac{H_3}{q_1(s)} = \frac{4}{8s^3+12s^2+6s+1} \tag{11}$$

$$\frac{H_4(s)}{q_1} = \frac{4}{16s^4+32s^3+24s^2+8s+1} \tag{12}$$

$$\frac{H_5(s)}{q_1} = \frac{4}{32s^5+80s^4+80s^3+40s^2+8s+1} \tag{13}$$

Transfer function of valve (R) = $\left[\frac{0.133}{3s+1}\right]$ (14)

- Simulink Models

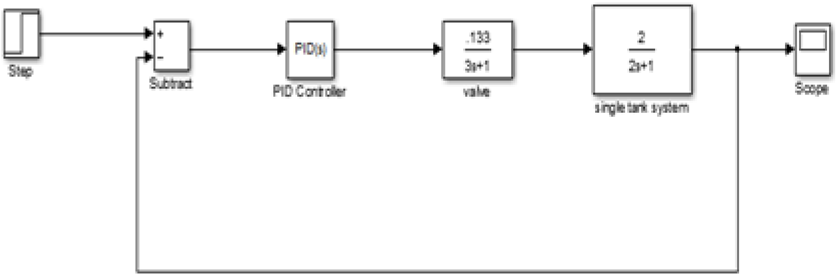

Fig.4 Simulink Model of Single Tank PID Control System

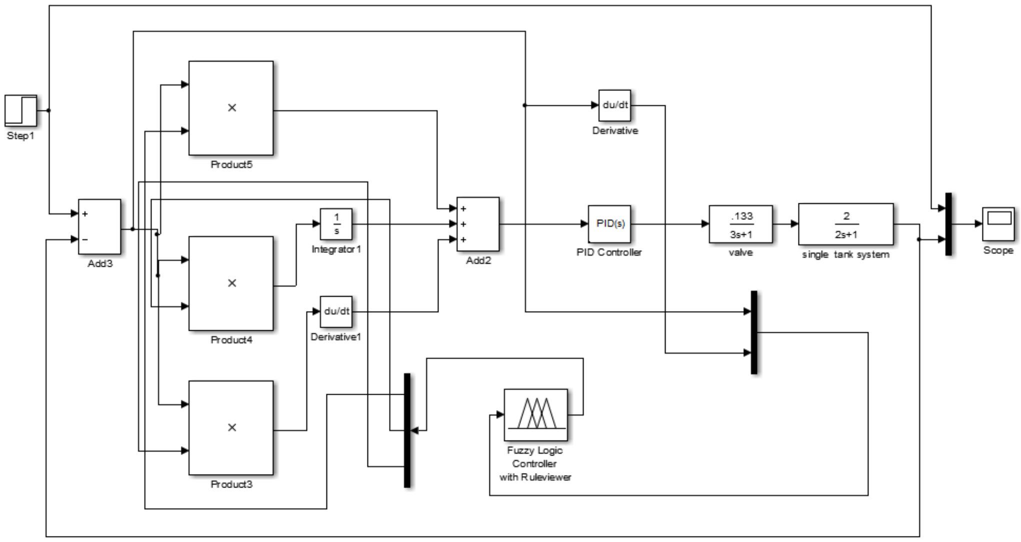

Fig.5 Simulink Model of Single Tank Fuzzy PID Control System

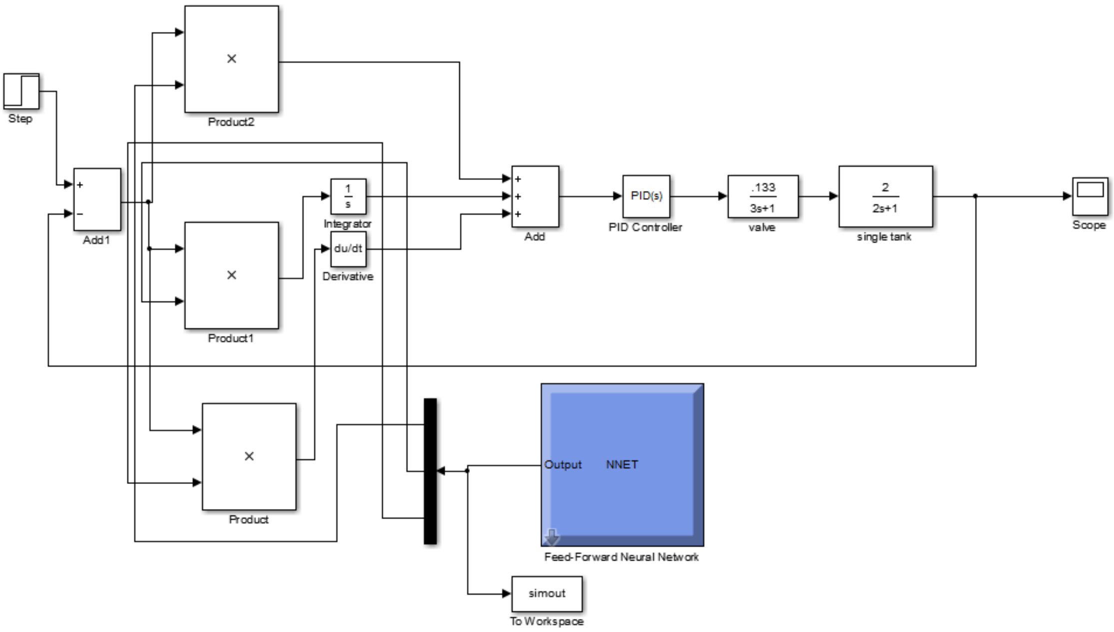

Fig.6 Simulink Model of Single Tank Neural PID Control System

III. SIMULATION

In this paper, the threecontrollers are explored in simulation using MATLABSimulink. The reference input of this control system is a step function signal, and a default tuning with 0.6 transient behaviour of the PID was used to obtain the response.

The neural network controller used has 12 neurons in the hidden layer and 2000 epochs. The MATLAB code used for the controller network is:

```
IP = [0.1*ones (1, 12); 0.1*ones (1, 12); 0.2*ones (1, 12)];
OP=[50,100,0.1;60,100,0.2;80,100,0.3;80,100,0.4;60,100,0.5;50,50,0.5;10,60,0.5;40,70,0.5;10,80,0.5;50,80,0.5;
80,80,0.5;40,80,0.5];
net=feedforwardnet (12,'trainlm');
net.performFcn = 'mse';
net.trainParam.goal = 10;
net.trainParam.show = 20;
net.trainParam.epochs = 2000;
net.trainParam.mc = 0.4;
net=train(net,IP,OP');
```

IV. RESULTS

4.1 Results of Single Tank Control System

PID (Response Time= 4.9 & Transient Behaviour = 0.6)

Fuzzy (Response Time= 4.0 & Transient Behaviour = 0.6)

Neural (Response Time= 4.95 & Transient Behaviour = 0.6)

	PID	Fuzzy PID	Neural PID
Rise Time (sec)	3.27	2.71	3.36
Overshoot (%)	9.12	9.26	8.13
Settling Time (sec)	10.9	8.98	9.75
Rise Time *Overshoot	29.82	25.09	27.31

4.2 Results of Couple Tank Control System

PID (Response Time= 5.62 & Transient Behaviour = 0.6)

Fuzzy (Response Time= 5.33 & Transient Behaviour = 0.6)

Neural (Response Time= 9.38 & Transient Behaviour = 0.6)

	PID	Fuzzy PID	Neural PID
Rise Time (sec)	3.73	3.75	5.61
Overshoot (%)	8.62	6.49	8.99
Settling Time (sec)	11.6	75.3	23.0
Rise Time *Overshoot	32.15	24.34	50.97

4.3 Results of Three Tank Control System

PID (Response Time= 6.45 & Transient Behaviour = 0.6)

Fuzzy (Response Time= 11.1 & Transient Behaviour = 0.6)

Neural (Response Time= 13.4 & Transient Behaviour = 0.6)

	PID	Fuzzy PID	Neural PID
Rise Time (sec)	4.05	6.43	7.28
Overshoot (%)	7.6	10.1	10.3
Settling Time (sec)	19.3	NaN	33
Rise Time *Overshoot	30.78	64.94	74.98

4.4 Results of Four Tank Control System

PID (Response Time= 19.2 & Transient Behaviour = 0.6)

Fuzzy (Response Time= 22.9 & Transient Behaviour = 0.6)

Neural (Response Time= 25.4 & Transient Behaviour = 0.6)

	PID	Fuzzy PID	Neural PID
Rise Time (sec)	9.72	12.6	13.4
Overshoot (%)	9.78	7.6	7.42
Settling Time (sec)	44.3	41.2	44.1
Rise Time *Overshoot	95.06	95.76	99.43

4.4 Results of Five Tank Control System

PID (Response Time= 45.4 & Transient Behaviour = 0.6)

Fuzzy (Response Time= 45.9 & Transient Behaviour = 0.6)

Neural (Response Time= 48.4 & Transient Behaviour = 0.6)

	PID	Fuzzy PID	Neural PID
Rise Time (sec)	21.7	22.6	23.4
Overshoot (%)	4.22	2.06	3.08
Settling Time (sec)	63.2	54.6	67.6
Rise Time *Overshoot	91.57	46.56	72.07

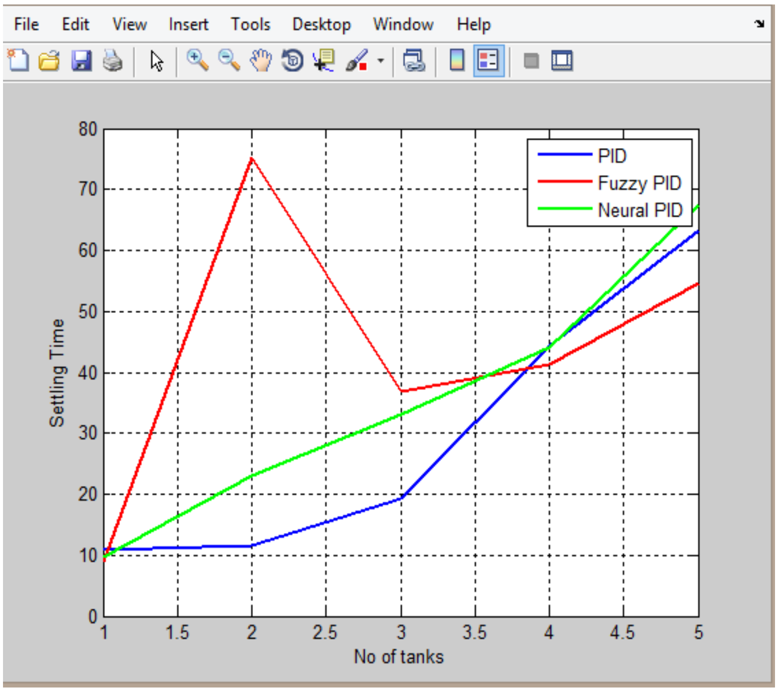

Fig10. Comparison plot of Conventional PID, Fuzzy PID and Neural PID controllers

V. CONCLUSION

The simulation results using MATLAB Simulink comparatively in Fig 7 shows that Fuzzy PID controller has smaller settling time in single, four and five tank control systems while conventional PID has smaller settling time in couple and three tank control system, generally the simulation results shows thatFuzzy PID controller has smaller settling time than Conventional PID and Neural PID while Conventional PID has smaller rise time and quicker response time than Fuzzy PID and Neural PID controller.

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