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DETERMINATION OF THE PERFORMANCE OF NEURAL PID, FUZZY PID AND CONVENTIONAL PID CONTROLLERS ON SYSTEMS WITH SEVERAL OVERSHOOTS

Mustapha Umar Adam[1], Mutari Hajara Ali[2], Suman late Dhar[3]

[1,3]Dept. of Elecrical and Electronic Sharda University, G.Noida (India)

[2]Department of Physics Bayero University, Kano (Nigeria)

ABSTRACT

In liquid industrial control systems, the liquid level is carrying its importance as the control action for level control in tanks containing different chemicals or mixtures of liquids. From the various controllers available one would find it difficult to identify the most suitable one for systems with many overshoots. Comparative studies of the performances of the conventional PID, Fuzzy PID and Neural PID controllers on systems of tanks with multiple overshoots are conducted in this work. The simulation results show that Neural PID controller has smaller overshoot than the others.

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

I. INTRODUCTION

The control of liquid level in tanks and flow between tanks is a basic problem in the process industries. The process industries require liquid to be pumped, stored in tanks, and then pumped to another tank. Many times the liquid will be processed by chemicals or mixing treatment in the tanks, but always the level of the fluid in the tanks must be controlled, and the flow of the liquid most be regulated [1]. 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, water purification systems, industrial chemical processing and boilers in all the industries. 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. 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 systems with many overshoots.

In this work, we investigated the performances of the conventional PID, Fuzzy PID and Neural PID controllers on systems with known overshoots from 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.

2.1 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.

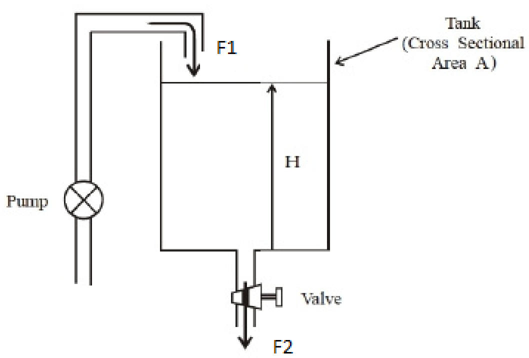

Fig.1 Single Tank Liquid Level Control Structure

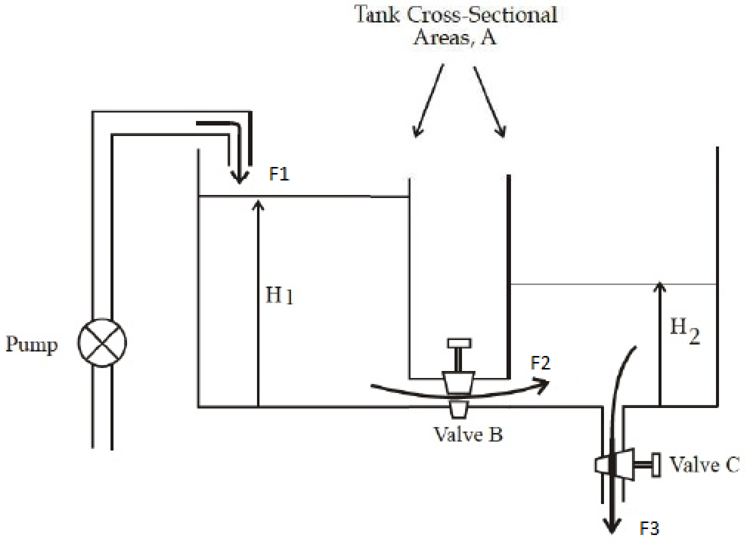

Fig.2 Couple Tank Liquid Level Control Structure

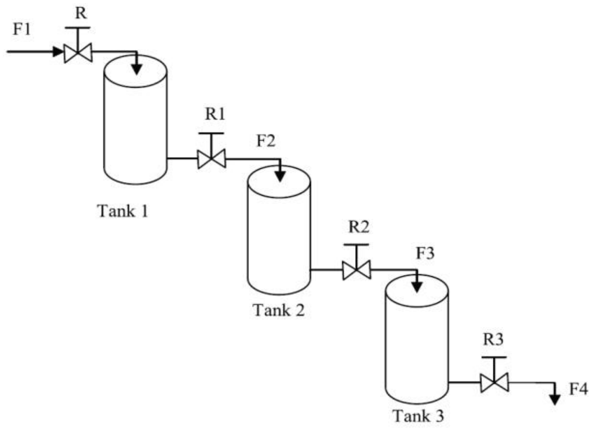

Fig.3 Three Tank Liquid Level Control Structure

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

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

Where F_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

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

For Couple Tank

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

For Three Tank

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

For Four Tank

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

For Five Tank

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

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)

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

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

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

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

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

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

- Simulink Models

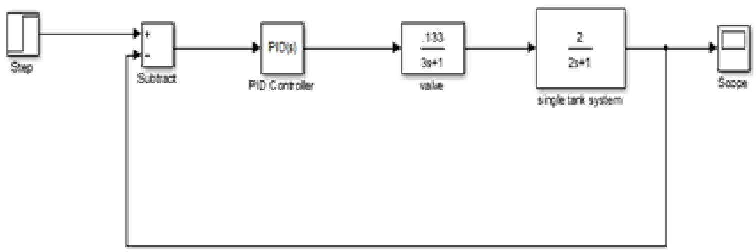

Fig.4 Simulink Model of Single Tank PID Control System

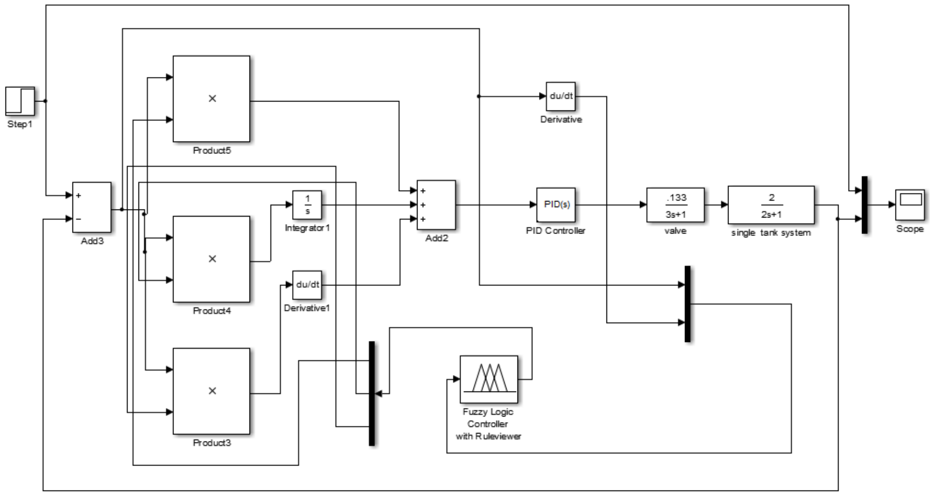

Fig.5 Simulink Model of Single Tank Fuzzy PID Control System

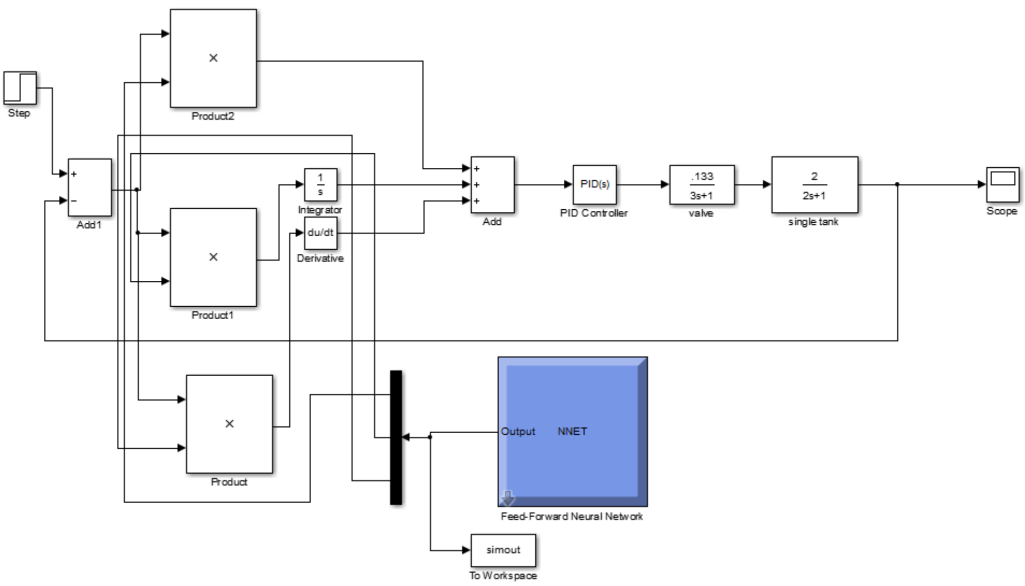

Fig.6 Simulink Model of Single Tank Neural PID Control System

I. SIMULATION

In this paper, the three controllers are explored in simulation using MATLAB Simulink. The reference input of this control system is a step function signal.

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 Single Tank Control System

PID (Response Time= 2.83 & Transient Behaviour = 0.87)

Fuzzy (Response Time= 2.64 & Transient Behaviour = 0.79)

Neural (Response Time= 16.7 & Transient Behaviour = 0.69)

	PID	Fuzzy PID	Neural PID
Rise Time (sec)	2.84	2.45	10.7
Overshoot (%)	0.76	0.569	0.327
Settling Time (sec)	4.51	3.74	17.7
Rise Time *Overshoot	2.16	1.39	3.49

4.2 Couple Tank Control System

PID (Response Time= 7.76 & Transient Behaviour = 0.69)

Fuzzy (Response Time= 15.4 & Transient Behaviour = 0.74)

Neural (Response Time= 25.8 & Transient Behaviour = 0.69)

	PID	Fuzzy PID	Neural PID
Rise Time (sec)	5.5	11.4	15.5
Overshoot (%)	1.12	0.76	0.504
Settling Time (sec)	8.41	20.4	28
Rise Time *Overshoot	6.16	8.66	7.81

4.3 Three Tank Control System

PID (Response Time= 9.32& Transient Behaviour = 0.68)

Fuzzy (Response Time= 22.1& Transient Behaviour = 0.67)

Neural (Response Time= 20.2& Transient Behaviour = 0.67)

	PID	Fuzzy PID	Neural PID
Rise Time (sec)	5.69	12.9	11.5
Overshoot (%)	0.94	0.72	0.60
Settling Time (sec)	22.7	21.8	19.5
Rise Time *Overshoot	5.35	9.29	6.9

4.4 Four Tank Control System

PID (Response Time= 24.9& Transient Behaviour = 0.66)

Fuzzy (Response Time= 30.1& Transient Behaviour = 0.69)

Neural (Response Time= 23.7& Transient Behaviour = 0.71)

	PID	Fuzzy PID	Neural PID
Rise Time (sec)	13.2	18.6	12.1
Overshoot (%)	0.93	0.81	0.44
Settling Time (sec)	23.1	33.5	44.8
Rise Time *Overshoot	12.28	15.06	5.32

4.5 Five Tank Control System

PID (Response Time= 48.8 & Transient Behaviour = 0.6)

Fuzzy (Response Time= 40.0& Transient Behaviour = 0.66)

Neural (Response Time= 46.2& Transient Behaviour = 0.65)

	PID	Fuzzy PID	Neural PID
Rise Time (sec)	24.2	20.3	22.6
Overshoot (%)	1.48	0.47	0.40
Settling Time (sec)	42.2	36.6	42.0
Rise Time *Overshoot	35.82	9.54	9.04

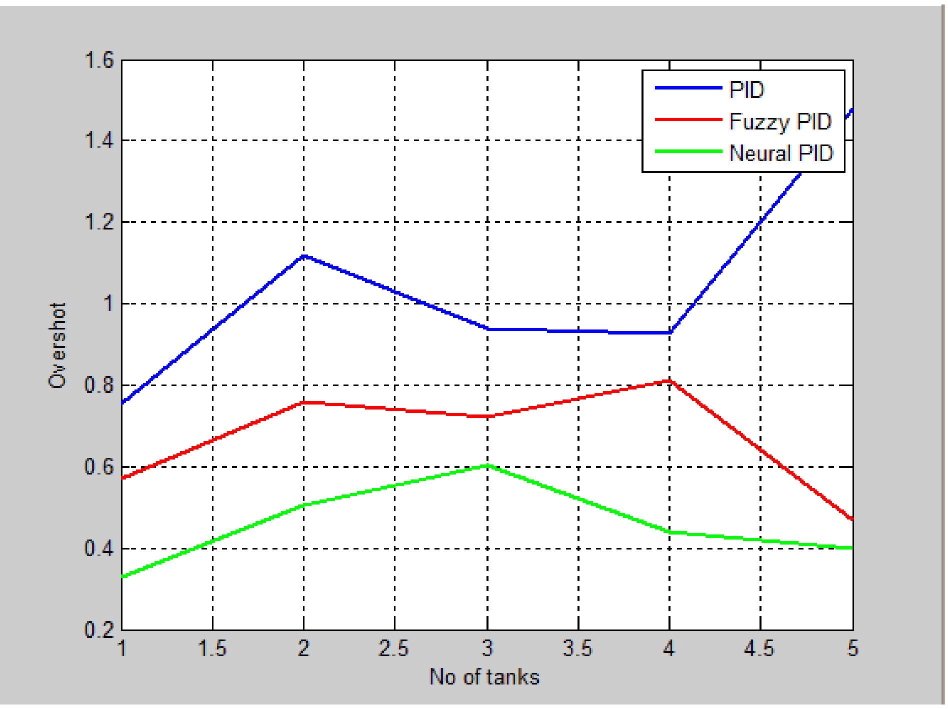

Fig7. Comparison Plot of Conventional PID, Fuzzy PID and Neural PID controllers

The simulation results comparatively in Fig7 show that Fuzzy PID controller has smaller overshoots than the conventional PID controller; Neural PID controller has smaller overshoots than Fuzzy PID controller, generally the simulation results shows that the new Neural PID controller has smaller overshoots than conventional PID and Fuzzy PID controllers.

V. CONCLUSION

Neural PID controller is proposed in this paper, and applied to single, couple, three, four and five tank-level control system. MATLAB simulations show that this method results in a smaller overshoot than the conventional PID controller and fuzzy PID. Moreover, it has a strong ability to adapt to the significant change of system parameters based on its nature of understanding. To sum up, the Neural PID controller has been proved to be an effective method in the level control. It can be also used in a variety of nonlinear control systems with time-varying, pure delay, and large time constants.

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