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Comparing the effect of PI and I controllers on a four tank process

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Abstract: **In industrial control systems the liquid level is carrying its significance as the control action for level control in tanks containing different chemicals or mixtures is essential for further control linking set points. In this paper we will investigate the effect of PI and I controllers on a four tank process and will compare this controllers together. We want to know how much is the effect of, I and PI controllers on a process control. For more clarification we simulate the effect of PI and I controllers on this system.**

Keywords: **PI controller, I controller, four tank process, Level control, Coupled water tanks.**

I. INTRODUCTION

The PID controllers have been at the heart of control engineering practice over the last decades. They are widely used in industrial applications as no other controllers match the simplicity, clear functionality, applicability and ease of use. The PID controllers was introduced in 1910 and their use and popularity had grown particularly after the Ziegler–Nichols empirical tuning rules in 1942 This control approach is an online and proven method however it requires experiences and very aggressive tuning for the process. At the past years the researchers proposed Several control strategies Some of these strategies are reviewed below.

As shown in [1], the controlled process of three-tank system has obviously character of volume-lag. Due to the complexity of the controlled object, traditional PID control can't satisfy the control requirements of the system. Smith-PI controller was used in [1]. Because the parameter Kp and Ki were man-set, the control effect was not satisfactory. In [2], The Smith-PID Control of Three-Tank-System Based on Fuzzy Theory investigated. Recently, several books and surveys reported research works about tuning MIMO PID controllers, see, [3], [4], [5], and [6]. MIMO PID controllers tuning approaches can be classified into empirical, artificial intelligence and analytical approaches, see, [7],[8],[9],[10]. In [11] we can see combination of fuzzy and PID controller. In this paper we will investigate and compare the *quadruple-tank process* at three position without controller, by use of I controller and by use of PI controller and will draw the results and compare together. The paper is organized as follows. The model of the Tank system is in section 2, in section 3 we have Simulation and results, the conclusions are presented in section 4, acknowledgment and references are at the end.

II. THE MODEL OF THE TANK SYSTEM

A. *Physical Model*

The quadruple-tank process (Johansson, 2000; Gatzke et al., 2000; Rusli E. et al., 2002) is a multivariable process which consists of four interconnected water tanks and two pumps. The system is shown in figure 1. The output of each pump is split into two using a three-way valve. The inlet flow of each tank is measured by an electro-magnetic flow-meter and regulated by a pneumatic valve. The level of each tank is measured by means of a pressure sensor.

The regulation problem aims to control the water levels in the lower two tanks with two pumps. The two pumps convey water from a basin into the four tanks. The tanks at the top (tanks 3 and 4) discharge into the corresponding tank at the bottom (tanks 1 and 2, respectively). The three way valves are emulated by a proper calculation of the set points of the flow control loops according to the considered ratio of the three-way valve. The positions of the valves determine the location of a zero for the linearized model.

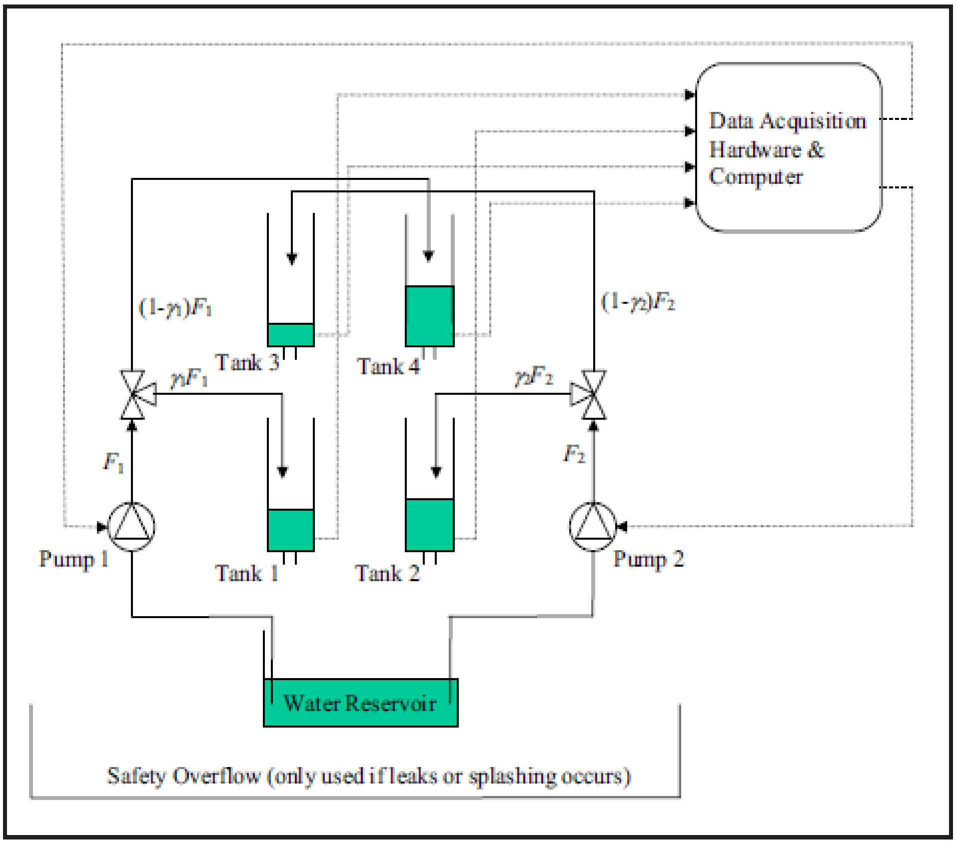

Figure 1. *Schematic of the quadruple-tank process*

The nonlinear model of the process is described by (Gatzke et al., 2000):

$$\frac{dh_1}{dt} = -\frac{a_1}{A_1}\sqrt{2gh_1} + \frac{a_3}{A_1}\sqrt{2gh_3} + \frac{\gamma_1 k_1}{A_1}V_1 \quad (1)$$

$$\frac{dh_2}{dt} = -\frac{a_2}{A_2}\sqrt{2gh_2} + \frac{a_4}{A_4}\sqrt{2gh_4} + \frac{\gamma_2 k_2}{A_2}V_2 \quad (2)$$

$$\frac{dh_3}{dt} = -\frac{a_3}{A_3}\sqrt{2gh_3} + \frac{(1-\gamma_2)k_2}{A_3}V_2 \quad (3)$$

$$\frac{dh_4}{dt} = -\frac{a_4}{A_4}\sqrt{2gh_4} + \frac{(1-\gamma_1)k_1}{A_4}V_1 \quad (4)$$

Where,

A_i - cross-section of Tank;
a_i - cross-section of the outlet hole;
h_i - water level

The voltage applied to Pump i is V_i and the corresponding flow is k_iV_i . The parameters $\gamma_1, \gamma_2 \epsilon (0,1)$ are determined from how the valves are set prior to an experiment. The flow to Tank 1 is $\gamma_1 k_1 V_1$ and the flow to Tank 4 is $(1-\gamma_1)k_1V_1$ and similarly for Tank 2 and Tank 3. The acceleration of gravity is g. The measured level signals are $k_c h_1$ and $k_c h_2$.

The parameter values of the laboratory process given by Johansson are as shown below:

TABLE I: Values of the laboratory process given by Johansson

(A_1, A_2) (cm^2)	28
(A_3, A_4) (cm^2)	32
(a_1, a_3) (cm^2)	0.071
(a_2, a_4) (cm^2)	0.057
(h_3^0, h_4^0) (cm)	4.8, 4.9
K_c (V/cm)	0.5
(g) (cm/s^2)	981

The model and control of the four-tank process are studied at two operating points: P- at which the system will be shown to have minimum phase characteristics and P+ at which it will be shown to have non-minimum phase characteristics. The chosen operating points correspond to the following parameter values:

TABLE II: The chosen operating points correspond to the following parameter values

	P+	P-
(h_1^0, h_2^0) (cm)	12.6,13.0	12.4,12.7
(h_3^0, h_4^0) (cm)	4.8,4.9	1.8,1.4
(v_1^0, v_2^0) (V)	3.15,3.15	3.0,3.0
(k_1, k_2) (cm^3/Vs)	3.14,3.29	3.33,3.35
(γ_1, γ_2)	0.43,0.34	0.7,0.6

B. State space Model

The linearized state-space equation of the model in (5) is then given by (6)

$$\frac{dx}{dt} = \begin{bmatrix} \frac{-1}{T_1} & 0 & \frac{A_3}{A_1T_3} & 0 \\ 0 & \frac{-1}{T_2} & 0 & \frac{A_4}{A_2T_4} \\ 0 & 0 & \frac{-1}{T_3} & 0 \\ 0 & 0 & 0 & \frac{-1}{T_4} \end{bmatrix} x + \begin{bmatrix} \frac{\gamma_1 k_1}{A_1} & 0 \\ 0 & \frac{\gamma_2 k_2}{A_2} \\ 0 & \frac{(1-\gamma_2)k_2}{A_3} \\ \frac{(1-\gamma_1)k_2}{A_4} & 0 \end{bmatrix} u \quad (5)$$

$$y = \begin{bmatrix} k_c & 0 & 0 & 0 \\ 0 & k_c & 0 & 0 \end{bmatrix} x \quad (6)$$

Where the time constants are :

$$T = \frac{A_i}{a_i}\sqrt{\frac{2h_i^0}{g}} \quad (7)$$

i=1 . . . 4

Substitution of actual values of process parameters yields the two transfer matrices for minimum phase and non-minimum phase that we consider non-minimum phase:

$$G = \begin{bmatrix} \frac{1.69}{1+76.75s} & \frac{1.69}{(1+76.75s)(1+52.3s)} \\ \frac{3.11}{(1+56.36s)(1+111.55s)} & \frac{1.97}{1+111.55s} \end{bmatrix} \quad (8)$$

The model used in the present study includes the disturbance effect of flows in and out of the upper-level tanks 3 and 4 as depicted in Figure 1.
The corresponding model is as in (9)

$$\frac{dx}{dt} = \begin{bmatrix} \frac{-1}{T_1} & 0 & \frac{A_3}{A_1T_3} & 0 \\ 0 & \frac{-1}{T_2} & 0 & \frac{A_4}{A_2T_4} \\ 0 & 0 & \frac{-1}{T_3} & 0 \\ 0 & 0 & 0 & \frac{-1}{T_4} \end{bmatrix} x + \begin{bmatrix} \frac{\gamma_1 k_1}{A_1} & 0 \\ 0 & \frac{\gamma_2 k_2}{A_2} \\ 0 & \frac{(1-\gamma_2)k_2}{A_3} \\ \frac{(1-\gamma_1)k_2}{A_4} & 0 \end{bmatrix} u + \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ \frac{-kd_1}{A_3} & 0 \\ 0 & \frac{-kd_2}{A_4} \end{bmatrix} d \quad (9)$$

III. SIMULATION AND RESULTS

We simulate this system at three positions:

1- Without controller

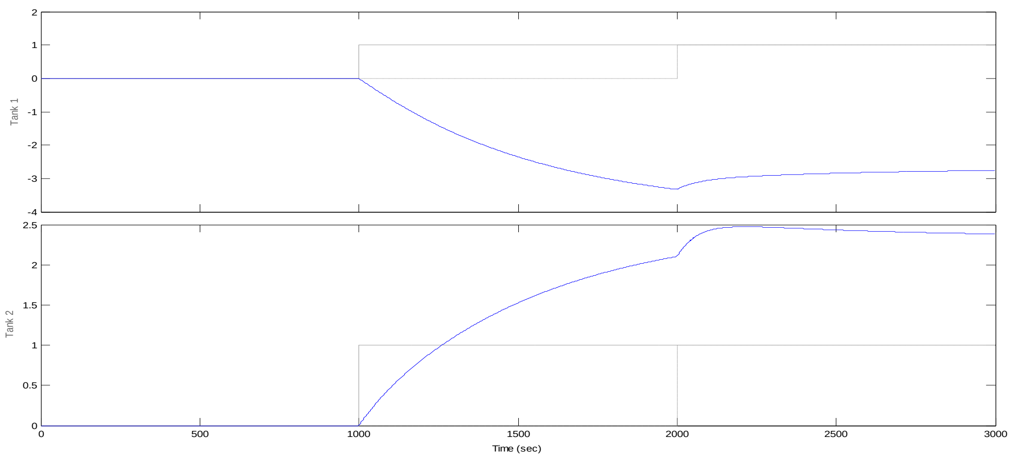

Fig.2 *level of Tank without controller, T=3000 s*

In this situation the level of Tank 1 is bellow of normal position or we can say the tank is empty. In Tank 2 the tank is in over flow position.

2- By use of I controller

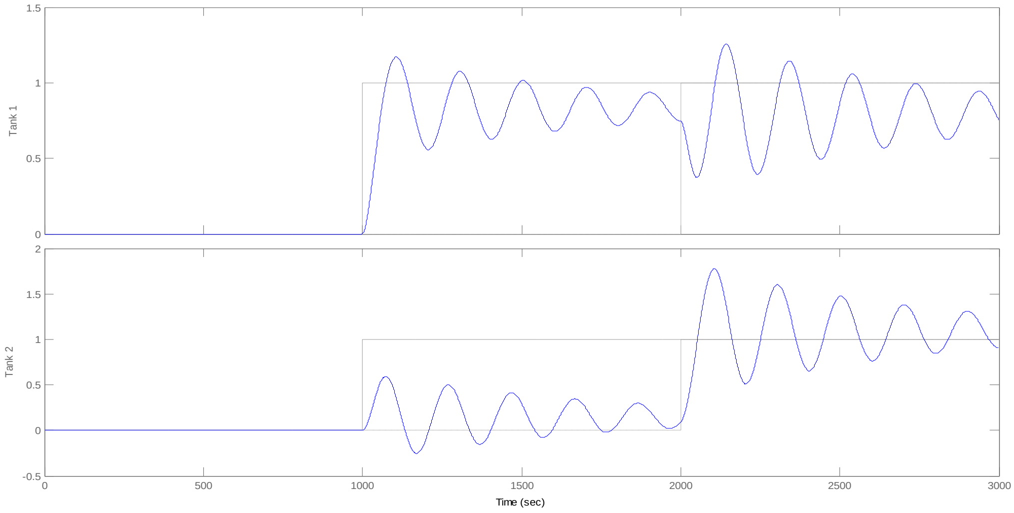

Fig.3 *Level of Tank by use of I controller, T=3000 s*

In this case we have a control on this system and controller keep the level of the tank but there is an alternative in this system.

3- By use of PI controller

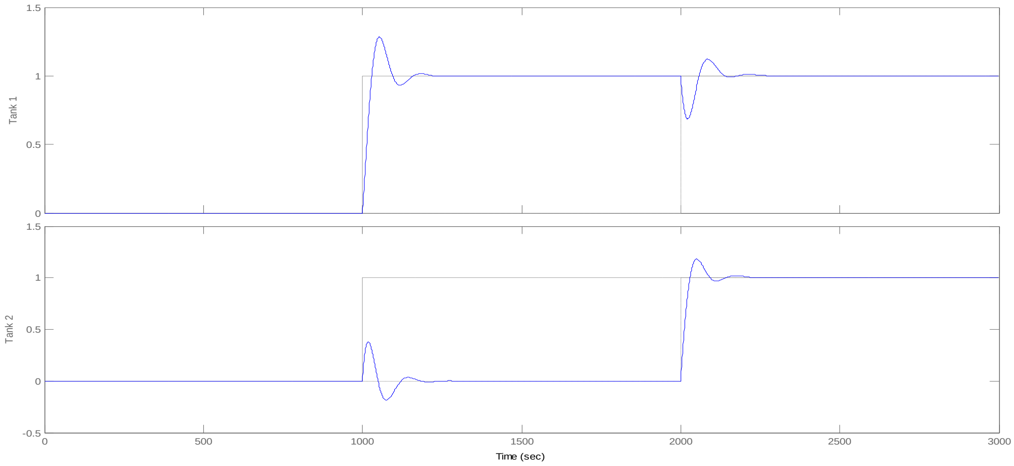

Fig.4 *Level of Tank by use of PI controller, T=3000 s*

In this case we have a good controller and have a small alternative this controller is better behavior and accuracy.

IV. CONCLUSION

In this paper we introduced quadruple-tank process and presented equations after that we investigated amount the effect of PI and I on a four tank process. Three position investigated and drawn. After drawn, we concluded that the PI controller is a smooth and fast track , demanded level. The fluctuation in PI is a little and less than I controller. We can say the PI controller can control and satisfy and sate demand of control for a four tank process. Note that this system is an unstable system without controller and this system will be over flow or will be empty.

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