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# A REVIEW ON COMPARISION OF THE EFFECT OF I AND PI CONTROLLER ON A QUADRUPLE-TANK PROCESS

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**ABSTRACT**

*In this paper we will present a PI and I controller and comparison of the effect of I and PI controller on a quadruple-tank process. Ideal for us is to have a stable and fix level of water (for example) in tanks. 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. We want to know how much is the effect of I and PI controllers on a process control. Numerical simulations are given to illustrate the effectiveness and validity of the proposed approach.*

***Keywords: Electrical Engineering, I and PI controller, quadruple-tank process***

## 1. INTRODUCTION

First, let's take a look at how the PID controller works in a closed-loop system using the schematic shown bellow. The variable (error ) represents the tracking error, the difference between the desired input value and the actual output is error. This error signal will be sent to the PID controller, and the controller computes both the derivative and the integral of this error signal. The control signal to the plant is equal to the proportional gain times the magnitude of the error plus the integral gain times the integral of the error plus the derivative gain times the derivative of the error.

This control signal is sent to the plant, and the new output is obtained. The new output is then fed back and compared to the reference to find the new error signal. The controller takes this new error signal and computes its derivative and it's integral again, ad infinitum.

The transfer function of a PID controller is found by taking the Laplace transform of Eq.(1). As shown below:

$$u(t)=k_p e(t)+k_i\int_0^t e(\tau)d\tau+k_d\frac{d}{dt}e(t) \quad (1)$$

Kp: Proportional gain

Ki: Integral gain

Kd: Derivative gain

e: Error

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 quadruple -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],[6]. MIMO PID controllers tuning approaches can be classified into

International Journal of Engineering and Applied Sciences

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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.

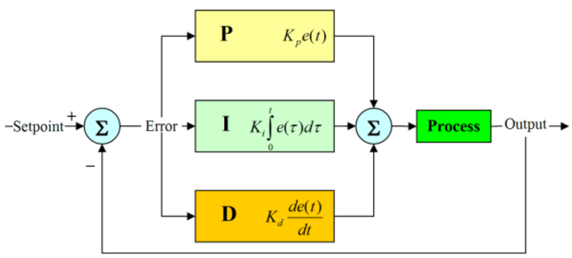


***Figure 1.*** *A practical PID controller*

## 2. The Model OF THE TANK SYSTEM

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 setpoints 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.

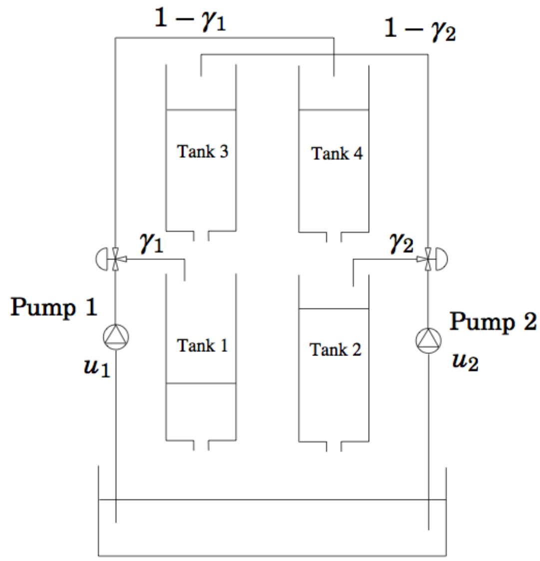


***Figure 2.*** *Schematic of the quadruple-tank process*

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

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

$$\frac{dh_2}{dt} = -\frac{a_2}{A_2}\sqrt{2gh_2} + \frac{a_4}{A_2}\sqrt{2gh_4} + \frac{\gamma_2 k_2}{A_2}V_2 \quad (3)$$

$$\frac{dh_3}{dt} = -\frac{a_3}{A_3}\sqrt{2gh_3} + \frac{(1-\gamma_2)k_2}{A_3}V_2 \quad (4)$$

$$\frac{dh_4}{dt} = -\frac{a_4}{A_4}\sqrt{2gh_4} + \frac{(1-\gamma_1)k_1}{A_4}V_1 \quad (5)$$

Where:

Ai - cross-section of Tank;

ai - cross-section of the outlet hole;

hi - water level;

The voltage applied to Pump i is Vi and the corresponding flow is kiVi . 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 $(1-\gamma_1)k_1 V_1$ and similarly for Tank 2 and Tank 3. The acceleration of gravity is g. The measured level signals are kc h1 and kc h2 The parameter values of the laboratory process given by Johansson are as shown below:

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| | |
|---|---|
| $(A_1, A_2)$ (cm²) | 28 |
| $(A_3, A_4)$ (cm²) | 32 |
| $(a_1, a_3)$ (cm²) | 0.071 |
| $(a_2, a_4)$ (cm²) | 0.057 |
| $(h_3^0, h_4^0)$ (cm) | 4.8,4.9 |
| $k_c$ (V/cm) | 0.5 |
| $(g)$ (cm/s²) | 981 |

***Table1.*** *Values of the laboratory process given by Johansson*

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:

| | 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 |
| $(k_1, k_2)$ (cm³/Vs) | 3.14,3.29 | 3.33,3.35 |
| $(\gamma_1, \gamma_2)$ | 0.43,0.34 | 0.7,0.6 |

***Table2.*** *The chosen operating points correspond to the following parameter values*

State Space Model

The linearized state-space equation of the model in (6) is then given by (7)

$$\frac{dx}{dt} = \begin{bmatrix} \frac{-1}{T_1} & 0 & \frac{A_3}{A_1T_3} & 0 \\ 0 & \frac{-1}{T_2} & 0 & \frac{A_4}{A_2T_4} \\ 0 & 0 & \frac{-1}{T_3} & 0 \\ 0 & 0 & 0 & \frac{-1}{T_4} \end{bmatrix} x + \begin{bmatrix} \frac{\gamma_1 k_1}{A_1} & 0 \\ 0 & \frac{\gamma_2 k_2}{A_2} \\ 0 & \frac{(1-\gamma_2)k_2}{A_3} \\ \frac{(1-\gamma_1)k_2}{A_4} & 0 \end{bmatrix} u \quad (6)$$

$$y = \begin{bmatrix} k_c & 0 & 0 & 0 \\ 0 & k_c & 0 & 0 \end{bmatrix} x \quad (7)$$

Where the time constants are :

$$T = \frac{A_i}{a_i}\sqrt{\frac{2h_i^0}{g}} \quad (8)$$

i=1 . . . 4

Case Study

In this section we suppose the real transfer matrix that really there is in industrial. Substitution of actual values of process parameters yields the two transfer matrices for minimum phase and non-minimum phase that we consider minimum phase:

$$G = \begin{bmatrix} \frac{1.69}{1+76.75s} & \frac{1.69}{(1+76.75s)(1+52.3s)} \\ \frac{3.11}{(1+56.36s)(1+111.55s)} & \frac{1.97}{1+111.55s} \end{bmatrix} \quad (9)$$

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 2. The corresponding model is as in (10):

$$\frac{dx}{dt} = \begin{bmatrix} \frac{-1}{T_1} & 0 & \frac{A_3}{A_1T_3} & 0 \\ 0 & \frac{-1}{T_2} & 0 & \frac{A_4}{A_2T_4} \\ 0 & 0 & \frac{-1}{T_3} & 0 \\ 0 & 0 & 0 & \frac{-1}{T_4} \end{bmatrix} x + \begin{bmatrix} \frac{\gamma_1 k_1}{A_1} & 0 \\ 0 & \frac{\gamma_2 k_2}{A_2} \\ 0 & \frac{(1-\gamma_2)k_2}{A_3} \\ \frac{(1-\gamma_1)k_2}{A_4} & 0 \end{bmatrix} u + \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ \frac{-kd_1}{A_3} & 0 \\ 0 & \frac{-kd_2}{A_4} \end{bmatrix} d \quad (10)$$

## 3. SIMULATION AND RESULTS

We simulate this system at three positions:

Without controller

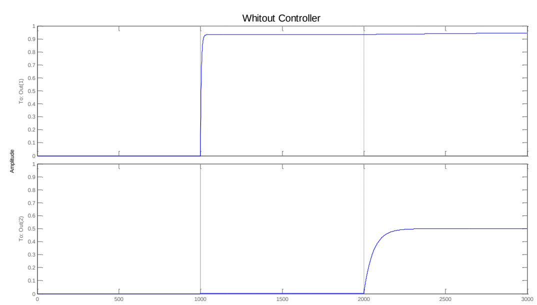


***Fig.3*** *level of Tank without controller T=3000 s*

In this situation we have a desired level; here is 1; we haven't any control and the level will not be full, we want the level flow the desiered level but without controller output of tanks are a lot.

By use of I controller

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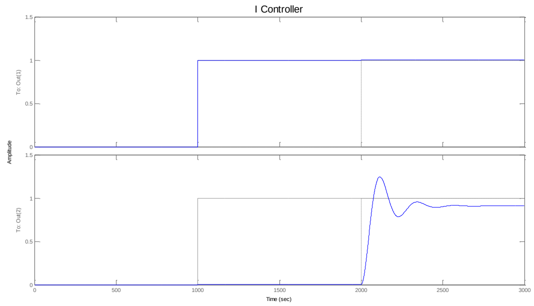


***Fig.4*** *Level of Tank by use of I controller T=3000 s*

In this case we have a control on this system; I controller in this section; and controller keep the level of the tank near the desired level but there is an alternative in this system and an offset that means the level of tanks is near the full.

By use of PI controller

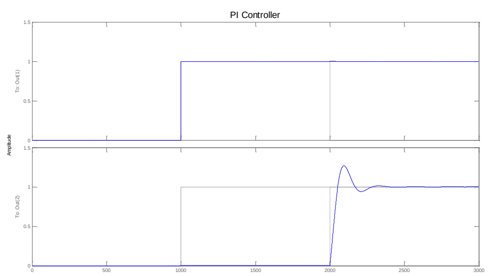


***Fig.5*** *Level of Tank by use of PI controller T=3000 s*

In this case we have a good controller and have a small alternative this controller is better behavior and accuracy. After a flactuate the level of tanks is full and we have full controller on system.

## 4. 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, desire level. The fluctuation in PI is a little and the same of I controller but the I controller has an offset that we can't have full conntrol on this system. We can say the PI controller can control and satisfy desire level of 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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## REFERENCES

[1] WA NG Qing-lan, Xie Xue-jun, "Smith Control of Three Tank Water System Based on C++ Builder", Journal of Qufu Normal University(in Chinese), vol.1.2008, pp. 33-35.

[2] Jianqiu Deng, Cui Hao, "The Smith-PID Control of Three-Tank-System Based on Fuzzy Theory", JOURNAL OF COMPUTERS, VOL. 6, NO. 3, MARCH 2011, pp.514-523.

[3] Zhuang M. and Atherton D.P. (1994). PID controller design for a TITO system. *IEEE Proceedings – Control Theory and Applications*, Vol. 141(2), pp. 111–120.

[4] Willjuice M., Baskar S. (2009). Evolutionary algorithms based design of multivariable PID controller. *Expert Systems with Applications*, Vol. 35(5), pp. 9159-9167.

[5] Isakson A.J. and Graebe S.F. (1999). Analytical PID parameter expressions for higher order systems. *Automatica*, Vol. 35(6), pp. 1121–30.

[6] Rames C. Panda. *Introduction to PID controllers Theory, tuning and application to frontier areas*. InTech ,Rijeka . (2012).

[7] Luan Vu T.N. and Lee M. (2010). Independent design of multi-loop PI/PID controllers for interacting multivariable processes. *Journal of Process Control*, Vol. 20(8), pp.922-933.

[8] Soliman M., Elshafei A.L., Bendary F. and Mansour W. Robust decentralized PID-based power system stabilizer design using an ILMI approach. *Electric Power Systems Research*, Vol. 80(8), pp. 1488-1497. (2010).

[9] Vilanova R. and Visioli A. PID Control in the Third Millenium – Advances in Industrial Control. Springer, New York. (2012).

[10] W. Belhaj, O. Boubaker, "On MIMO PID Control of the quadruple-tank process via ILMIs Approaches : Minimum and Non-Minimum Case studies", 10th IFAC International Symposium on Dynamics and Control of Process Systems The International Federation of Automatic Control December 18-20, 2013. Mumbai, India.

[11] Xiao-Feng Li, Jian Sun, Hui-Yan Wu, Wei-Dong Zong,*"Application of the fuzzy PID to the Power Plant*", IEEE 2007.

[12] Gholipour, Y., & Mola, M. (2014). Investigation stability of Rikitake system.Journal of Control Engineering and Technology, 4(1).

[13] Gholipour, Y., Ramezani, A., Mola, M. (2014). Illustrate the Butterfly Effect on the Chaos Rikitake system. Bulletin of Electrical Engineering and Informatics, 3(4).

[14] Gholipour, Y., Mola, M. (2015). STABILIZATION OF CHAOS RIKITAKE SYSTEM BY USE OF FUZZY CONTROLLER. Sci.Int.(Lahore),27(1),2015, ISSN 1013-5316.