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PERFORMANCE COMPARISON OF INDUSTRIAL CONTROLLER AND FUZZY LOGIC CONTROLLER FOR WATER LEVEL TANK CONTROL SYSTEM

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ABSTRACT

The purpose of this work is to compare and contrast industrial controllers such as P, PI, and PID, as well as fuzzy logic controllers, for tank water level control. PID controllers are widely utilised in various sectors for level control and non-linear systems. It's tough to tune, and it relies on a mathematical model of the system, which is difficult to come by for nonlinear systems. Fuzzy logic controllers are used in scientific studies to regulate systems since they are simple and straightforward. MATLAB/ Simulink software is used to conduct a review study of PID and fuzzy logic for level control.

Keywords: PID Controller, Fuzzy Logic Controller, MATLAB/Simulink, Coupled Tank System And Valve.

I. INTRODUCTION

Numerous uses, such as chemical processes [3], necessitate liquid level management in many sectors. Because of its nonlinearity, unreliability, and delay time, it is a complicated system. PI and PID controllers are used to control liquid level in numerous industries. PID controllers are employed in industries for process control because of their simple structure and ease of installation [1, 2]. PID controllers employ a mathematical model of the system to reduce the current mistake in adjusting time only. Because finding the right gain in a PID controller is challenging, it is not suitable for highly nonlinear systems[4]. The linked tank system is used in this work, which is a non-linear system in which the dynamic behaviour of the tanks affects each other since the inflow between the tanks is dependent on the level of both tanks. Because the PI controller is only useful for low-order processes where accuracy is not critical, it is not suitable for higher-order processes. It's also tough to get the desired effect with a PI controller. It performs poorly in higher-order processes [5]. Because fuzzy logic control does not rely on a mathematical model of the process, it can be utilised in situations where PID controllers are difficult to implement[6]. Because this approach is based on human logic, it is adaptable and simple to comprehend. Because FLC is acceptable for industrial requirements, it is widely used in industrial applications[7]. A review of P, PI, PID, and FLC for connected tank systems in terms of rising time, setting time, overshoot, and steady state error is presented in this paper. In MATLAB/Simulink, the simulated results are compared and confirmed, and it is discovered that the fuzzy logic control system outperforms other control systems.

II. MATHEMATICAL MODELLING OF COUPLED TANK SYSTEM

Consider the following schematic diagram of a connected tank system in an industrial application (fig.1). Equations 1.1 and 1.2 reveal that the mathematical model for this connected tank system is nonlinear.

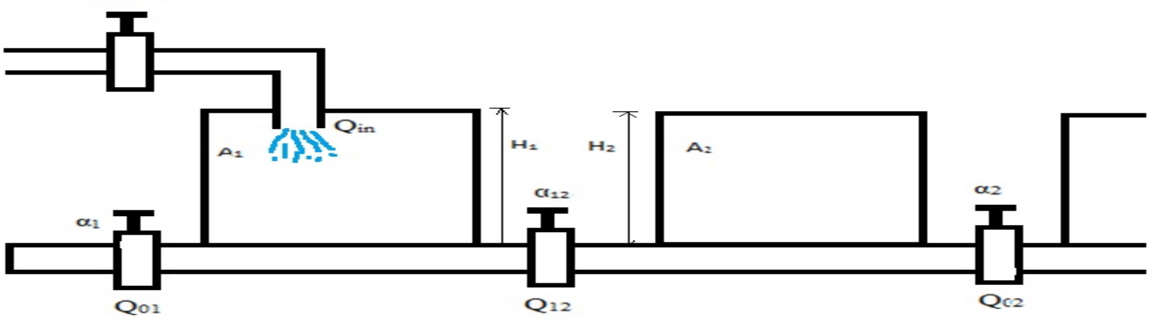

Fig 1: Schematic diagram of coupled tank system

Quantity of liquid flow in the tanks, quantity of liquid flow out of tank1, quantity of liquid flow in between the tanks, and quantity of liquid flow out of tank2 are represented by Qin, Q01, Q12, and Q02. The height of the liquid in the tanks is H1, H2, the cross-sectional area of the tanks is A1, A2, and the cross sectional area of the output pipe tank1, tank2, and in between tank1 and tank2.

Equation for tank 1-

$$A_1 \frac{dH_1+h_1}{dt} = Q_{i1} + q_1 - \alpha_1 \sqrt{H_1 + h_1} - \alpha_{12} \sqrt{H_1 - H_2 + h_1 - h_2} \quad 1.1$$

Equation for tank2:

$$A_2 \frac{dH_2+h_2}{dt} = \alpha_{12} \sqrt{H_1 - H_2 + h_1 - h_2} - \alpha_2 \sqrt{H_2 + h_2} \quad 1.2$$

Using these two equations a Simulated model for the coupled tank has been designed. A linearization method is applied to get linear equation and Laplace transfer function for the coupled tank system. Laplace transfer function will be as shown below:

$$\frac{h_2(s)}{q_1(s)} = \frac{K_{21}K_1}{T_1T_2s^2 + (T_1 + T_2)s + 1 - K_{21}\,K_{12}}$$

Where T_1= 2.6085, T_2= 2.5839 are the time constants and K_1 = 0.081516, K_{12}=0.8934 and K_{21}= 0.8850 are the gains for the coupled tank system. Transfer function of the coupled tank model is as below.

$$\frac{0.07212}{6.7401s^2 + 5.1924s + 0.2093}$$

The analysis of this mathematical model is done using MATLAB/Simulink toolbox for P, PI, and PID controllers.

III. CONTROLLER DESIGN FOR COUPLED TANK SYSTEM

❖ **PID controller design for the system**

A simulated model for PID control system is as shown fig.3 the difference of set point and measured variable goes to the controller. The PID controller helps to get our output (velocity, temperature, position) where we want it, in a short time, with minimal overshoot, and with little error. Proportional Integral Derivative (PID) controllers are widely used in industrial practice. PID controller combines the control action of Proportional, Integral and derivative controller where Proportional controller reduces the rise time, integral controller eliminates steady state error and derivative controller reduces overshoots of the system. PID controller involves three tuning parameters K_p, K_i and K_d. In this paper parameters are tuned within MATLAB/Simulink block signal constraint. This tool helps in optimization of parameters very fast. In this tool we used 0 to infinity tolerance for finding optimal solution or feasible solution. Parameters values found for P, PI and PID controller which is shown below.

Proportional controller- K_p=328.34 not found any feasible solution

Proportional plus Integral controller- K_p = 67.4043, K_i=1.1154 found a feasible solution

Proportional plus Integral plus Derivative controller- K_p=67.3394, K_i=1.1552, K_d=10.7037 found a feasible solution

This optimization method gives fast response.

❖ **Fuzzy logic controller design for the system**

FLC consist of fuzzification, fuzzy rules and defuzzification. Where fuzzification converts the crisp inputs into fuzzy inputs. We used rate and level as an input and valve as an output for this application. Fuzzification next step is selection of membership function for input and output variables. Triangular membership function is used for both input and output variables. In the next step range of subset for variables is selected within the display range variables. Here we have used low, high and ok subsets for error variable and negative, zero, positive subsets for rate of change variable and OF, OS, CF, CS, NC subsets for valve variable. Ranges of these subsets are selected within the variables membership function range. After the selection of range for each subset these subsets are used for the designing of rules in rule editor tool box. Response of the controller depends upon the rules. Nine rules are designed for this application which is shown in matrix form. Response of the designed rules can be viewed in surface viewer tool box. When a control rule generates from the FIS it must be defuzzified from fuzzy value to crisp value center of gravity rule method is used for defuzzification. The rules shown in the rule matrix are expressed as shown below.

If the level is low AND rate is zero THEN open fast valve.

Table-1: Rule matrix

Level \ Rate	Low	Okay	High
Negative	OF	OS	CF
Zero	OF	NC	CF
Positive	OF	CS	CF

Where

OF- Open Fast

OS- Open Slowly

CF- Close Fast

CS- Close Slowly

NC- No Change

IV. SIMULINK RESULTS AND COMPARISON

The Simulated model for coupled tank, PID controller and fuzzy logic control system and their simulated response to find rise time, setting time overshoot and steady state error of the controllers are shown below.

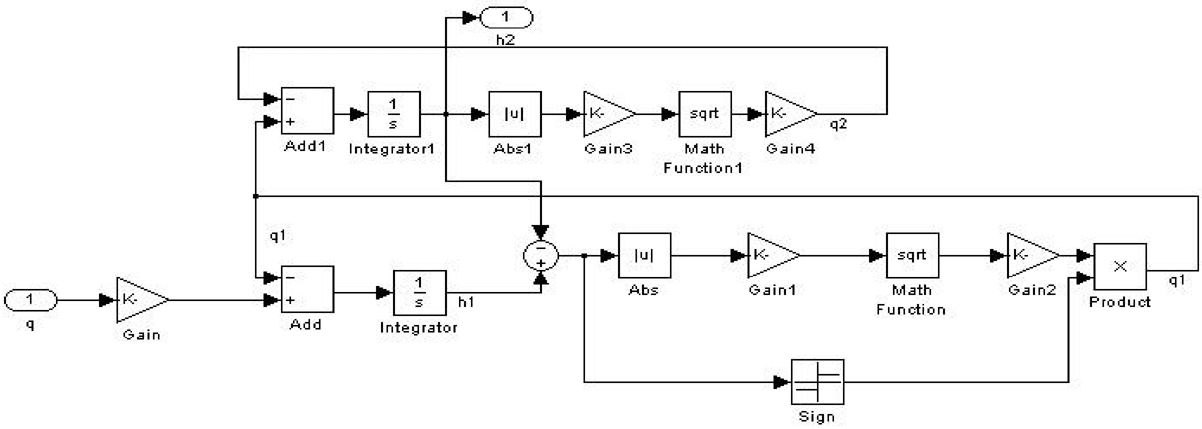

Fig 2: Simulated model for coupled tank

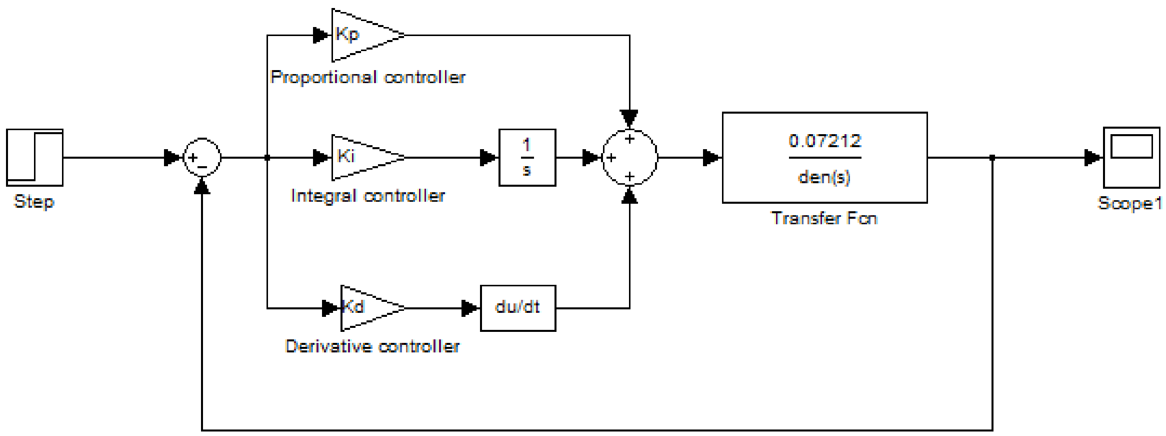

Fig 3: Simulated model for PID control system

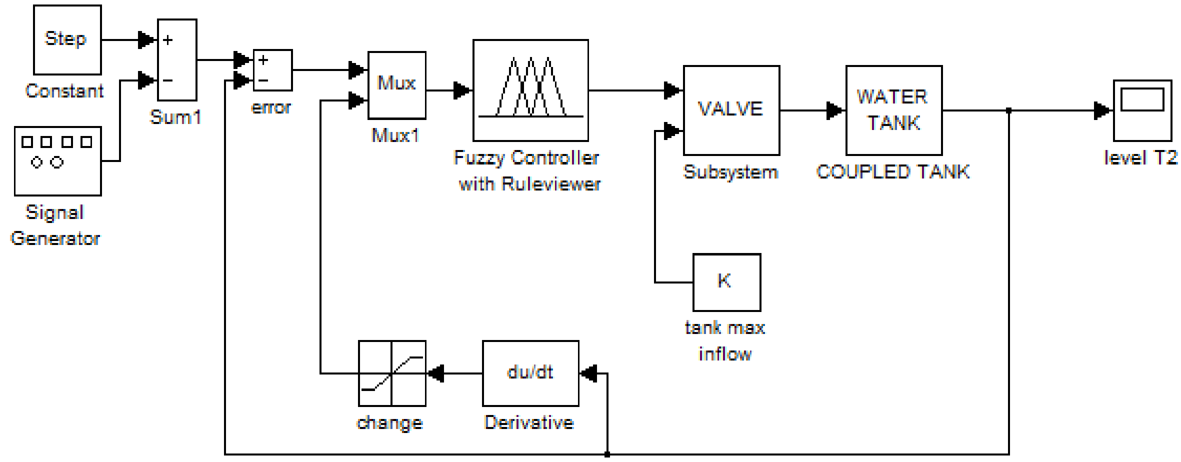

Fig 4: Simulated model for FLC syste

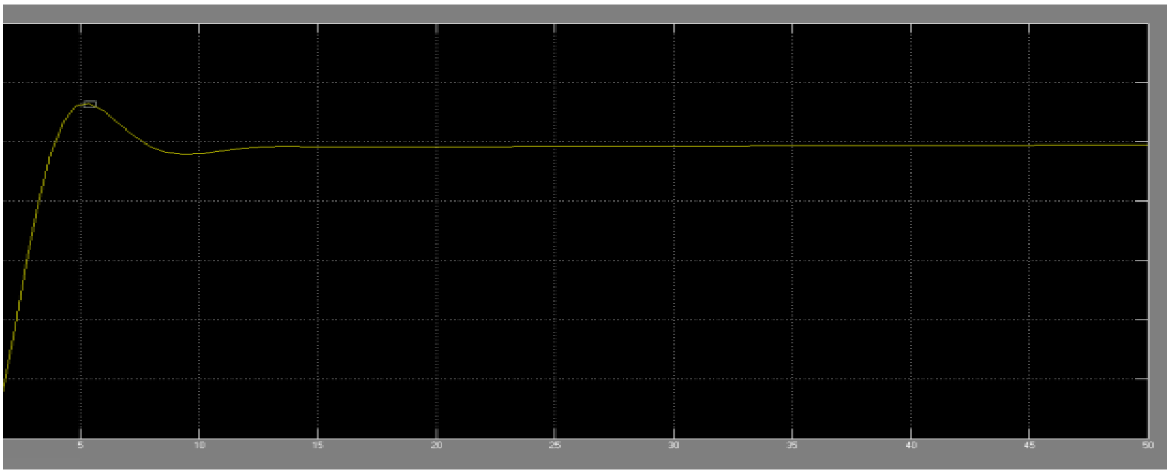

Fig 5: Simulink response of PID controller

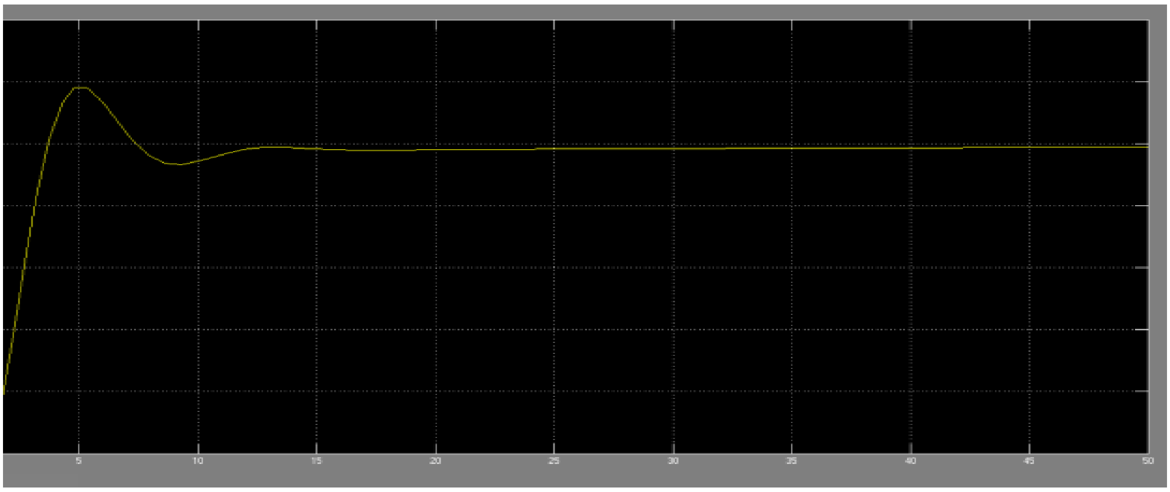

Fig 6: Simulink response of PI controller

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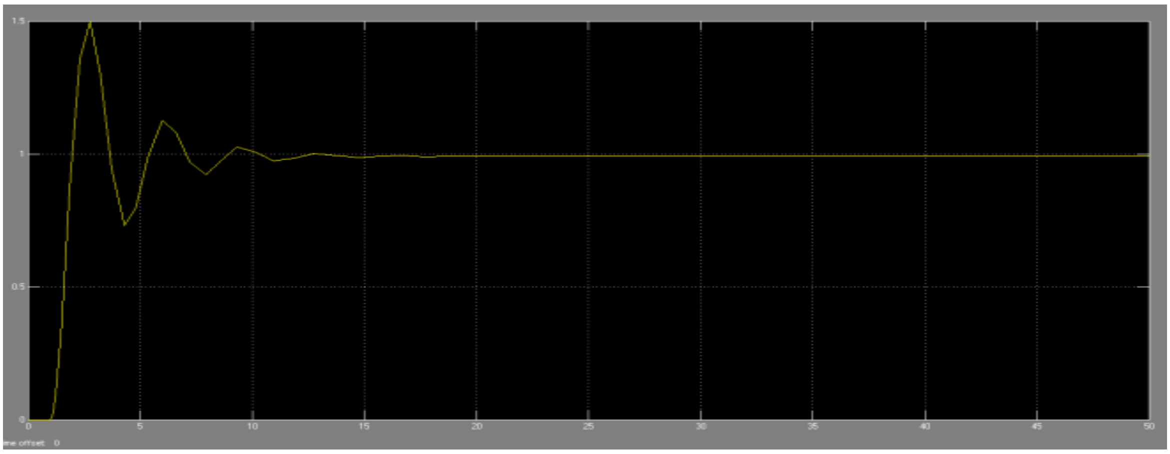

Fig 7: Simulink response of P controller

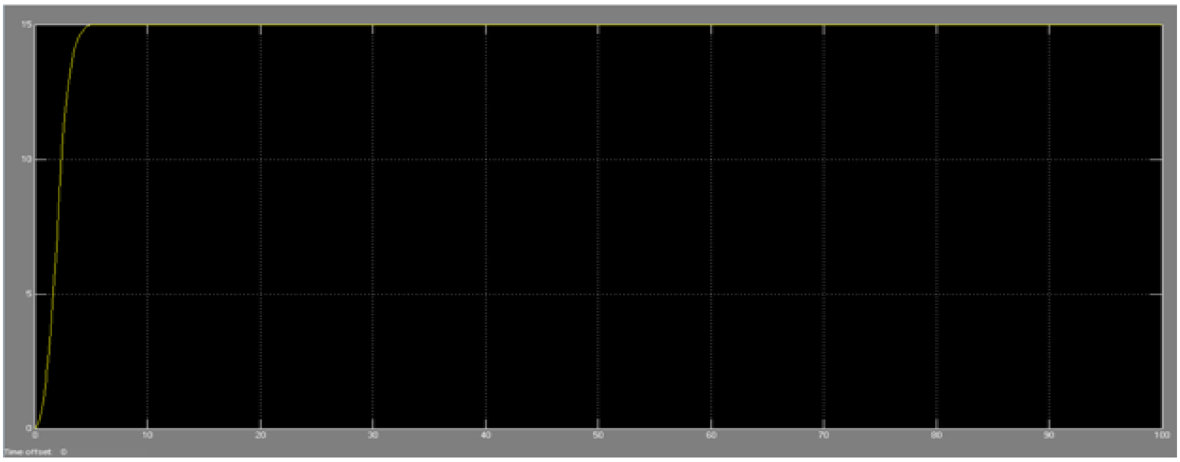

Fig 8: Simulink Response of FLC

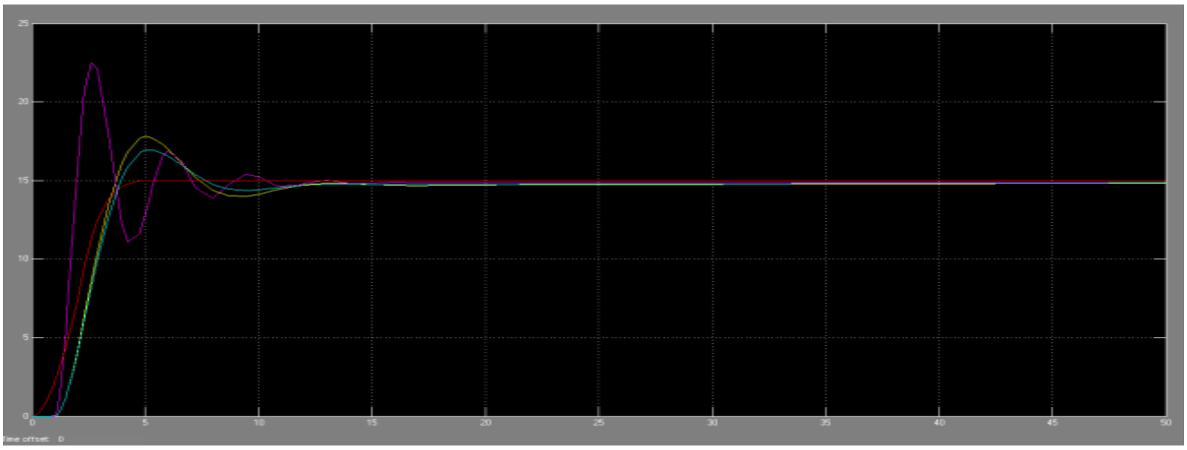

Fig 9: Comparative Simulink response of P, PI, PID andFLC for parameters

Table-2: Comparisons of controllers in tabularform

Controllers	Risetime	Steadystate error	Peak overshoot	Setting time
P	1.9sec	0.9%	50%	20sec
PI	3.41se c	1.6%	18%	16sec
PID	3.56se c	1.6%	13%	12sec
FLC	3.25se c	0	0	5sec

V. CONCLUSION

In this paper, we developed the mathematical model of coupled tank system and design a Simulated model for coupled tank, PID controller and fuzzy logic control system. Designed model are simulated within MATLAB/Simulink and comparatively analyzed in terms of rise time, steady state error, peak overshoot and setting time. From the analysis we concluded that coupled tank system with fuzzy logic controller gives better performance. The simulated results shows that fuzzy logic controller is a better option for real world applications as we can see in the results shown in table 2.

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