Artificial Intelligence Based Liquid Level Control of Coupled Tanks using Fuzzy Logic Controller

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Abstract- This paper investigates the usage of Artificial Intelligence using Fuzzy Logic Controller (FLC) in controlling the liquid level in the second tank of Coupled-Tanks plant through variable manipulation of liquid pump in the first tank. System modelling involves developing a mathematical model by applying the fundamental physical laws of science and engineering. Simulation studies are then conducted based on the developed model using MatlabR2012a for Simulink. In this papers also study behaviour system in terms of time response (e.g., steady state error, a certain rise-time, and overshoot) and compare FLC adverse PID controller.

Keywords – Artificial Intelligence , Fuzzy Logic Controller, Simulink, System Model.

I. INTRODUCTION

The industrial application of liquid level control is tremendous especially in refineries petroleum and chemical process industries. Usually, level control exists in some of the control loops of a process control system. An evaporator system is one example in which a liquid level control system is a part of control loop. Evaporators are used in many chemical process industries for the purpose of separation of chemical products. Level control is also very important for mixing reactant process. The quality of the product of the mixture depends on the level of the reactants in the mixing tank. Mixing reactant process is a very common process in chemical process industries and food processing industries .Many other industrial applications are concerned with level control, may it be a single loop level control or sometimes multi-loop level control. In some cases, level controls that are available in the industries are for interacting tanks. Hence, level control is one of the control system variables which are very important in process industries . Nowadays, chemical engineering systems are also at the heart of our economics . The process industries such as refineries petrol, petro-chemical industries, paper making and water treatment industries require liquids to be pumped, stored in tanks, and then pumped to another tank. In the design of control system, one often has a complicated mathematical model of a system that has been obtained from fundamental physics and chemistry . The above mentioned industries are the vital industries where liquid level and flow control are essential . Many times the liquids will be processed by chemical or mixing treatment in the tanks, but always the level fluid in the tanks must be controlled, and the flow between tanks must be regulated. Level and flow control in tanks are the heart of all chemical engineering systems .

The controller designed using fuzzy logic implements human reasoning that has been programmed into fuzzy logic language (membership functions, rules and the rules interpretation)It is interesting to note that the success of fuzzy logic control is largely due to the awareness to its many industrial applications. Industrial interests in fuzzy logic control as evidenced by the many publications on the subject in the control literature has created an awareness of its interesting importance by the academic community .

II. SYSTEM MODEL

Two interacting tanks in series with outlet flow rate being function of the square root of tank height shown Fig.1.

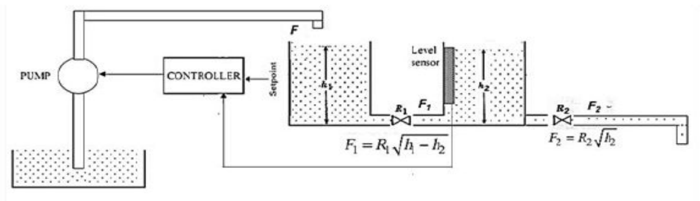


Fig.1 A Typical Couple Tanks Control System

A. Modeling equations

By applying the laws of physics to get a mathematical model of the system to become the dynamic equation of the system, as in equations (1)&(2).

$$\frac{dh_1}{dt} = \frac{F}{A_1} - \frac{R_1}{A_1}\sqrt{h_1 - h_2} \qquad (1)$$

$$\frac{dh_2}{dt} = \frac{R_1}{A_2}\sqrt{h_1 - h_2} - \frac{R_2}{A_2} \qquad (2)$$

Where :

F =steady-state liquid flow rate ,c m^3/sec. F_1 = out flow rate from first tank, cm^3/sec.

F_2 = out flow rate from second tank, cm^3/sec.

R_1 and R_2 = coefficients, cm$^{2.5}$/sec.

(h_1 = level first tank ,cm . h_2 = level second tank ,cm).

A_1 =the cross sectional area for first tank, cm^2.

A_2 =the cross sectional area for second tank ,cm^2.

III. SIMULINK BLOCK DIAGRAM DESCRIPTION

Simulink model for liquid level control and Fuzzy Logic Controller and by using program MatlabR2012a. Based on the dynamic equations (1) and (2) a simulink block diagram

Design Fuzzy Logic Controller for Liquid Level Control

Fig.2 showing the nonlinear model of the plant can be formed successively .Fig.3 shows the subsystem embedding the Simulink block diagram of the nonlinear model of the plant. For pumping liquid is pumping capacity (F = 5 cm^3\sec).

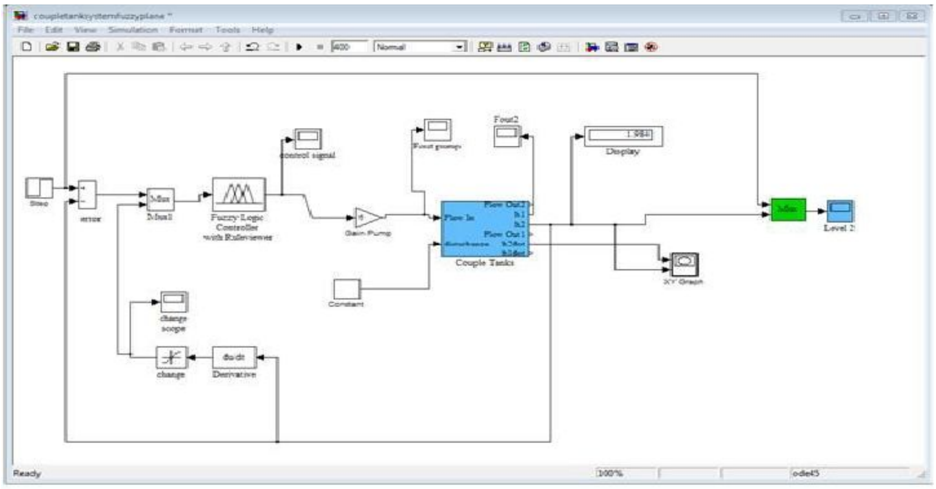


Fig2. Simulink for Control System with FLC

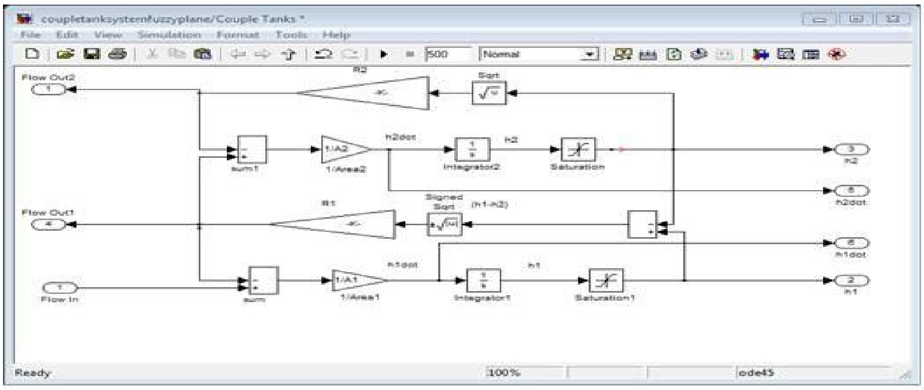


Fig3. Non-linear Model of Coupled-Tanks in Simulink

IV. DESIGNING OF FUZZY LOGIC CONTROLLER

A. *Fuzzy Logic Controller Review*

Fuzzy logic is a part of artificial intelligence or machine learning which interprets a human's actions. Fuzzy techniques have been successfully used in control in several fields. Fuzzy logic is a form of logic whose underlying modes of reasoning are approximate instead of exact. The general idea about fuzzy logic is that it takes the inputs from the sensors which is a crisp value and transforms it into membership values ranging from 0 to 1. Unlike crisp logic ,it emulates the ability to reason and use approximate data to find solutions.

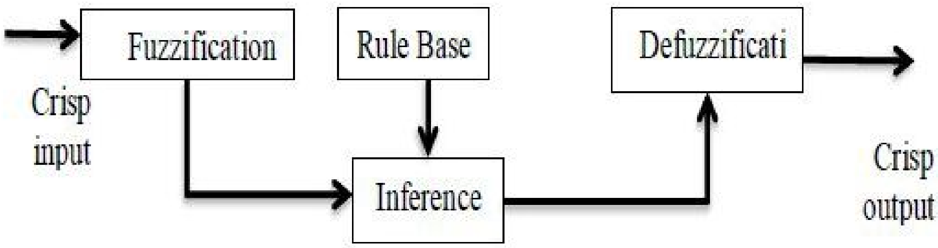
Fuzzy logic controllers (FLCs) are knowledge-based controllers (Artificial Intelligence) consisting of linguistic "IF-THEN" rules that can be constructed using the knowledge of experts in the given field of interest[6].Despite the variety of possible fuzzy controller structures, the Fig.4 is shown all common types of controllers consist of:

• Input fuzzification (binary-to-fuzzy [B/F] conversion)

• Fuzzy rule base

• Inference engine

• Output defuzzification (fuzzy-to-binary [F/B] conversion) [4].



B. Inputs and Output for System

We have defined two inputs and one output for the fuzzy logic controller may be shown as Fig.5. One is error that range of the liquid in the second tank denoted as "error" that represented error = href – h2 if href the set point for level that control on it, and the other one is ratio of change of liquid in the second tank denoted as "rate" . The highest value of the liquid level is 13, which represents the height of each tank of two tanks that the error rate ranging from -13 to 13, so the error range of input "error" is from -13 to 13 either input "rate" range from -0.2to 0.2 ,the range output -100 to 100 that represents "pump" . The input "error" is divided into three membership functions are "low" , "okay" and "high", either input "rate" is divided into three membership functions "negative" , "none" and "positive", the output "pump" is divided into five membership functions "close fast" , "close low" and "no change" , "open low" and "open fast" and are used triangular membership functions in the inputs and output Fig.6 illustrate this. Both these inputs are applied to the rule editor. According to the rules written in the rule editor the controller takes the action and governs the running of the pump which is the output of the controller and is denoted by "pump".

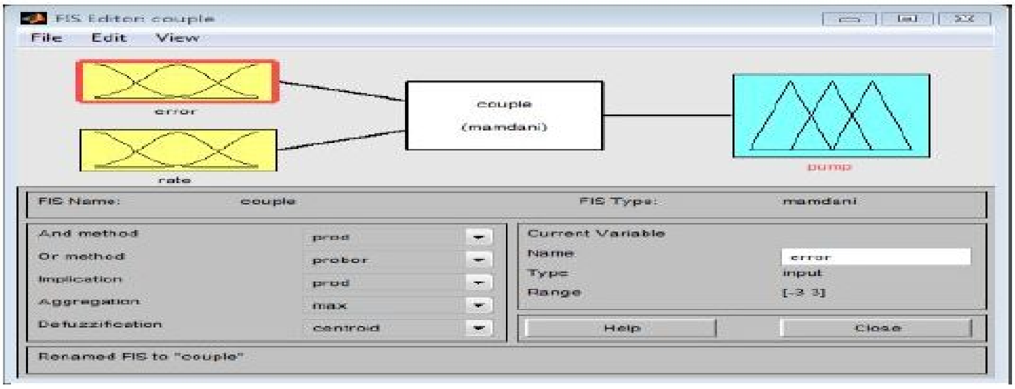


Fig 5. FIS Editor

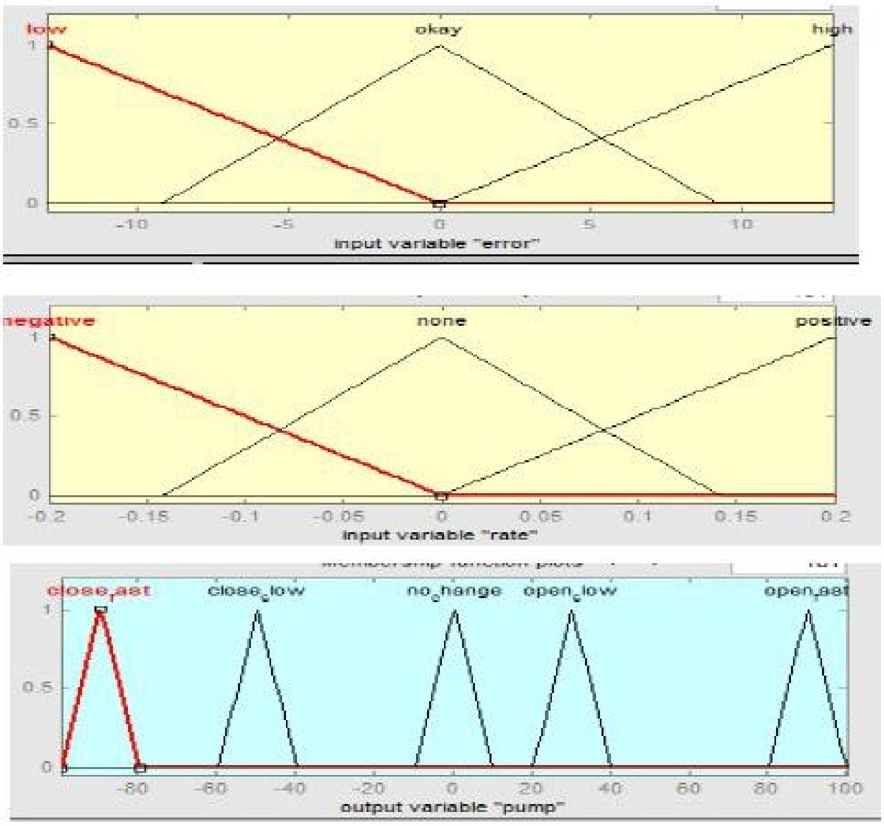


Fig 6. Memberships Inputs and Outputs

C. The Fuzzy Rule

Constructing rules using the graphical Rule Editor interface is very clearly. Based on the descriptions of the input and output variables defined with the FIS Editor, the Rule Editor allows you to construct the rule statements automatically, by clicking on and selecting one item in each input variable box, one item in each output box, and one connection item .Fig.7 illustrate rule bases that used in the fuzzy logic controller.

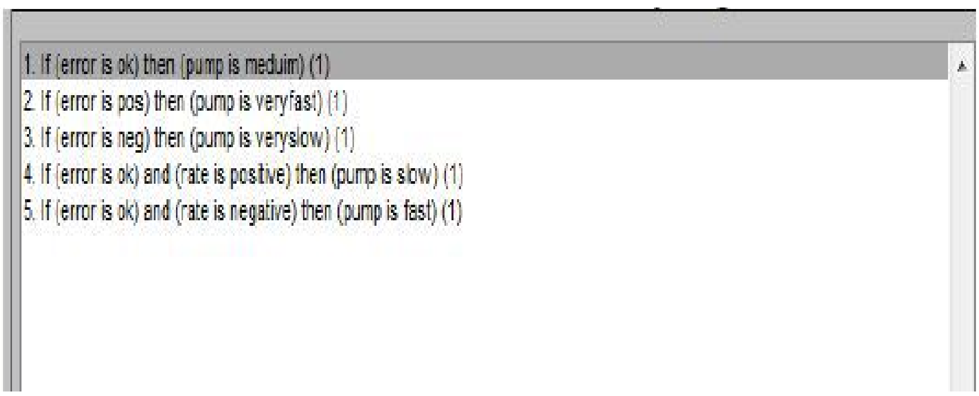


Fig 7. Rules Bases for Fuzzy Logic Controller

V. PID CONTROLLER

We are using PID controller to compare with fuzzy logic controller ,for finding constants controller use tool "PID" in simulation of MatlabR2012a program, which depends on the frequency response at the calculate of constants controller

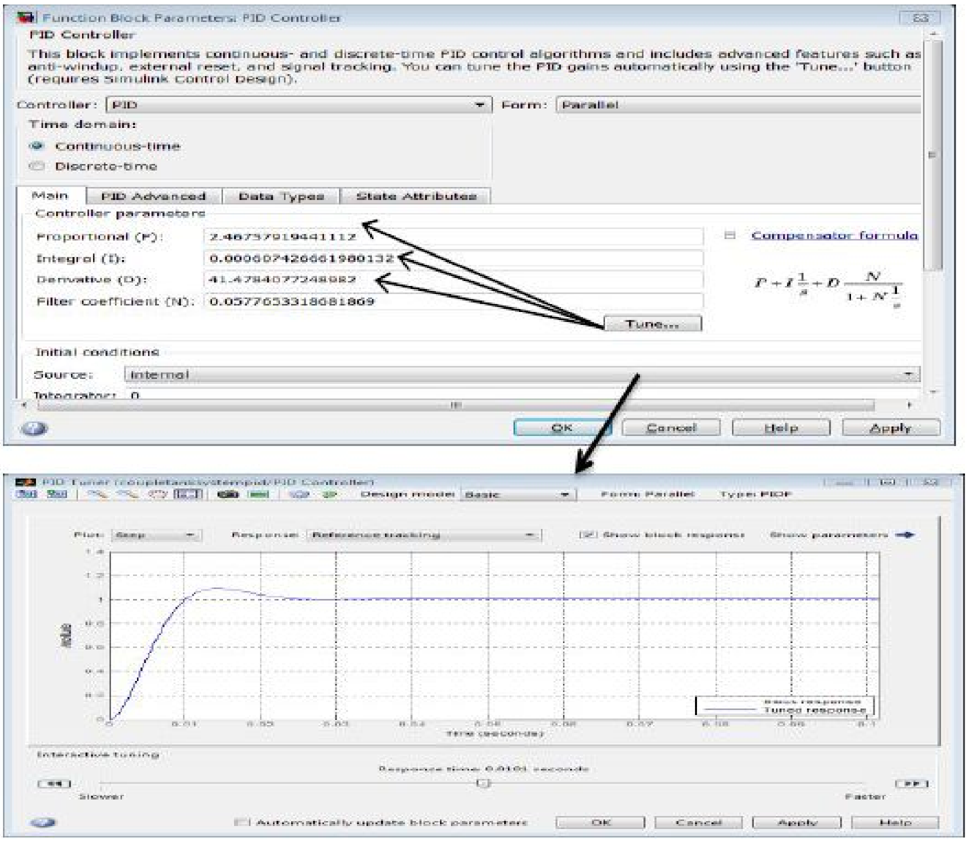


Figure 8. Illustrates the method To Calculate The Constants Controller

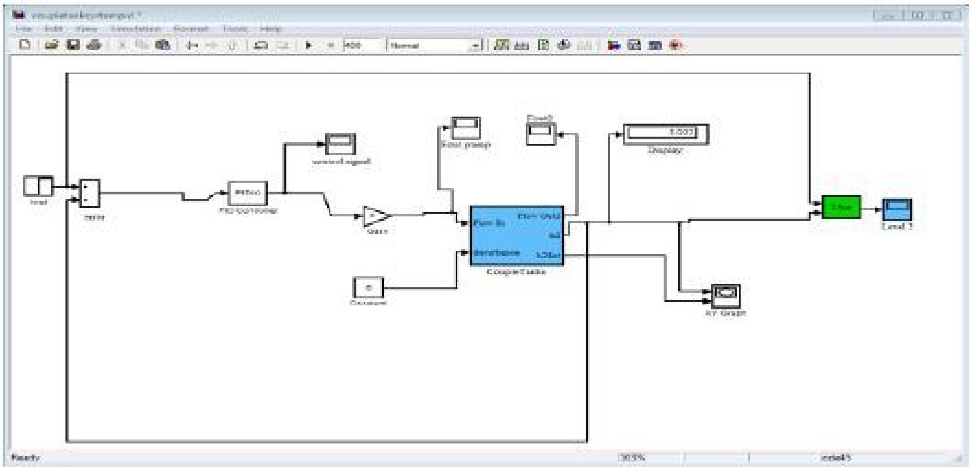


Figure 9. Simulink for Control System With PID Controller

VI. SIMULATION RESULTS

Response of second tank level using fuzzy logic controller Fig.10 provide good performance in terms of oscillations and overshoot in the absence of a prediction mechanism and Fig.11 illustrate response of second tank if acquire any leakage or disturbance in tank and that demonstrates how to return the controller to control the liquid level and the same performance without get any oscillations or overshoot .Otherwise, Response of liquid level controller using PID controller Fig.12 it is seen that PID controllers provide performance in terms of oscillations and overshoot in the presence of a prediction mechanism and Fig.13 illustrate response of second tank if acquire any leakage or disturbance in tank and that demonstrates how to return the controller to control the liquid level and the same performance in transients with presence oscillations or overshoot that lead to instability system.

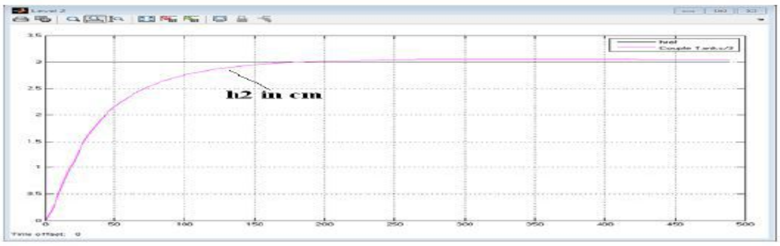


Figure 10. Response of Second Tank Using FLC

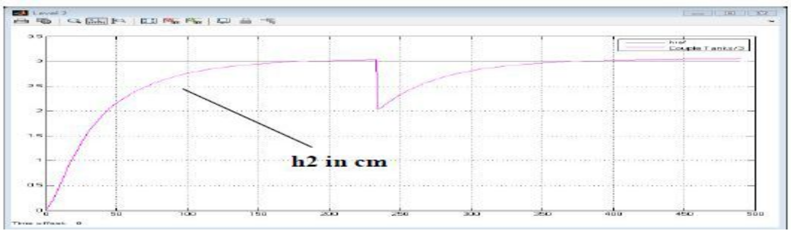


Figure 11. Response of Second Tank With Leakage or Disturbance in Liquid Level for FLC

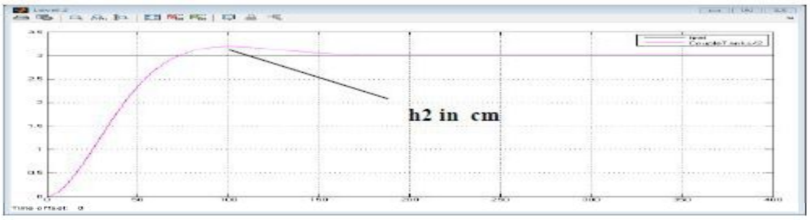
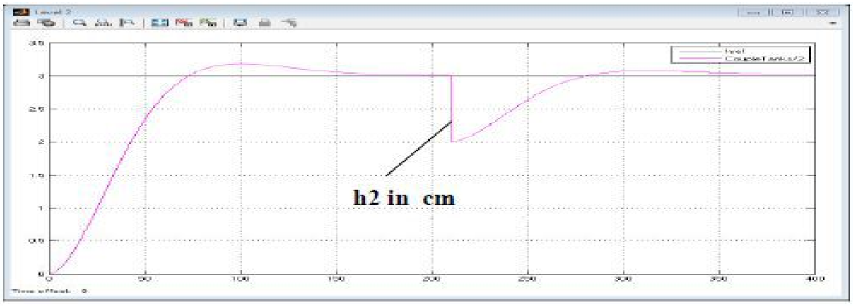


Figure 12. Response of Second Tank Using PID



Response of Second Tank With Leakage or Disturbance in Liquid Level for PID

VII. DISCUSSION

The FLC is applied to the plant, the results have been obtained from simulation are plotted against with that of conventional controller PID controller for comparison purposes. The simulation results are obtained using a 5 rule FLC. Rules shown in Rule Editor provide inference mechanism strategy and producing the control signal as output. For comparison purposes, simulation plots include a conventional PID controller, and the fuzzy algorithm. FLC provide good and satisfactory time domain response performance in terms of oscillations and overshoot are quite absence due to prediction mechanism. The FLC algorithm adapts quickly to longer time delays and provides a stable response while the PID controllers may drive the system unstable due to mismatch error generated by the inaccurate time delay parameter used in the plant model. From the simulations, in the presence of unknown or possibly varying time delay, the proposed FLC shows a significant improvement in maintaining performance and preserving stability over standard PID method .To strictly limit the overshoot, a Fuzzy Control can achieve great control effect. In this paper, we take the liquid level tank, and use MatlabR2012a to design a Fuzzy Control. Then we analyze the control effect and compare it with the effect of PID controller. As a result of comparing, Fuzzy Control is superior to PID control. Especially, it can give more attention to various parameters, such as the time of response, the error of steadying and overshoot. Comparison of the control results from these two systems indicated that the fuzzy logic controller significantly reduced overshoot and steady state error. Comparison results of PID and FLC are shown Table I below. The overall performance may be summarized as:

Table I. Comparison results of PID and FLC

Parameter	**PID**	**FLC**
Overshoot	Present	Not Present
Settling Time	More	Less
Transient	Present	Not Present
Rise Time	Less	More

VIII. CONCLUSION

Unlike the conventional PID controller the Fuzzy Logic Controller has benefits on the system response ,a unique FLC using a small number of rules and straightforward implementation has been proposed to solve a class of level control problems with unknown dynamics or variable time delays commonly found in industry. Additionally, the FLC can be easily programmed into many currently available industrial process controllers. The FLC on a level control problem with promising results can be applied to an entirely different industrial level controlling apparatus .As a future work one can develop design a FLC for a couple tanks system as adaptive Fuzzy Logic Controller like PID algorithm, which gives high. performance for systems and high intelligence.

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