# Fuzzy Logic Control of Coupled Liquid Tank System

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**Abstract-This paper presents a fuzzy control of coupled liquid tank system. The Coupled Liquid Tank system is developed at PIEAS. It has three liquid tanks coupled together. The liquid level in tank 2 is maintained using fuzzy logic. The results are compared with the PID control, mostly used in industries.**

## I. INTRODUCTION

The past few years have witnessed a rapid growth in the number and variety of applications of fuzzy logic. The applications range from consumer products such as cameras, camcorders, washing machines, and microwave ovens to industrial process control, medical instrumentation, decision-support systems, and portfolio selection [1].

This increase in popularity is due to the fact that fuzzy logic provides a powerful tool that allows engineers to incorporate human reasoning in the control algorithm. As opposed to the modern control theory, fuzzy logic design is not based on the mathematical model of the process, so it can be easily applied to systems with nonlinearities such as saturation, dead zones, delays etc. The controller designed using fuzzy logic implements human reasoning that can be programmed into fuzzy logic language (membership function, rules and the rele interpretation) [2]. Fuzzy logic is conceptually easy to understand and is flexible.

Fuzzy logic is tolerant of imprecise data. Everything is imprecise if you look closely enough. Fuzzy reasoning builds this understanding into the process rather than tacking it onto the end. This paper shows that fuzzy logic is an effective alternate to the current PID method used widely in the industry. The special case of coupled liquid tank system is discussed.

## II. DESCRIPTION OF THE PLANT

The plant shown in Fig. 1, consists of three water tanks. Each water tank is about 5 liter capacity and water level in each tank may be varied between 0-20 cm. All three tanks are cylindrical in shape. Top tank and lower tank are placed vertically so that their crosssectional area remains same as the water level rises in these tanks. The middle tank is placed horizontally so that its cross-sectional area changes with water level. A small 12V DC pump is used to pump water from lower tank to the upper tank. At full speed pump produces flow rate of about 4 lit/min. A flow transducer is used to record the flow rate of the pump. Water level in each tank is measured using floats and servo potentiometers.

To model this system we used the basic equation

*Rate of flow in - Rate of flow out = Rate of accumulation.*

We get following three coupled non-linear differential equations for this system

$$\dot{H}_1 = \frac{C_2\sqrt{H_2} - Q}{A_1}$$
$$\dot{H}_2 = \frac{1}{A_2}(C_3\sqrt{H_3} - C_2\sqrt{H_2}) \qquad \dots \qquad (1)$$
$$\dot{H}3 = \frac{Q - C3\sqrt{H3}}{A3}$$

Where $H_1$, $H_2$ $H_3$ are the levels in Tank 1, Tank 2 and Tank 3, respectively. $c_1$, $c_2$, $c_3$ are discharge coefficients. $A_1$, $A_3$ are cross-sectional areas of Tank 1 & 3 and $A_2 = 2L\sqrt{r^2 - (r - H_2)^2}$.

## III. FUZZY LOGIC CONTROL DESIGN

Fuzzy logic Control is an appealing alternative to conventional control methods when system follows some general operating characteristics and a detailed process understanding is unknown or traditional models become overly complex [3]. The FLC developed here is a two-input single output controller. The two inputs are the deviation from reference level *errore*$(k)$, and *error rate* $\Delta e(k)$. Fig 2 shows the operational structure of the fuzzy controller. The two inputs error and change in error are generated by preprocessing unit. The post-processing unit generates the control input from FLC output which is change in control input. The conventional controller is replaced by the FLC.

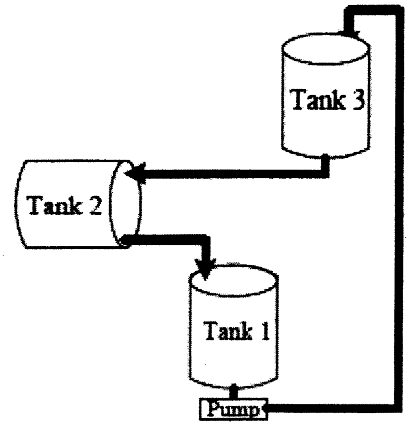



**Figure 1: Sketch of Coupled Liquid Tank System**

The fuzzy logic controller consists of three stages:

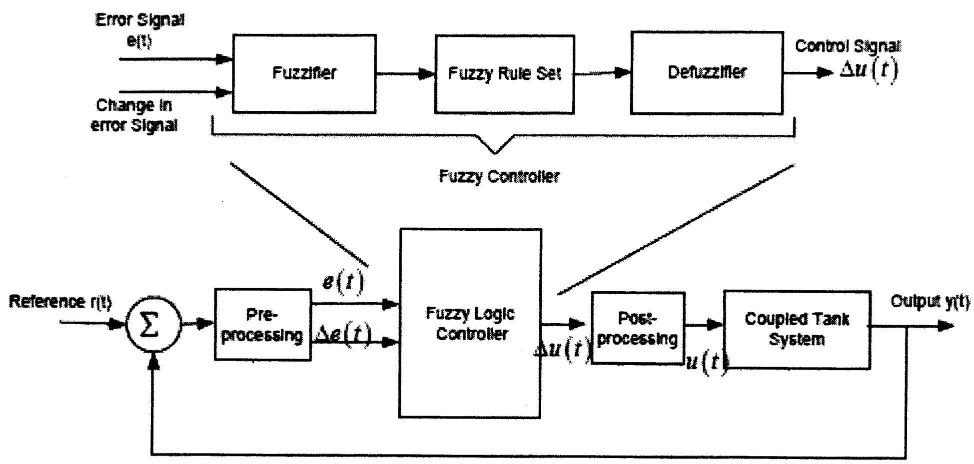
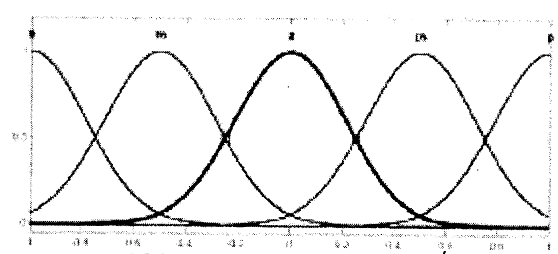


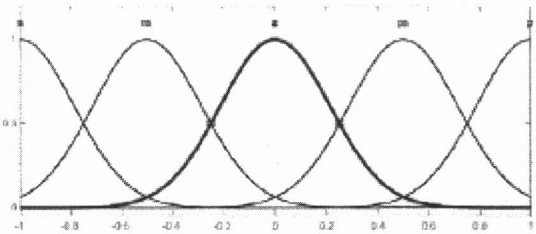

**Figure 2: Fuzzy logic control system**

1. Fuzzification
2. Fuzzy Rule Set
3. Defuzzification

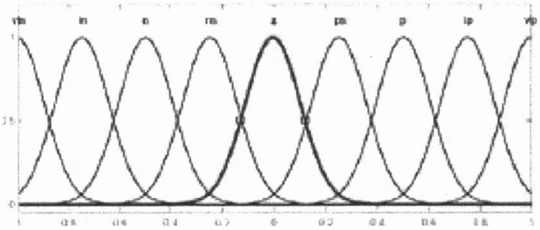
Fuzzification generates the control input from the FLC output which is change in control input. The Fuzzification and Defuzzification involves mapping the fuzzy variables of interest to "crisp" numbers used by the control system. Fuzzification translates a numeric value for the errore$(k)$, or error rate $\Delta e(k)$, into a linguistic value such as positive large with a membership grade. Defuzzification takes the fuzzy output of the rules and generates a "crisp" numeric value used as the control input to the plant. We used the sigmoid membership functions for error, error rate and control input as shown in figure 3.



a) Membership function for error



b) Membership function for change in error



c) Membership function for control input

**Figure 3: Membership functions**

The Fuzzy Rule Set are IF-THEN rule statements that formulate the conditional statements that comprise fuzzy logic. An example of such a rule might be

*If error is positive and change in error is zero then change in pump speed is positive.*

**Table 1: Fuzzy Rule Set**

| | NCE | NSCE | ZCE | PSCE | PCE |
|---|---|---|---|---|---|
| NE | ZU | NSU | NU | LNU | VLNU |
| NSE | PSU | ZU | NSU | NU | LNU |
| ZE | PU | PSU | ZU | NSU | NU |
| PSE | LPU | PU | PSU | ZU | NSU |
| PE | VLPU | LPU | PU | PSU | ZU |

The set of fuzzy rules we used for our plant are shown in the Table 1. Where E is for error, CE is for change in error and the prefixes N, NS, Z, PS, and P are for negative, negative small, and so on. The Fig. 4 shows the graphical representation of these rules.

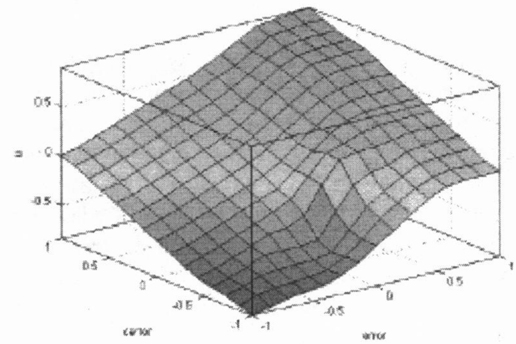


**Figure 4: The graphical visualization of the rules**

## IV. SIMULATION RESULTS

With the fuzzy logic controller used for the coupled tank system, the response of simulating is shown in Fig 5. The results are compared with that of PID control. It is obvious that FLC is a good alternate to PID. The response of the plant when desired level was set to 8 cm is shown in Fig 5.

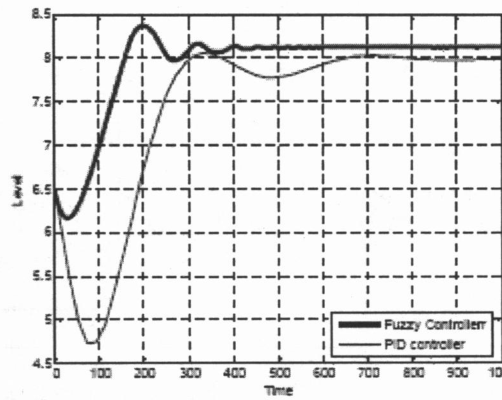



**Figure 5: Simulation result for Coupled Liquid Tank System.**

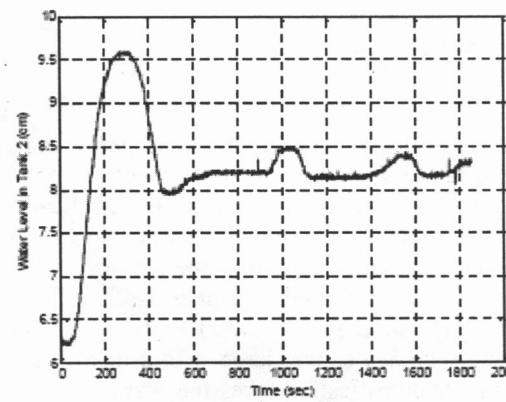



**Figure 6: Response of the Couple Liquid Tank System when ref. level was set to 8 cm.**

## REFERENCES.

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