A Robust Fuzzy Logic Control of Two Tanks Liquid Level Process

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Abstract— *An attempt has been made in this paper to analyze the efficiency of Fuzzy Logic, PID controllers on Non Interacting Two Tanks (Cylindrical) Liquid Level Process. The liquid level process exhibits Nonlinear square root law flow characteristics. The control problem formulated as level in second tank is controlled variable and the inlet flow to the first tank is manipulated variable. The PID Controller is designed based on Internal Model Control (IMC) Method. The Artificial Intelligent Fuzzy logic controller is designed based on six rules with Gaussian and triangular fuzzy sets. MATLAB - Simulink has been used to simulate and verified the mathematical model of the controller.*

Simulation Results show that the proposed Fuzzy Logic Controller show robust performance with faster response and no overshoot, where as the conventional PID Controller shows oscillations responses for set point changes. Thus, the Artificial Intelligent FLC is founded to give superior performance for a Non linear problem like two tanks. This paper will help the method suitable for research findings concerning on two tank liquid level system.

Keywords—Fuzzy Logic Controller, MATLAB–Simulink, PID and Two tank Non-interacting level system.

I. INTRODUCTION

In many industries process such as petro chemical industries, paper making industries and water treatment industries are using the tank system to control the liquid level. The liquid level must be controlled by the proper controller. The objective of the controller in the level control is to maintain a level set point at a given value and be able to accept new set point. The control of liquid level in tanks and flow between tanks is a basic problem in the process industries. The process industries require liquids to be pumped, stored in tanks, then pump to another tank. Many times the liquids will be processed by chemical or mixing treatment in the tanks, but always the level of liquid in the tanks must be controlled, and the flow of the tank must be regulated. Level and flow control in tanks are at the heart of all chemical engineering systems. But chemical engineering system is also at the heart of our economies.

Two tanks Non-interacting liquid level control of industrial process is a challenging task for numerous bases due to its nonlinearity. The control of liquid level in two tanks is a major trouble in industrial process. A level that is too high may upset reaction equilibria, cause damage to equipment, or result in spillage of valuable or hazardous material. If the level is too low, it may have bad consequences for the sequential operations. Hence, control of liquid level is an important and common task in process industries. Chemical processes present many challenging control problems due to their nonlinear dynamic behaviour. Nonlinear models are used where accuracy over a wider range of operation is required where they can be directly incorporated into control algorithms. Because of the inherent nonlinearity most of the chemical process industries are in need of traditional control techniques. The nonlinear system taken up for the study is the two tanks [1, 2].

Designing of controller for a nonlinear process is an important problem. Conventional controllers are broadly used in industries since they are trouble free, robust, and well known to the field operator. The feedback controller cannot anticipate and prevent errors, it can only initiate corrective action after an error has already developed. It cannot give close control when there is a large delay in the process [3]. So, one of the remedy for the problem is fuzzy control system . Unlike a feedback control system, a fuzzy control system was developed using expert knowledge and experience gained about the process. The conventional feedback controller is not replaced by the intelligent fuzzy controller. The fuzzy controller design consists of three stages: Fuzzificationstage, Decision making logic and Defuzzification stage [4, 5]. In this paper an attempt has been made to analyze the efficiency of fuzzy control using two tank level control system and the effects are studied through computer simulation using Matlab/Simulink toolbox [6, 7, 8, and 9]. The simulation results of FLC are compared with classical control method.

II. MATHEMATICAL MODELING

2.1. Non interacting system

The basic model equations of Non interacting two tank system is given by

Tank1: $A_1 \frac{dh_1}{dt} = q_i - Cd_1 a_1 \sqrt{2gh_1}$ (1)

Tank2: $A_2 \frac{dh_2}{dt} = Cd_1 a_1 \sqrt{2gh_1} - Cd_2 a_2 \sqrt{2gh_2}$ (2)

$A_1=A_2=A=$ 25 Cm^2 Cross sectional area of the tanks= $\frac{\pi}{4} d^2 ; d = 6Cm$

$a_1=a_2=a=$ 1.4cm^2 Cross sectional area of the orifice = $\frac{\pi}{4} d^2 ; d = 13.61mm$

For Free Flow, Co-efficient of Discharge $Cd_1 = Cd_2 =$ 0.575.

Where q_i is Tank1 inlet flow rate (i.e Manipulated Variable) (m^3/s), h_1 is the liquid level in tank1 and h_2 is the liquid level in tank2 (Controlled variable).

III. INTERNAL MODEL CONTROL (IMC)-BASED PID DESIGN FOR A FIRST-ORDER + DEAD TIME PROCESS

a. The simulation study was carried out as shown in below Fig.1. MATLAB - Simulink for PID control system

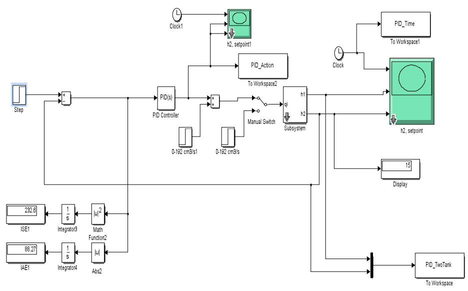

Fig.1: Block diagram of two tank liquid level non interacting system using IMC-PID Controller

b. DESIGN OF A FLC FOR TWO TANK LIQUID LEVEL PROCESS

The simulation study was done as shown in Fig.2. MATLAB- Simulink for Fuzzy Logic control system. Design of a fuzzy logic controller requires a sufficient knowledge about the response of the controlled process. The data from the process study constitute the knowledge base for the fuzzy logic controller.

3.2.1. Steps involved in designing fuzzy control

The steps involved in designing a simple fuzzy logic controller are as follows:

- Identify the variables (input states and outputs) of the plant.
- Partition the universe of discourse or the interval spanned by each variable into a number of fuzzy subsets, assigning each a linguistic label (subsets include all the elements in the universe).
- Assign or determine a membership function for each fuzzy subset.
- Assign the fuzzy relationships between the inputs or states fuzzy subsets in one hand and the outputs fuzzy subsets on the other hand, thus forming the rule base.
- Choose appropriate scaling factors for the input and the output variables in order to normalize the variables to the [-1, +1] and the [-1, +1] interval.
- Fuzzify the inputs to the controller
- Use fuzzy approximate reasoning to infer the output contributed from each rule.
- Aggregate the fuzzy outputs recommended by each rule.
- Apply defuzzification to form a crisp output. In the fuzzification step, the Flow and flow rate selected as input variables. Universes of discourse of these input variables are divided into three fuzzy sets and they are linguistically named as HIGH, LOW and OK as shown in the Fig.3. and Fig.4. The Gaussian membership functions with the appropriate ranges have been used for these fuzzy sets. The values of the valve have been selected as Fuzzy output variables like input variables of the universe of discourse the output variables are divided into five fuzzy sets with linguistic names OPENFAST, OPENSLOW, NOCHANGE, CLOSESLOW and CLOSEFAST as shown in the Fig.5.

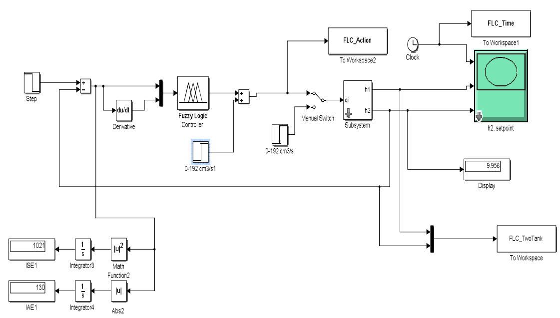

Fig.2: Block diagram of two tank liquid level non interacting system using Fuzzy logic Controller

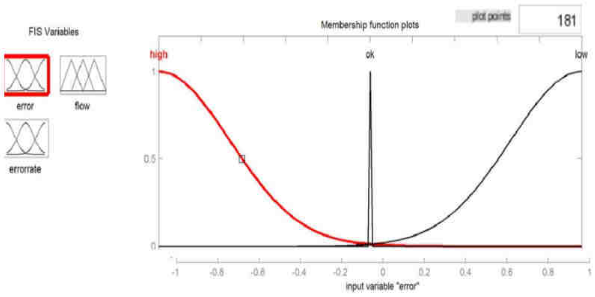

Fig.3: Input membership function of error

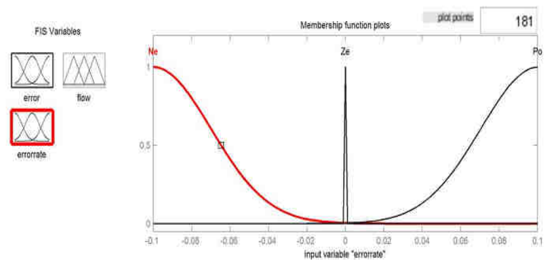

Fig.4: Input membership function of change in error

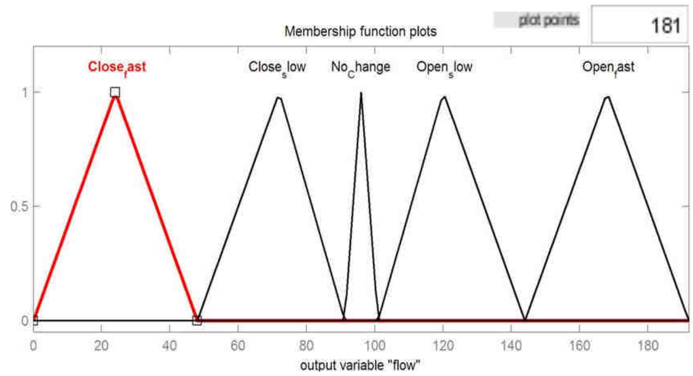

Fig.5. Output membership function of valve

The Six rules are:

1. If(Flow HIGH) then (Valve is CLOSEFAST)

2. If (Flow is OK) then (Valve is NOCHANGE)

3. If (Flow is LOW) then (Valve is OPENFAST)

4. If (Flow is OK) and (Flow rate is POSITIVE) then (Valve is CLOSESLOW)

5. If (Flow is OK) and (Flow rate is OK) then (Valve is NOCHANGE)

6. If (Flow is OK) and (Flow rate is NEGATIVE) then (Valve is OPENSLOW)

The centroid method has been used to obtain the crisp value.

IV. RESULTS AND DISCUSSION

4.1 Simulation Results

In the simulation we choose different set points 10-12, 10-14, 10-08, and 10-06 cm w.r.t time.

The below comparative simulation results at different set points shows that the fuzzy logic controller have good performance and minimum oscillations than PID Controller and results are Shown in Fig.6-Fig.13.

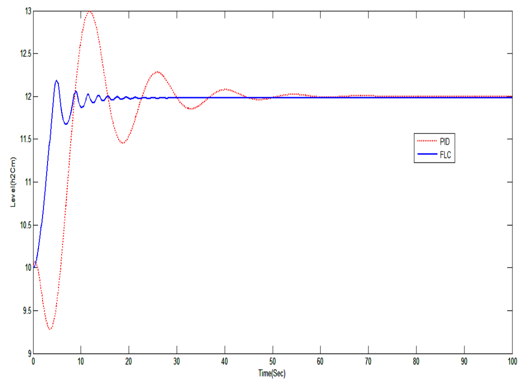

Fig.6: Servo Response of PID and Fuzzy logic Output Level (Cms) Vs Time (sec), SP1=10-12.

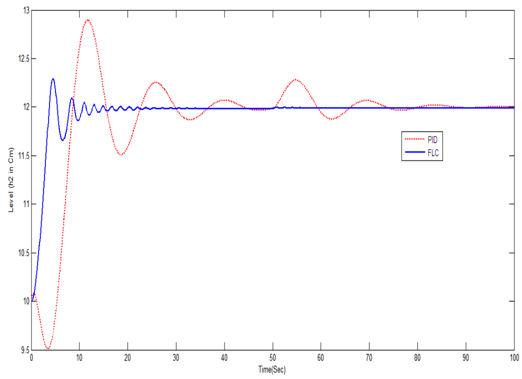

Fig.7: Regulatory Response of PID and Fuzzy logic Output Level (Cms) Vs Time (sec) at 50 Sec (qi) is 10% for SP1=10-12.

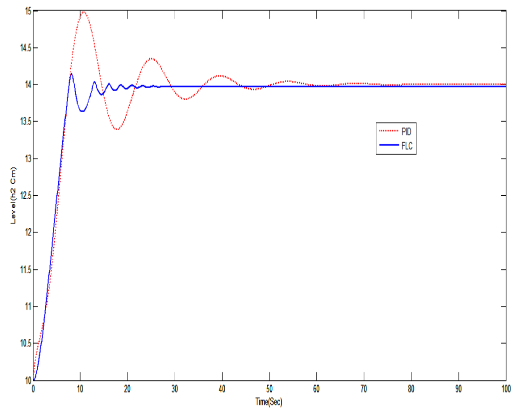

Fig.8: Servo Response of PID and Fuzzy logic Output Level (Cms) Vs Time (sec), SP2=10-14.

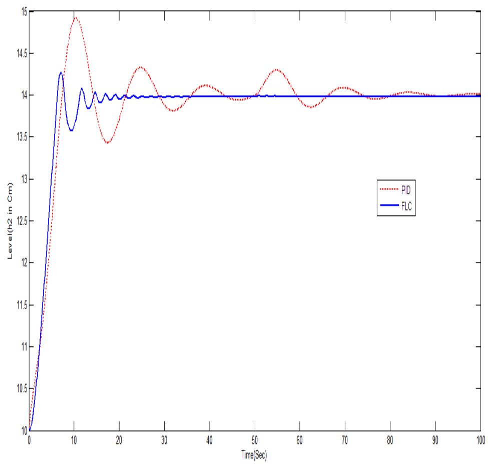

Fig.9: *Regulatory Response of PID and Fuzzy logic Output Level (Cms) Vs Time (sec) at 50 Sec (qi) is 10% for SP2=10-14.*

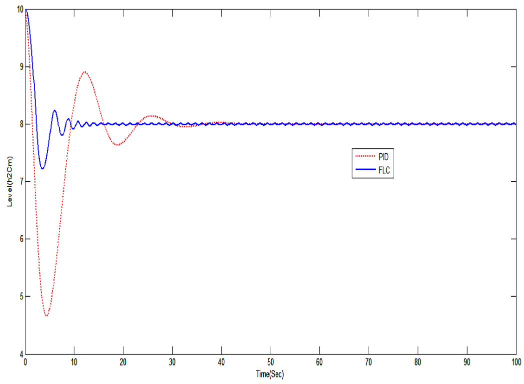

Fig.10: *Servo Response of PID and Fuzzy logic Output Level(Cms) Vs Time (sec), SP3=10-08.*

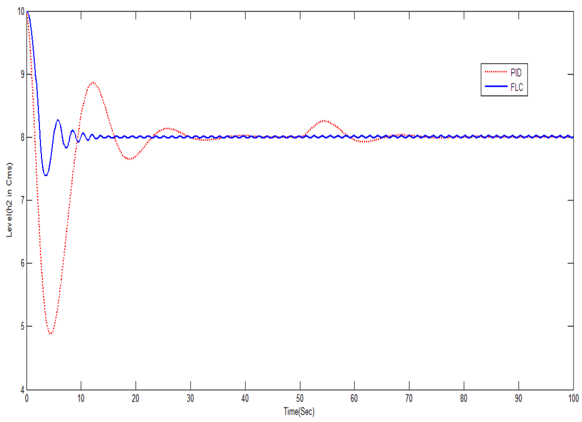

Fig.11: Regulatory Response of PID and Fuzzy logic Output Level (Cms) Vs Time (sec) at 50 Sec (qi) is 10% for SP2=10-08.

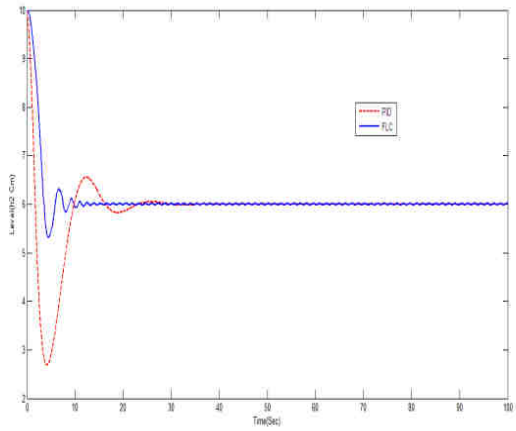

Fig.12: Servo Response of PID and Fuzzy logic Output Level (Cms) Vs Time (sec), SP4=10-06.

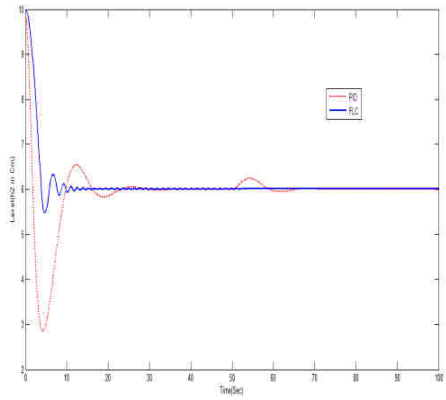

Fig.13: Regulatory Response of PID and Fuzzy logic Output Level (Cms) Vs Time (sec) at 50 (q_i) is 10% for SP2=10-06.

4.2. Comparison of PID and FLC Controllers response

Table 1 and Table 2 shows error parameter IAE and ISE for servo and regulatory control problems with different set points. It is found that irrespective of the control problems, Fuzzy logic controller has less error than PID controller and hence FLC shows superior performance than PID controller.

Table 1. SERVO Problem: Set Point = 10-12, 10-14, 10-08 and 10-06.

SETPOINT	ERROR	PID	FLC
10-12	ISE	35.69	7.251
	IAE	26.20	6.886
10-14	ISE	50.92	43.95
	IAE	29.11	17.85
10-08	ISE	41.30	5.606
	IAE	24.39	5.673
10-06	ISE	49.47	29.98
	IAE	23.74	11.92

Table: 2REGULATORY Problem: Set Point = 10-12, 10-14,10-08 and 10-06 (10%)

SETPOINT	ERROR	PID	FLC
10-12	ISE	41.49	8.168
	IAE	26.03	8.097
10-14	ISE	55.66	50.59
	IAE	28.32	20.94
10-08	ISE	46.41	5.743
	IAE	23.88	6.409
10-06	ISE	53.12	28.21
	IAE	23.05	11.27

V. CONCLUSIONS

This paper presents the control of the level in two tanks using different controllers such as PID and fuzzy logic Controller. Numerical simulation indicates that the fuzzy logic controller has more advantages than the conventional PID controller. The fuzzy logic controller has less overshoot, good robustness and low settling time. Also, it has a strong ability to adapt to the changes of the system parameters and anti-disturbance performance. The controller efficiently tracks the set point. The fuzzy logic controller gives better performance in terms of error indices such as IAE and ISE respectively.

The future scope of this work is the rejection of disturbance enters into the system as well as its real time implementation.

VI. ACKNOWLEDGEMENTS

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