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Real Time Implementation and Performance Analysis of a PID and a Fuzzy Controller for a Linear Process using LabVIEW

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ABSTRACT: This paper proposes two different methods of water level control in case of a linear tank. The methods are being a conventional PID controller and a fuzzy controller. The defuzzification method used is Mamdani method. The flow controlling element used here is a feed-pump. Both the Fuzzy and PID controller are implemented using LabVIEW and arduino Mega2560. Finally the performances of both the control schemes are evaluated regarding IAE, ISE, rise time and peak time.

KEYWORDS: PID, FUZZY, LabVIEW, arduino mega2560, Mamdani, IAE, ISE, rise time, peak time.

I.INTRODUCTION

Around 80% of control loops in industries are PID or a variant of PID. Although gain scheduling, cascade and fractional order PIDs shows a better response regarding steady state error suppression and transient response, the PID loops still suffer from the disadvantage of tuning. Tuning a PID for zero residual error is a highly precise work and there are various methods of tuning available of which each method is quite different. With the wear and tear of the actuators non linearity is introduced into the system which again leads to periodic tuning of PID loops which is a cumbersome and costly practice.

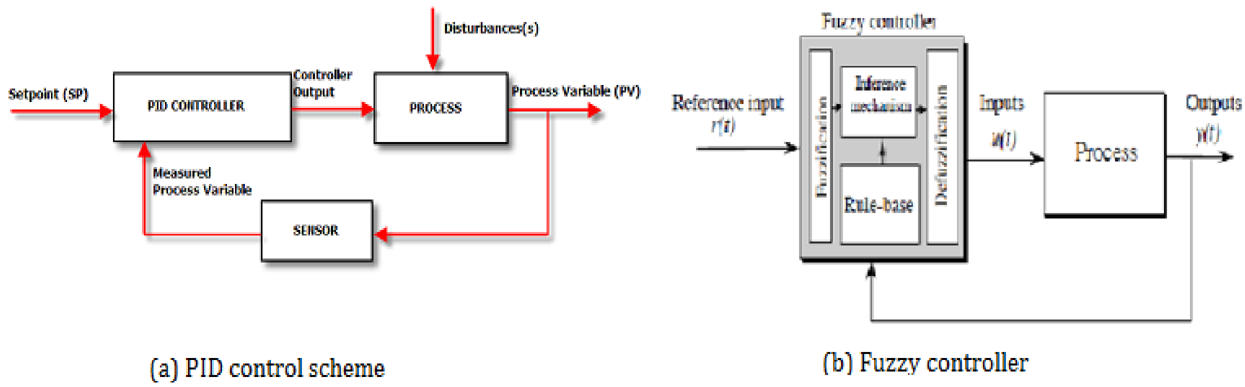

Fig. 1 (a) a PID scheme & (b) a Fuzzy control scheme

A fuzzy controller on the other hand uses human like intuition and hence gives a better response. A fuzzy controller is a model less design hence it can be tuned with the knowledge of input and output variations.

The fuzzy controller has four main components: (1) The rule-base holds the knowledge, in the form of a set of rules, of how to control the system. (2)The inference mechanism evaluates which control rules are relevant at the current time and then decides what the input to the plant should be. (3) The fuzzification interface simply modifies the inputs so that they can be interpreted and compared to the rules in the rule-base and (4) the defuzzification interface converts the conclusions reached by the inference mechanism into the inputs to the plant.

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II. SYSTEM SETUP

The setup used for level control has following hardware components:

Sump: The Sump is made up of transparent acrylic and also contains a submersible water pump as an actuator. The dimensions of the tank are 24.5cmx19.5cmx34.5cm.
Process Tank: The upper process tank is of dimension 14.5cmx14.5cmx29.4cm and is made up of transparent acrylic.
Level sensor(Ultrasonic):In this setup a HC-SR04 distance sensor is used to measure the depth. It uses +5V DC with effectual Angle <15° and a ranging distance of 2cm to 400 cm
Flow Sensor (YF-S201): Hall Effect turbine type sensor with Max flow rate: 8-9 ltr/min, min. flow rate: 2 ltr/min with frequency range from 16 Hz to 65 Hz respectively. Error range +10% to -10%
Pump: 0-12V submersible DC motor with flow rate of 2ltr/min to 20ltr/min.
Arduino Mega 2560 for data acquisition
Software toolkits: makerhub Linx, arduino ide and LabVIEW Fuzzy and PID toolkit

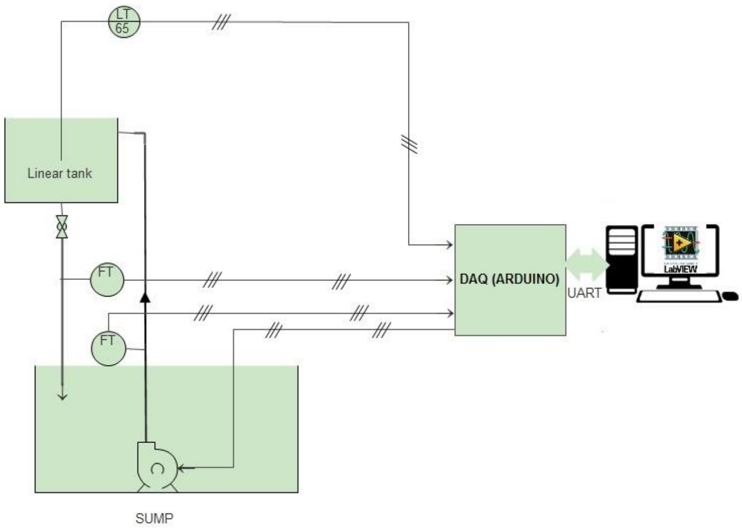

Fig. 2 System block diagram

III. SYSTEM MODELLING

The trainer system is a FOPTD model which is a single tank level control system. The model is developed on mass-balance principle.
Process: It is the change in level in the process tank with inflow rate (q_i) where the manipulated parameter being inflow and output parameter is level.
Tank: The governing equation for the change in liquid volume is given by the following equation:
Rate of change of volume of liquid = inflow (q_i) – outflow (q_o)
So, if q_i becomes equal to the q_o then there would be no change in the volume of liquid which is obtained by the tank.

$$dy/dt = q_i(t) - q_o(t) \qquad (1)$$

Where q_i-inflow, q_o-outflow
To find out T (time constant) and R (resistance to the outflow) we assume the following
Assumptions:
1. The cross-sectional area of the tank is constant that is A= 210.25 cm2
2. The outflow of the liquid is proportional to the height of liquid: $q_o(t) = h(t)/R$
From step response the time constant is found out to be 118sec and Resistance to flow (gain) R=0.63s/cm2

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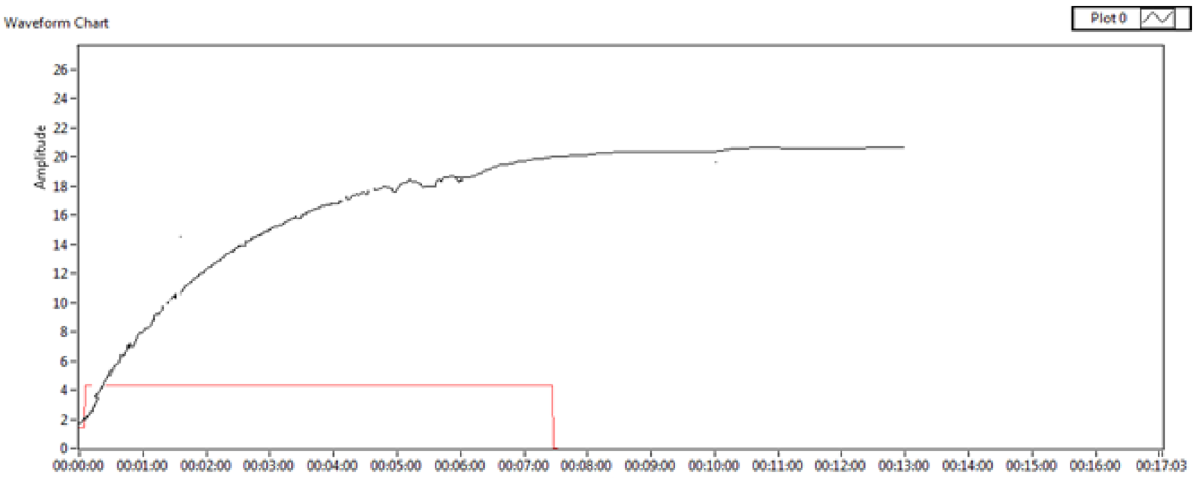

Fig. 3 Step response curve for a controller output change of 30%

The estimated transfer function of the process from the response curve is as follows.

$$\frac{H(s)}{Q(s)} = \frac{0.63}{1 + 118s} e^{-2s}$$

IV. FUZZY SYSTEM DESIGNING

The Fuzzy system is designed using Fuzzy system designer in LabVIEW with error ($e(t)$) and rate of error ($\dot{e}(t)$) as the linguistic input variables and the PWM duty cycle as the output variable and named as PWM.

Input:

Error ($e(t)$) is subdivided into five sets **Negative(n), Negative Zero(nz), Zero(z), Positive Zero(pz), Positive(p)**.
The **rate of error** ($\dot{e}(t)$) is subdivided into three subsets namely **Negative (n), Zero (z), Positive (p).**

The membership function of each input is shown below

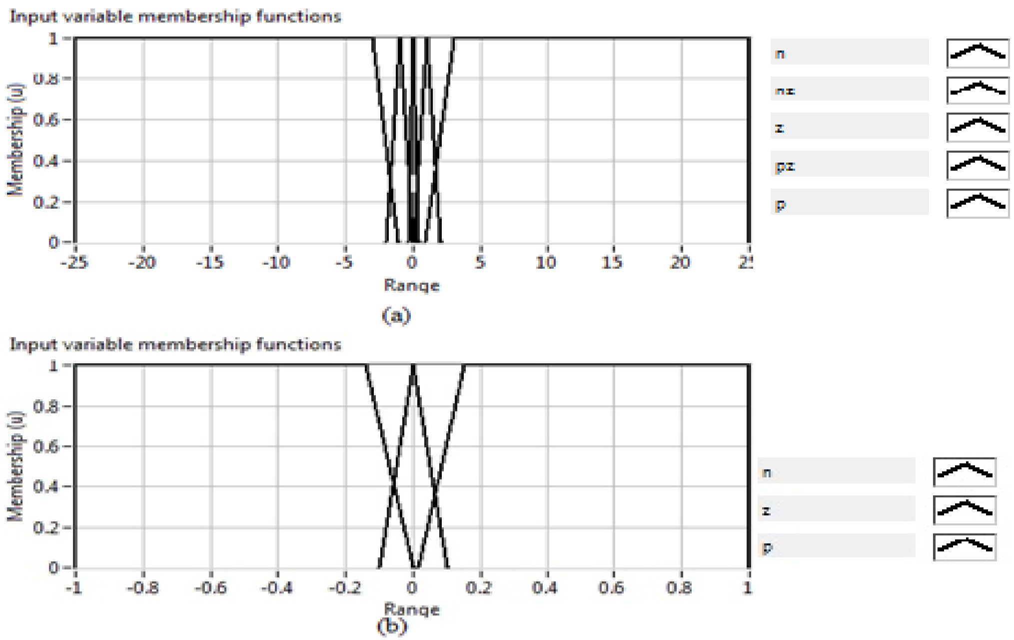

Fig. 4 Input membership functions (a) $e(t)$ and (b) $\dot{e}(t)$

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Output:

Variable **PWM** is subdivided into five subsets as **very less, less, medium, high, very high.**

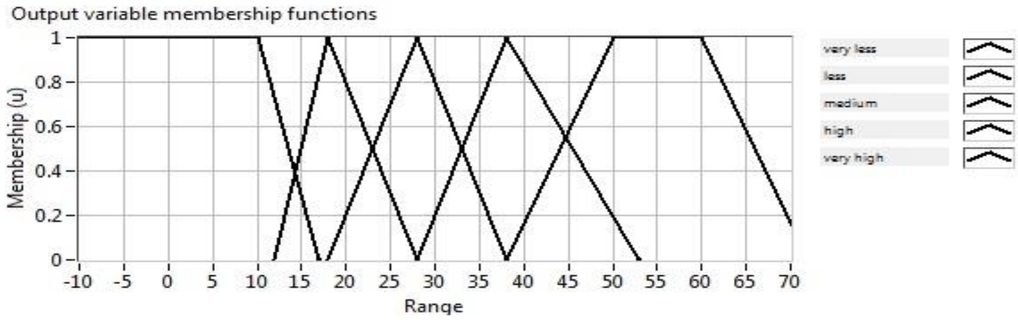

Fig. 5 Output membership function (PWM)

The rule base for output is shown in the following table. The premise is determined by minimum operator.

$\dot{e}(t)$ \ $e(t)$	n	nz	Z	pz	p
n	very less	less	medium	high	very high
z	very less	less	medium	high	very high
p	very less	very less	medium	high	very high

Table. 1 The rule base

The defuzzification method used is centre of area method. The output function plot with system inputs is shown below.

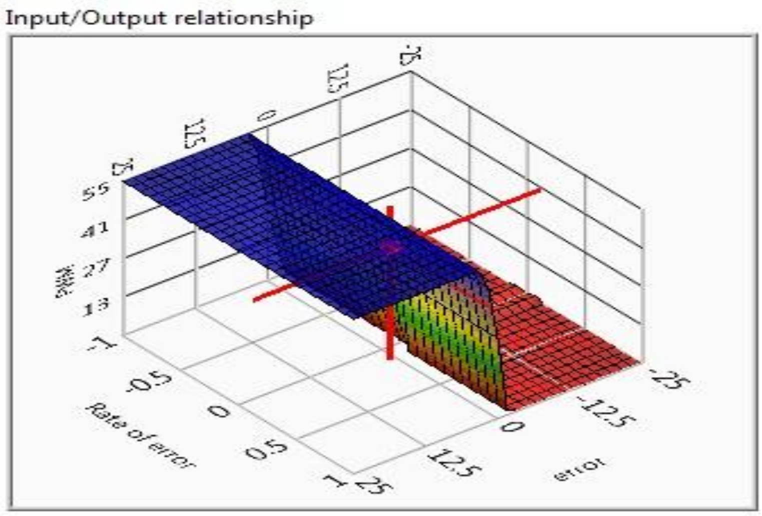

Fig. 6 Antecedent and Consequent relationship

V. IMPLEMENTATION

Both the controllers are implemented using an Input subVI and an Output subVI. The only difference in between the both scheme is the use of control scheme.

Linear sensor (Input subVI): This VI measures the level of the water using the HC-SR04 ultrasonic sensor.

Pump (Output subVI): This VI gives the PWM duty cycle percentage and thus an analog output through the Pin 10 of the Arduino Mega 2560 board.

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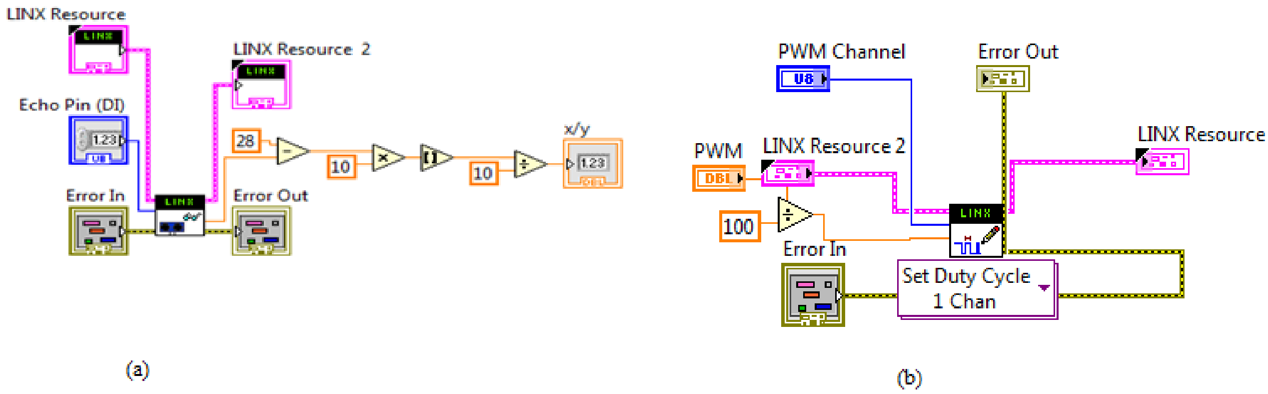
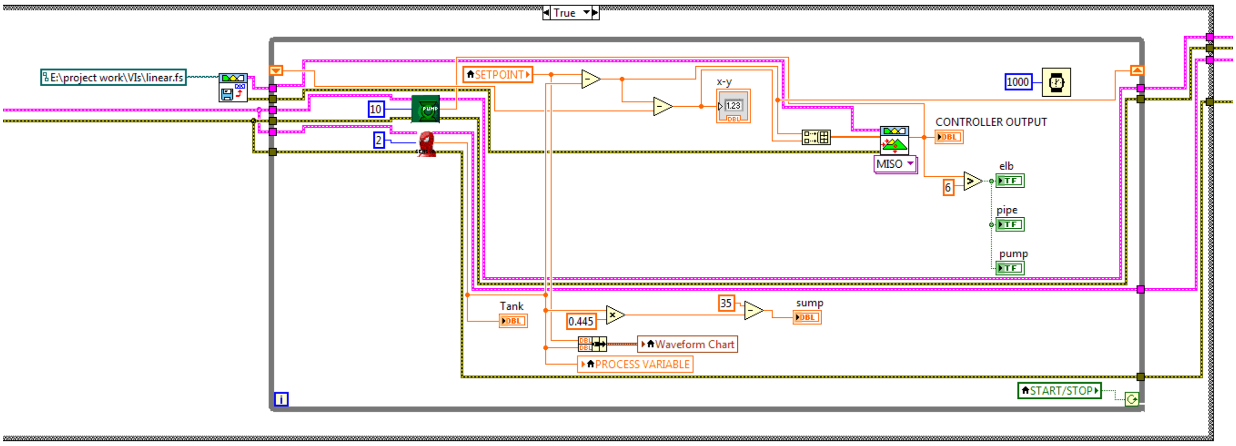
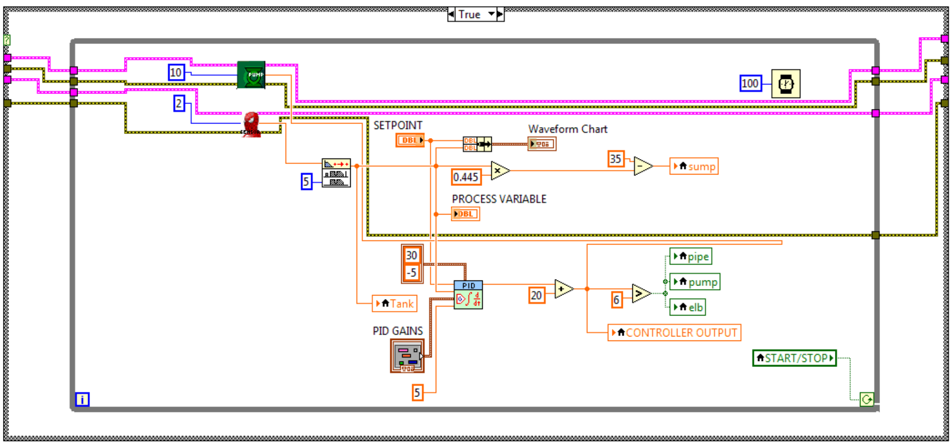


Fig. 6 (a) Linear Sensor and (b) Pump

The block diagrams of both PID and Fuzzy system is shown below



(a)



(b)

Fig. 7 (a) Fuzzy control scheme and (b) PID control scheme

VI. RESULT AND DISCUSSION

Performance evaluation of the PID and Fuzzy is done for the following tuned PID parameters.
$K_c = 80$, $T_i = 1s$ and $T_d = 0.73s$.

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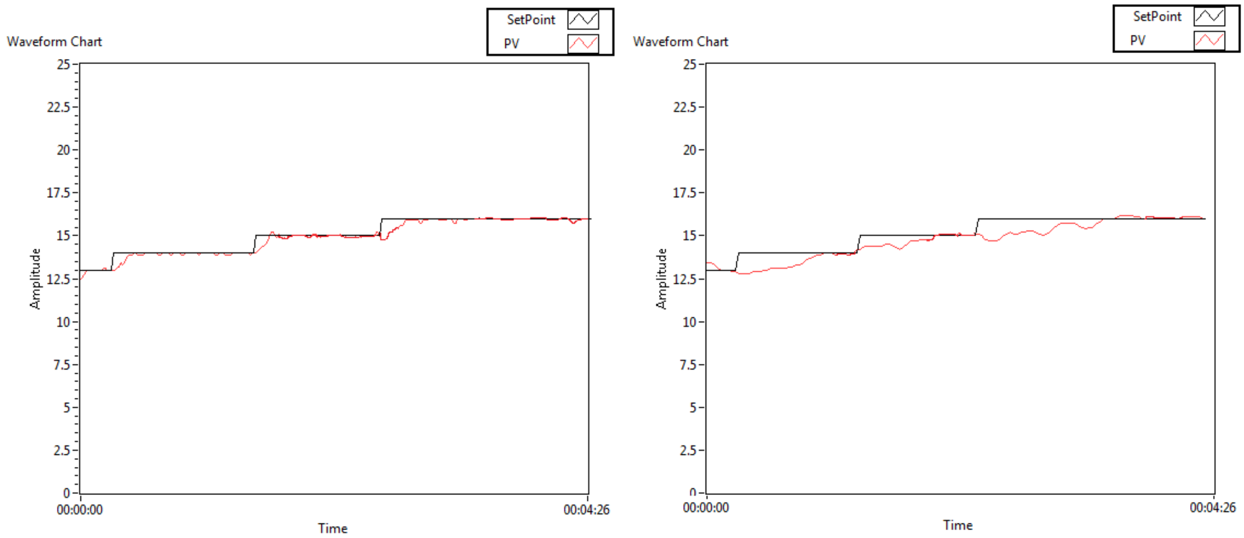
The method used for tuning the PID is Cohen and Coon process reaction method. The Set point tracking is done for both the controllers and IAE and ISE is found for both the controllers.



(a) (b)

Fig. 8 Set point tracking of (a) Fuzzy controller and (b) PID controller

A step change in set point is made to both the controllers and for set point changes from 13-14cms, 14-15cms and 15-16cms and the following results are found.

		PID	FUZZY
IAE	13-14 cm	20.4	8.1
	14- 15 cm	13.6	13.1
	15-16 cm	30.2	17.6
ISE	13-14 cm	18.6	4.49
	14- 15 cm	7	4.43
	15-16 cm	23.7	20.52

Table. 2 IAE and ISE for PID and Fuzzy controller

The maximum IAE for PID is found to be 30.2 whereas for Fuzzy its 17.6. Similarly the maximum ISE for Fuzzy controller is found out to be 20.52 compared to 23.7 for PID scheme.

Parameters	PID	Fuzzy
Settling time 1% error band(in sec)	40	28
Peak Time (in sec)	28	20
Rise Time (90%) (in sec)	25	19

Table. 3 Transient performances of PID and Fuzzy controller

The table 3 shows a better transient result in case of a Fuzzy controller in comparison to a PID controller. Moreover the

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Percentage peak overshoot is nil for a Fuzzy controller.

VII. CONCLUSION

The results show that a Fuzzy controller shows a better performance in comparison to a conventional PID controller. In case of a large error suppression the Fuzzy controller is a better choice which is evident from low ISE. In situations demanding zero or very less overshoot Fuzzy controller is a better option. Moreover Fuzzy is also able to handle non linearity introduced in a process with actuator wear and tear.

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