International Journal of Computer Sciences and Engineering Open Access
Research Paper Volume-4, Special Issue-6, Aug 2016 E-ISSN: 2347-2693

Performance Comparison of Conventional PID and Fuzzy Logic Controller in the Field of over headed Water Level Control System

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Available online at: www.ijcseonline.org

Received: Jun/26/2016 Revised: July/16/2016 Accepted: July/26/2016 Published: Aug/12/2016

Abstract—Conventional control system adopts PID controller which cannot well adapt to non-linearity, parameter variation, disturbance and change of objective architecture. To strictly limit the overshoot, using fuzzy control we can achieve great control effect. By using fuzzy logic, designers can realize lower development costs, superior features, and better end product performance. The only reasons are faster and cheaper. The Fuzzy control is very much useful for controlling the tank level of the liquid. The purpose of this setup is to design a simulation system of fuzzy logic controller for liquid level control by using Fuzzy Logic Toolbox and MATLAB Simulink software. That's why in this paper, an attempt is made to compare the control effect due to fuzzy control and conventional PID control and by comparing we will see that fuzzy control is superior to PID control. Result shows that the fuzzy control gives more concentration to different parameters, such as the time of response, the steady state error and overshoot.

Keywords—Level transducers, Control loop, Control system, Process control, Conventional controller, Crisp set, Fuzzy set, Fuzzy logic controller

I. INTRODUCTION

Conventional Controllers are used in many industrial applications due to their simplicity and robustness. All the real systems provide non-linear in nature; conventional controllers are not always able to provide good and accurate results. Fuzzy Logic Control is used to obtain better response [1-7]. A model for simulation is designed and all the assumptions are made before the development of the model. An attempt has been made to analyze the efficiency of a fuzzy controller over a conventional PID controller for a water level control system using fuzzification and defuzzification methods and their responses are compared [8-9]. Analysis is done through computer simulation using Matlab/Simulink toolbox. The present work indicates that the application of fuzzy logic controller (FLC) gives the best response with triangular membership function and centroid defuzzification method over conventional PID controller [10-12]. Considering final results, the comparison of the results in this paper and published literature illustrates that fuzzy logic controller results are considerably remarkable as compared to the others. The calculated maximum overshoot for fuzzy logic controller in comparison with the measured value for the conventional PID controller is minimised efficiently [13-14]. Besides, the settling times for both PID and fuzzy logic controllers are measured and it indicates that the efficiency of fuzzy logic controller is completely reliable than the others which signifies the dominance of fuzzy logic controller [15-16]. This paper is organized as follows. The material and methods for the over headed water level control system is described in section II. In Section III, design methodology is described. Simulation results and its analysis are discussed in section IV and conclusion is given in section V.

II. MATERIALS AND METHODS

A. Conventional PID controller

Conventional controller is one of the most popular controllers which are widely used in industrial control system. The difference between a measuring signal and the command signal or set point value defined as the error which is calculated by the controller. Conventional controllers are simple, easy to understand and implement in hardware and software, and do not require a process model for initialization or operation. Due to presence of non linearity in the system, conventional PID controller is not very efficient. In PID controller, three main parameters are the proportional (P), integral (I) and derivative (D) control action whose values are interpreted in terms of time, where, 'P' depends on the present error; 'I' on the accumulation of past errors and 'D' is a prediction of future errors, based on current rate of change. The basic block diagram of traditional PID controller is shown in Fig. 1. By tuning the three parameters of the PID controller, the controller can able to provide control action designed for specific process

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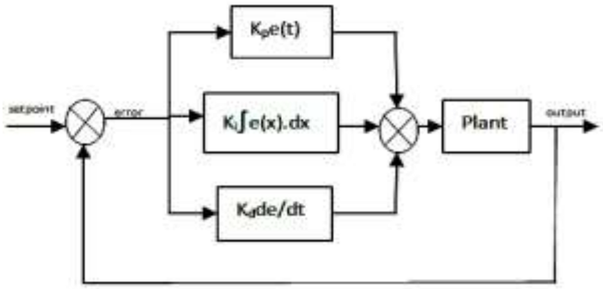

Fig. 1: Block diagram of conventional PID controller.

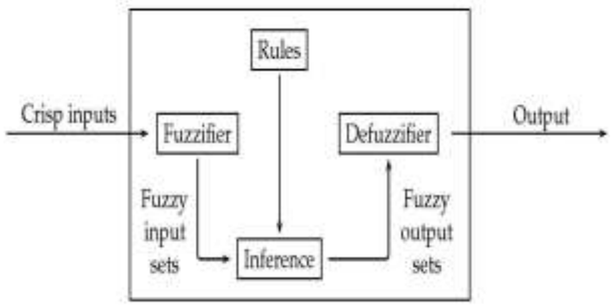

Fig. 2: Basic Configuration of FLC system.

requirements. The values of the above said parameters are chosen according to Ziegler-Nichols Continuous Cycling Tuning method.

To calculate the output of the PID controller, the proportional, integral and derivative terms are summed. The final output equation in time domain is defined given by

$$u(t) = K_p e(t) + K_i \int e(t)dt + K_d \frac{de(t)}{dt} \quad (1)$$

Where, K_P is the Proportional gain, a tuning parameter, K_i is the Integral gain, a tuning parameter, K_d is the derivative gain, a tuning parameter, e is an error present in the controller, t is the instantaneous time and x is the variable of integration, taken from time 0 to present 1.

B. Fuzzy Logic Controller

Fuzzy logic concept was put forward by Loti. A. Zadeh, a professor at the University of California at Berkley. Fuzzy logic is a multi-valued logic that gives intermediate values to be defamed between conventional evaluations like true/false, yes/no, high/low etc. Fuzzy Logic Controller's (FLC) are used in various industrial processes for taking proper actions like human control actions. Its simplicity makes it a better choice over other traditional control techniques. Fuzzy Logic Controllers consists of a number of parameters that need to be selected and configured prior, such as the selection of scaling factors, configurations of the center and width of the membership functions (MF) and so on. The basic block diagram of fuzzy logic controller is presented in Fig. 2.

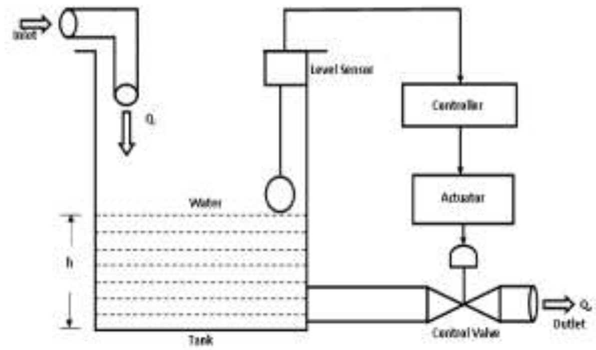

Fig. 3: Schematic diagram of over headed water level control system.

Fuzzy logic control is derived from fuzzy set theory where, the transition lies between membership and non-membership can be graded. Therefore, boundaries of fuzzy sets can be indistinct and ambiguous, making it helpful for approximate systems. Fuzzy Logic Controller (FLC) is an alternative choice when specific mathematical formulations are not possible. Other advantages are

- It needs less data storage in the form of membership functions and rules than conventional look up table for nonlinear controllers.
- It is more robust than other non-linear controllers.

The fuzzy logic controller is mainly composed of three principal elements. These are Fuzzification module (Fuzzifier), Rule base & Inference engine and Defuzzification module (Defuzzifier).

III. DESIGN METHODOLOGY

Consider a generic water level control application shown in Fig. 3. The water enters from the reservoir through pipe to top of the tank where water level is maintained or controlled. The water level is monitored by float type Level sensor-cum transmitter giving 4-20 mA DC output which is proportional to the water level (0-3m). This 4-20 mA DC output is fed to the PID controller and fuzzy logic controller (FLC). The controller processes the process variable input with respect to the set point and giving corrective output to be feed to the electrically operated linear control valve (FCE) located on outlet of the flow line to control the desired level as per the set point generated from controller.

A. PID Controller Design

A first order system is taken into consideration and a PID controller is designed for the following system by MATLAB Simulink using different icon blocks which are shown in Fig. 4.The above system is executed using both the traditional PID controller and

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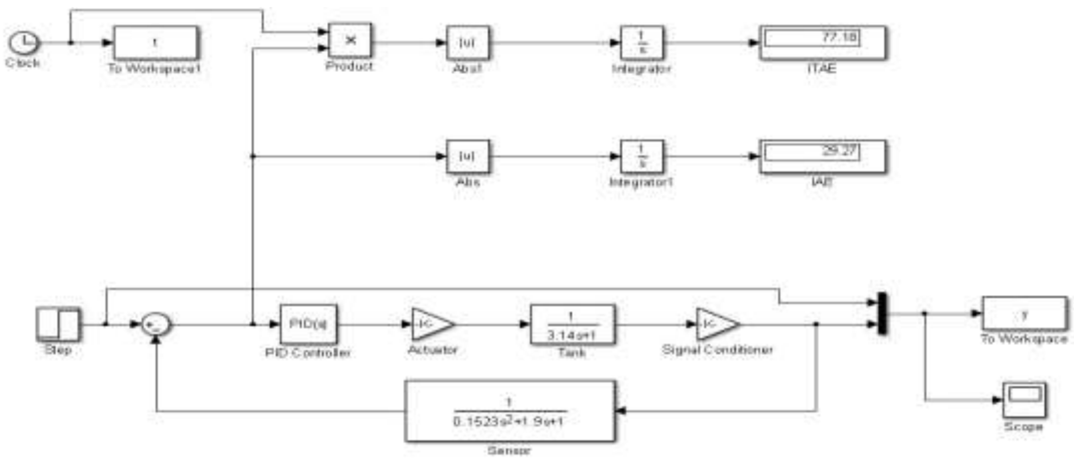

Fig. 4: Model of PID Controller by using MATLAB Simulink.

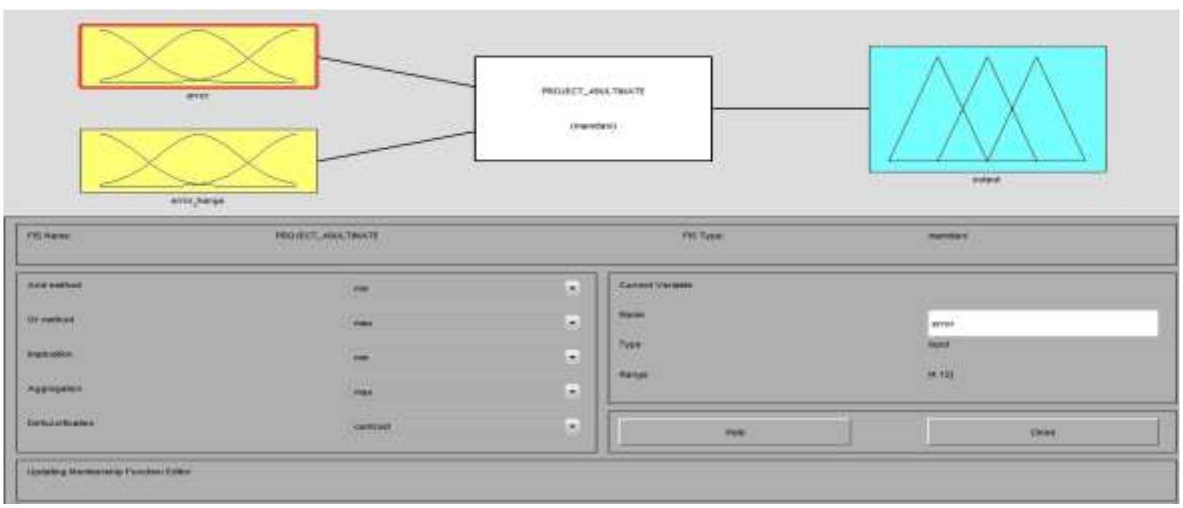

Fig. 5: Mamdani type Fuzzy Controller.

the Fuzzy Logic Controller. The Ziegler Nichols technique is used for designing the parameters for the tuning of PID controller. Thus the parameters values are taken from the assumed transfer function of the control loop are K_p= 148.56, K_i= 28.015 and K_d= 6.24. The parameters are further tuned using the MATLAB Simulink software to get a better response.

B. Fuzzy Rule Development

The Fuzzy Logic control action involves fuzzification, fuzzy inference and de-fuzzification. But the most important factor is the rule set. They define the accuracy with which the control actions will take place. There can be as many number of rule sets as possible. The rule base decides the accuracy of the Fuzzy controller and as many number of rule base as possible is taken. In this paper we try to implement the controller action with a 49 rule sets with the help of 7 membership functions which is shown in Table I. The main input of the Fuzzy controller includes the error and the derivative error.

Mamdani model of Fuzzy Logic Controller is illustrated in Fig. 5. The MF's are defined depending on the range in which the controller has to function. Using the Fuzzy Logic Toolbox in the MATLAB Simulink the required parameters

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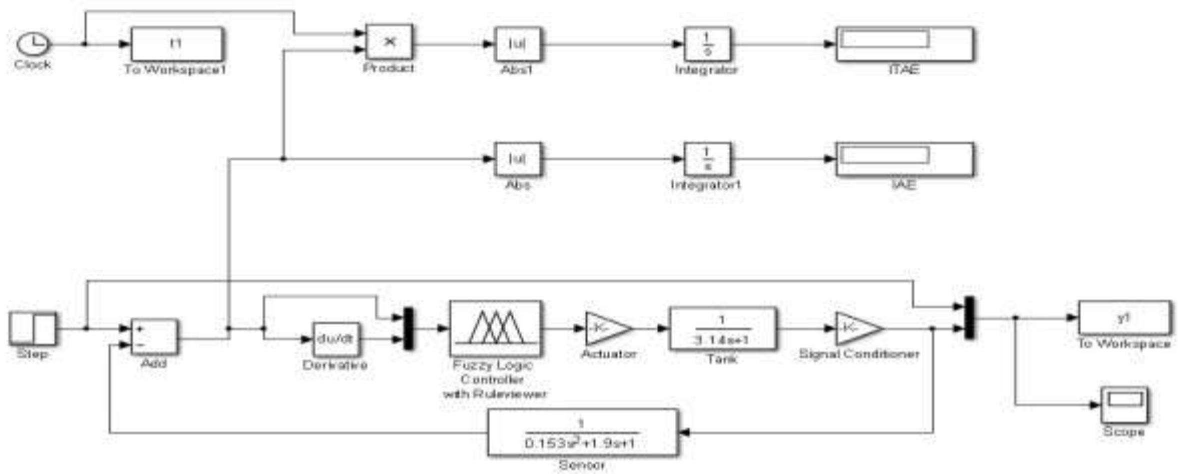

Fig. 6: Model of FLC Block by using MATLAB Simulink.

are defined for the membership functions. Fig. 6 shows the model of the setup controlling by fuzzy logic controller with the help of MATLAB Simulink software.

Table I: Rule-base design for FLC

EC=Change of Error, E=Error, U=output, NB=negative beep, NM=negative medium, NS= negative small, ZO= zero, PS=positive small, PM=positive medium, PB=positive beep.

EC | E / U	NB	NM	NS	ZO	PS	PM	PB
NB	PB	PB	PB	PB	PM	PS	ZO
NM	PB	PB	PM	PM	PS	ZO	NS
NS	PB	PB	PM	PS	ZO	NM	NM
ZO	PB	PM	PS	ZO	NS	NM	NB
PS	PM	PM	ZO	NS	NM	NB	NB
PM	PS	ZO	NS	NM	NM	NB	NB
PB	ZO	NS	NM	NB	NB	NB	NB

IV. Simulation Results And Analysis

In order to obtain the desired control action by fuzzy controller it is essential to choose the appropriate functioning range for error, rate of change of error and the output range as well. The zero error range is set relative to the values of the positive and negative error ranges of all the membership functions.

The fuzzy logic controller is also modeled with the above said set-point, i.e. 12 mA. For the modeling of fuzzy logic controller, the rules discussed before are used. They are: fuzzification, rule base design and defuzzification.

A. Fuzzification

The analog values are converted to fuzzy values using this method so that the fuzzy logic controller can work with it. A particular range of inputs with suitable membership functions are chosen for modeling. Here we have used triangular membership functions because of their shape and easy to represent and they also have low computation time.

Fig. 7: Rule viewer of FLC.

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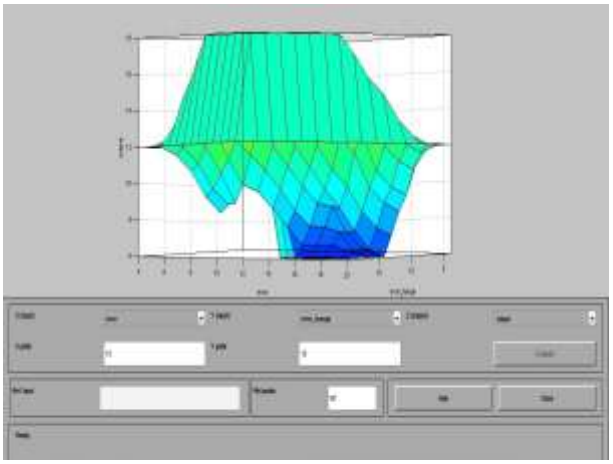

Fig. 8: Surface viewer of FLC.

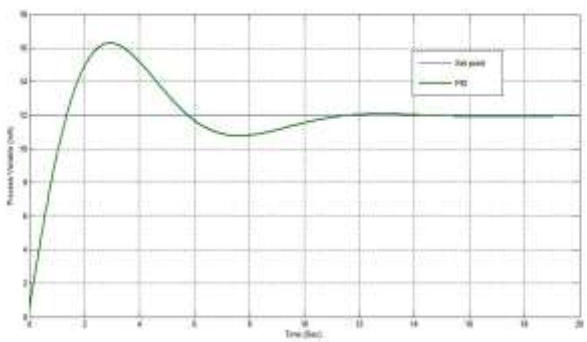

Fig. 9: Step Response of PID Controller.

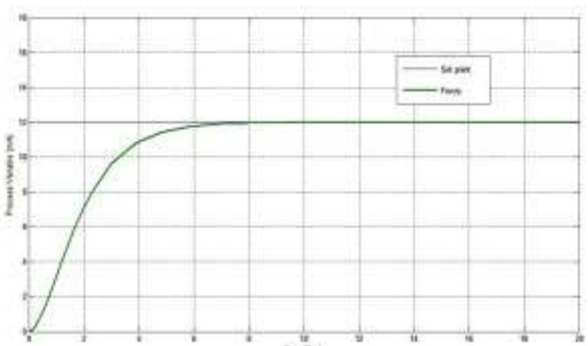

Fig. 10: Step Response with FLC.

B. *Rule Base Viewer*

It is composed of IF-THEN-clause and mentions the conditions required for control purpose. It is the brain of the fuzzy logic controller which is shown in Fig. 7 and 8 as the rule base viewer and the surface viewer respectively.

Fig. 9 shows the output response for the system using the PID controller with a set point 12 mA where as Fig. 10 represents the output to the same system using FLC for the same set point. For better understanding, the output response using both PID and FLC in same plot with respect to set point is shown in Fig. 11.

In this paper we have considered state and transient state parameters. The comparison of these parameters for conventional PID controller and fuzzy logic controller is shown in Table II. From Table III the comparison of Integral Absolute Error (IAE) and Integral of Time and Absolute Error (ITAE) for PID controller and fuzzy logic controller has been observed. Thus, in both the cases we see that the response of fuzzy logic controller is far better than conventional PID controller.

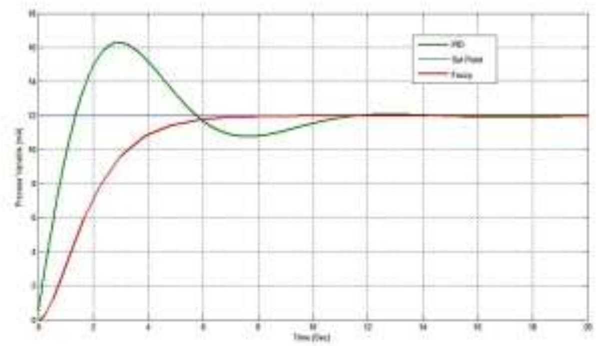

Fig. 11: Comparison between Step Response Conventional PID controller and FLC with same Set point.

Table II
Transient analysis of PID controller and FLC:

Controller	**Rise Time**(sec)	**Settling Time** (sec)	**% Overshoot**
Conventional PID Controller	0.74	10.64	35.67
Fuzzy Logic Controller	2.14	5.98	0

Table III
Comparison of IAE and ITAE for PID and FLC:

Controller	**IAE**	**ITAE**
Conventional PID controller	29.27	77.18
Fuzzy Logic Controller	14.49	31.80

V. CONCLUSION

This paper gives a performance comparison about the conventional PID controller and Fuzzy Logic Controller (FLC). The simulation is done with the help of MATLAB-SIMULINK software. The system is designed using the Ziegler Nichols Technique and later fine tuned using the software. Besides that, this system will be also tested by using different types of methods and membership functions. The purpose is to find the best way to get the result as close as the requirement for constancy of the level control for the tank of the water. The Fuzzy Logic Controller provides the accurate control of the water level in any industrial application.

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