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Performance Evaluation of Fuzzy Logic and PID Controller for Liquid Level Process

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Abstract: The objective of this paper is to investigate and find a solution by designing the PID and FUZZY Controllers for liquid level process. Measuring the level of liquids is a critical need in many industrial plants. Fuzzy control is based on fuzzy logic-a logical system that is much closer in spirit to human thinking and natural language than traitional logical systems. During the past several years, fuzzy control has emerged as one of the most active and fruitful areas for research in the applications of fuzzy set theory, especially in the realm of industrial processes, which do not lend themselves to control by conventional methods because of a lack of quantitative data regarding the input-output relations. The fuzzy logic controller (FLC) based on fuzzy logic provides a means of converting a linguistic control strategy based on expert knowledge into an automatic control strategy. Fuzzy Logic controller has better stability, small overshoot, and fast response. In this Paper, performance analysis of the PID controller and fuzzy logic controller has been done by the use of Matlab and Simulink and in the end comparison of various time domain parameters is done to prove that the fuzzy logic controller has small overshoot and fast response as compared to PID controller.

Keywords: Level Control, PID Control, Fuzzy Logic Control, Simulink.

I. INTRODUCTION

Traditionally, accurate mathematical model-based strategies have been applied to deal with control problems. However, liquid level control system is very complex system, because of the nonlinearities and uncertainties of a system. Fuzzy logic and PID control have emerged over the years and become one of the most active and fruitful areas of the research in the intelligent control applications. There are two major different types of the control rules in fuzzy control: the Mamdani type and the Sugeno type[1].The Mamdani control rules are significantly more linguistically intuitive while Sugeno rules appear to have more interpolation power even for a relative small number of control rules. PID controller is used when dealing with higher order capacitive processes (processes with more than one energy storage) when their dynamic is not similar to the dynamics of an integrator (like in many thermal processes) [2]. PID controller is often used in industry, but also in the control of mobile objects (course and trajectory following included) when stability and precise reference following are required. Conventional autopilot is for the most part PID type controllers [3].

II. PID CONTROLLER

PID tuning is a difficult problem, even though there are only three parameters and in principle is simple to describe, because it must satisfy complex criteria within the limitations of PID control [4]. There are accordingly various methods for loop tuning, some of them:

- Manual tuning method
- Ziegler–Nichols tuning method
- PID tuning software methods.

Ziegler–Nichols tuning method: This method was introduced by John G. Ziegler and Nathaniel B. Nichols in the 1940s. The Ziegler-Nichols' closed loop method is based on experiments executed on an established control loop (a real system or a simulated system) [5].
The tuning procedure is as follows:

I. Bring the process to (or as close to as possible) the specified operating point of the control system to ensure that the controller during the tuning is "feeling" representative process dynamic and to minimize the chance that variables during the tuning reach limits. Process is brought to the operating point by manually adjusting the control variable, with the controller in manual mode, until the process variable is approximately equal to the set-point.

II. Turn the PID controller into a P controller by setting set $Ti = \infty$ and $Td = 0$. Initially, gain Kp is set to "0". Close the control loop by setting the controller in automatic mode [6].

III. Increase Kp until there are sustained oscillations in the signals in the control system, e.g. in the process measurement, after an excitation of the system. (The sustained oscillations correspond to the system being on the stability limit.) This Kp value is denoted the ultimate (or critical) gain, Kpu. The excitation can be a step in the set-point. This step must be small, for example 5% of the maximum set-point range, so that the process is not driven too far away from the operating point where the dynamic properties of the process may be different [7]. On the other hand, the step must not be too small, or it may be difficult to observe the oscillations due to the inevitable

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measurement noise. It is important that Kpu is found without the control signal being driven to any saturation limit (maximum or minimum value) during the oscillations [8]. If such limits are reached, there will be sustained oscillations for any (large) value of Kp, e.g. 1000000, and the resulting Kp-value is useless (the control system will probably be unstable). One way to say this is that Kpu must be the smallest Kp value that drives the control loop into sustained oscillations.

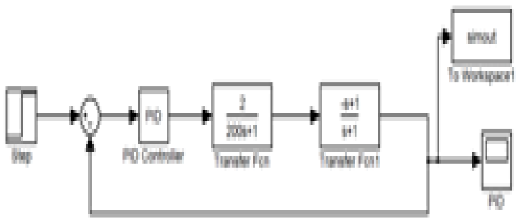
IV. Measure the ultimate (or critical) period Pu of the sustained oscillations [9].

V. Calculate the controller parameter values according to Table 1, and these parameter values are used in the controller. If the stability of the control loop is poor, stability is improved by decreasing Kp, for example a 20% decrease.

TABLE 1

Control Type	Kp	Ki	Kd
P	0.5*Ku	-	-
PI	0.45*Ku	1.2*Kp/Tu	-
PID	0.6*Ku	2*Kp/Tu	Kp*Tu/8

For our Transfer function $G(s)= 2*e^{(-2s+1)}/(200s+1)$, the matlab simulink diagram is as follows: Simulation of PID Controller : *Figure1*



III. FUZZY LOGIC CONTROLLER

The Fuzzy Logic tool was introduced by Lotfi Zadeh (1965), and is a mathematical tool for dealing with uncertainty [10]. It offers to a soft computing partnership the important concept of computing with words. It provides a technique to deal with imprecision. The fuzzy theory provides a mechanism for representing linguistic constructs such as “many,” “low,” “medium,” “often,” “few.” In general, the fuzzy logic provides an inference structure that enables appropriate human reasoning capabilities. Fuzzy logic systems are suitable for approximate reasoning. Fuzzy logic systems have faster and smoother response than conventional systems and control complexity is less. Fuzzy sets form the building blocks for fuzzy IF–THEN rules which have the general form “IF X is A THEN Y is B,” where A and B are fuzzy sets. The term “fuzzy systems” refers mostly to systems that are governed by fuzzy IF–THEN rules. The IF part of an implication is called the antecedent whereas the second, THEN part is a consequent. A fuzzy system is a set of fuzzy rules that converts inputs to outputs. The basic configuration of a pure fuzzy system is shown in Fig. 1.4. The fuzzy inference engine (algorithm) combines fuzzy IF–THEN rules into a mapping from fuzzy sets in the input space X to fuzzy sets in the output space Y based on fuzzy logic principles. From a knowledge representation viewpoint, a fuzzy IF–THEN rule is a scheme for capturing knowledge that involves imprecision. The main feature of reasoning using these rules is its partial matching capability, which enables an inference to be made from a fuzzy rule even when the rule’s condition is only partially satisfied [11].

Building a Fuzzy Inference System: Fuzzy inference is a method that interprets the values in the input vector and, based on user-defined rules, assigns values to the output vector. Using the GUI editors and viewers in the Fuzzy Logic Toolbox, you can build the rules set, define the membership functions, and analyze the behavior of a fuzzy inference system (FIS) [12]. The following editors and viewers are provided:

FIS Editor- Displays general information about a fuzzy inference system.

Membership Function Editor- Lets you display and edit the membership functions associated with the input and output variables of the FIS.

Rule Editor- Lets you view and edit fuzzy rules using one of three formats: full English-like syntax, concise symbolic notation or an indexed notation.

Rule Viewer- Lets you view detailed behaviour of a FIS to help diagnose the behaviour of specific rules or study the effect of changing input variables.

Surface Viewer- Generates a 3-D surface from two input variables and the output of an FIS [13].

FIGURE 1: FIS Editor, Membership Function Editor

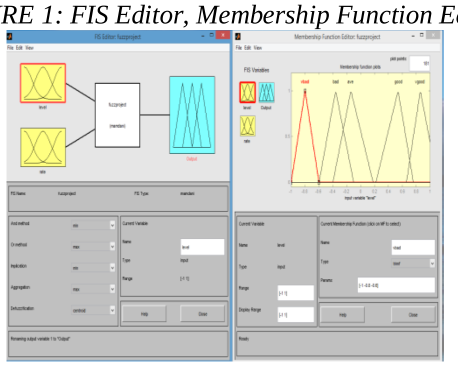
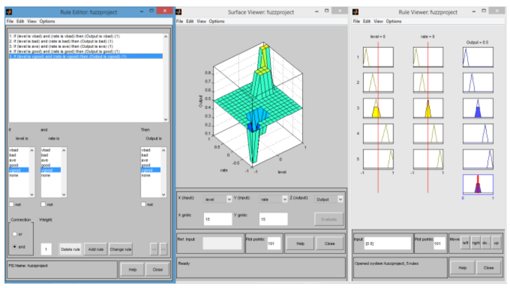


FIGURE 2: Rule Editor, Rule Viewer, Surface Viewer



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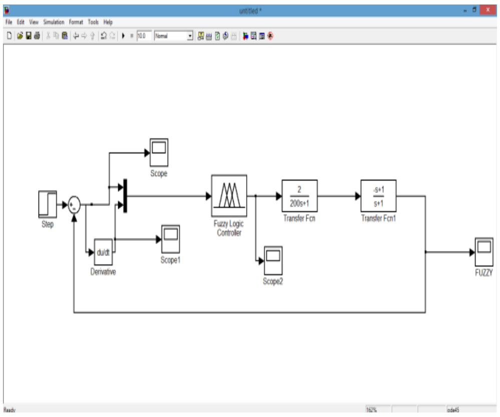
For our Transfer function **G(s)=2*e$^{(-2s+1)}$/(200s+1),** the matlab simulink diagram is as follows:

Simulation Block of Fuzzy Controller

FIGURE 3



Fuzzy Logic Controller Are Better Than Conventional Controllers. WHY?

Fuzzy control has emerged one of the most active and fruitful areas of research especially in industrial processes which do not rely upon the conventional methods because of lack of quantitative data regarding the input and output relations. Fuzzy control is based on fuzzy logic, a logical system which is much closer to human thinking and natural language than traditional logical systems. Fuzzy logic controller (FLC) based on fuzzy logic provides a means of converting a linguistic control strategy based on expert knowledge into an automatic control strategy. Fuzzification, defuzzification strategies and fuzzy control rules are used in fuzzy reasoning mechanism.

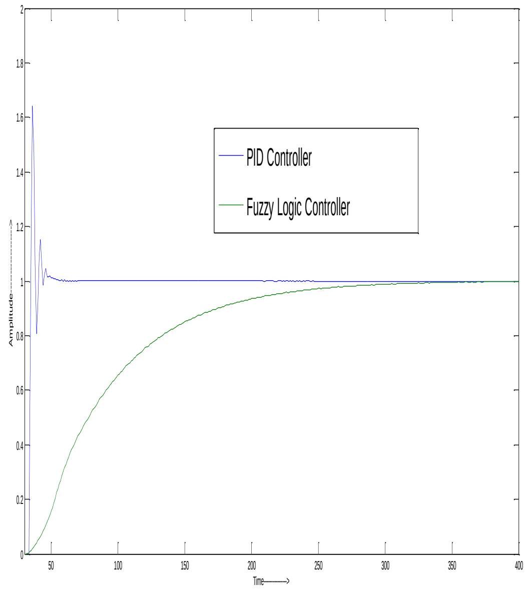
Fahid et al. [4] concluded that Proportional integrated Derivative (PID) controllers are widely used in process control applications, but they exhibit the poor performance when applied to systems, which are nonlinear, as controller tuning is difficult due to insufficient knowledge of the parameters of the system. Fluid level system is a typical example. Neuro fuzzy controller gave a better performance compared to the PID controller. It gives better performance with reduced oscillations and faster settling time [5]. The controller performance can still be improved by training the neural network with more number of input and output combinations.

Elangeshwaran et al. Overall, fuzzy logic controller is a good alternative to a PID controller, for level measurement and control applications. From all the above discussions we can conclude that Fuzzy Logic controller has better stability, small overshoot, and fast response.

Overall, fuzzy logic controller is a good alternative to a PID controller, for level measurement and control applications. From all the above discussions we can conclude that Fuzzy Logic controller has better stability, small overshoot, and fast response.

IV. SIMULINK RESULTS

The simulink results of the PID controller and the Fuzzy Logic Controller is shown in the below graph.



GRAPH 1: This graph is plotted b/t amplitude and time using Fuzzy shows step response

Comparing various time domain specifications:

TABLE 2

S.No	Controller → Specifications ↓	**PID CONTROLLER**	**Fuzzy Logic Controller**
1	Peak Overshoot(Mp)	1.6407	0
2	IAE	58.767	$1.369e^{004}$
3	ISE	38.1071	$1.25e^{005}$
4	ITAE	$1.8954e^{006}$	$1.017e^{007}$

V. SIMULATION RESULTS:

The Figure 10, 11 shows the formation of response of the system when using PID & Fuzzy Logic controllers respectively. Fuzzy logic controller is used in this process because of following reasons:

- It can work with less precise inputs.
- It doesn't need fast processors.
- It is more robust than other non-linear controllers.
- Fuzzy controllers have better stability, small overshoot, and fast response.

After comparing the graphs of conventional PID and fuzzy logic controller as shown in figure10, 11 it is clear that fuzzy logic has small overshoot and is having the fast response as compared to conventional PID Controller. Then, various time domain specifications of both the controllers are compared such as:

- Rise Time(Tr) and Delay Time (Td),
- Settling Time (Ts
- Peak Overshoot (Mp)
- Steady State Error (Ess)
- Transient Behavior

VI. CONCLUSION

Overall the project's feasibility lies in the simplicity of its implementation. The advantages of a fuzzy based controller over a PID controller are derived from results. Better control performance, robustness and overall stability can be expected from the fuzzy controller. Fuzzy controllers have better stability, small overshoot, and fast response. From the results the following parameters can be observed. Hence, fuzzy logic controller is introduced for controlling fluid levels.

1) Even though, the PID controller produces the response with lower delay time and rise time compared with fuzzy logic controller, but it offers very high settling time due to the oscillatory behavior in transient period. It has severe oscillations with a very high peak overshoot of 16% which causes the damage in the system performance.
2) The proposed Fuzzy logic controller can effectively eliminate these dangerous oscillations and provides smooth operation in transient period. Hence, it is concluded that the PID controller could not be used for the control of non-linear processes like fluid levels. So, the proposed fuzzy logic based controller design can be a preferable choice for this.

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