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Designing of Fuzzy Logic Controller for Set-Point Weight Tuning of Pid Controllers

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Abstract

In this paper, a novel methodology, based on fuzzy logic, for the tuning of proportional-integral-derivative (PID) controllers is presented. The purpose of this project tries to explore the potential of using soft computing methodology in controllers and their advantages over conventional methods. In control system there are a number of general systems and methods which are encountered in all areas of industry and technology. There are many ways to control any system, in which fuzzy is often the very best way. The only reason is faster and cheaper. For this paper, the set-point tuning was controlled by using three rules of membership function which then extended to five rules, seven rules and nine rules for verification purpose and further improvement of the system. There are various systems for the designing of PID controller and it is used to control the different parameters like settling time, rise time, overshoot, peak gain and phase margin, stability etc of the plant. Hence both the overshoot and the rise time in set-point following can be reduced. The conventional PID controller is not very efficient due to the presence of non linearity in the system of the plant and also it has a quite high overshoot and settling time. The main focus of this project is to apply soft computing technique that is fuzzy logic to design and tuning of PID controller to get better dynamic and static performance at the output. This project also discusses the benefits the soft computing methods.

Keywords - PID controller, Fuzzy logic controller

I. INTRODUCTION

A. Conventional PID Controller

Proportional- integral- derivative controllers have been used for industrial purpose due to their effortlessness, easy designing method, low cost and effectiveness. These are the most widely used type of controller for industrial applications. They are structurally simple and exhibit robust performance over a wide range of operating conditions. Due to presence of non linearity in this method, conventional PID controller is not very efficient. Proportional (P), integral (I) and derivative (D) are the three main parameters of the PID controller. The values of these three parameters interpreted in terms of time, where P indicate the present error, 'I' on the accumulation of past errors and 'D' is a prediction of upcoming errors, based on current rate of change. By regulation the three parameter in the algorithm of PID controller, the controller can offer control action designed for specific process requirements. The proportional, integral and derivative terms are summed to calculate the output of the PID controller. The final output defined by u (t) and it given by

$$u(\mathrm{t}) = K_P e(t) + K_d \frac{\mathrm{de(t)}}{\mathrm{dt}} + K_i \int_0^t e(x)\,\mathrm{dx} \quad (1)$$

Where

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K_P - Proportional gain, a tuning parameter
K_i - Integral gain, a tuning parameter
K_d - Derivative gain, a tuning parameter
e - Error present in the controller
t - Time or instantaneous time
x - Variable of integration, taken from time 0 to 1

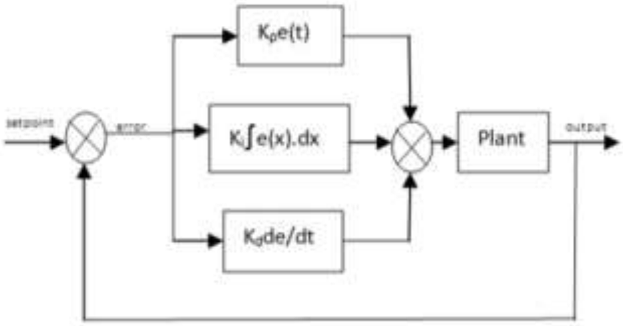

Figure 1. Block Diagram of Conventional PID Controller

B. Fuzzy Logic Controller

Fuzzy logic is a superset of conventional logic that has been extended to handle the concepts of 'completely true' and 'completely false' values. As its name suggests, it is the logic underlying modes of reasoning which are approximate rather than exact. The significance of Fuzzy logic derive from the fact that most modes of human reasoning and especially common sense reasoning are suitable in nature. Fuzzy logic have many values. Here these suitable values are not fixed time traditional binary sets. So, it is having a truth value that ranges in degree between 0 and 1. Hence this type of logic method is able to address the values of variables those lie between completely truths and completely false. The variables are called the linguistic variables and each linguistic variable is described by a membership function which gives the probable decision making is an important part of the fuzzy logic. The decision making is mainly the combination of concepts of fuzzy set assumption, fuzzy IF-THEN rules and fuzzy reasoning. The fuzzy structure make use of if then statement and with the help of connecters (such as AND gate) necessary rules are constructed.

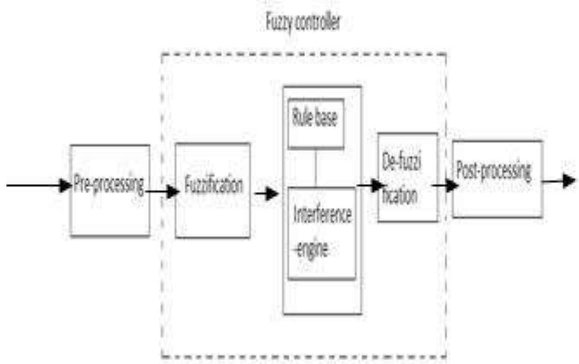

Figure 2:- Process Blocks for a Fuzzy Controller

The fuzzy logic controller (FLC) has been proposed to get better performance in conventional PID controller and for the purpose of fuzzification and defuzzification the Mamdani fuzzy system and mean of maximum methods are used respectively. The ideas of fuzzy set and fuzzy control are introduced by Zadeh. Fuzzy logic controllers are applied to many systems with linearity and uncertainty. The structure of fuzzy system can be classified according to the different application. One of the main popular type is the error feedback fuzzy logic controller, which is called fuzzy logic controller (FLC). In conventional FLC, there are also PD-type fuzzy logic controller, PI-type fuzzy logic controller and PID-type fuzzy logic controller.

C. Principle of FLC

The FLC having the following stages
- Fuzzification
- Fuzzy Inference
- Rule base
- Defuzzification

i. Fuzzification

The process of converting a numerical variable (real number or crisp variables) into a linguistic variable(fuzzy number) is called Fuzzification. In another it manner it means the assigning of linguistic value, defined by relative small number of membership functions to variable.

ii. Fuzzy Inference

Under inference, the truth value for the premise of each rule is computed, and applied to the conclusion part of each rule. This results in one fuzzy subset to be assigned to each output variable for each rule. Mostly MIN or PRODUCT is used as inference rules. The output membership function in MIN inference is clipped off at a height corresponding to the rule premise's computed degree of truth (fuzzy logic AND). In PRODUCT inference, the output membership function is scaled by the rule premise's computed degree of truth.

iii. Rule Base

For the rule bases a classic interpretation of Mamdani was used. Under rule base, rules are constructed for outputs. The rules are in “If Then” format and formally the If side is called the conditions and the Then side is called the conclusion. A rule base controller is easy to understand and easy to maintain for a non- specialist end user and an equivalent controller could be implemented using conventional techniques.

iv. Defuzzification

Defuzzification is a process in which crisp output is obtained by the fuzzy output. In other words, process of converting fuzzy output to crisp number. There is more Defuzzification methods in which two of the more common Techniques are the CENTROID and MAXIMUM methods. In the CENTROID method, the crisp value of the output variable is computed by finding the variable value of the centre of gravity of the membership function for the fuzzy Value. In the MAXIMUM method, one of the variable values at which the fuzzy subset has its maximum truth value is chosen as crisp value for the output variable [1].

II. DESIGNING OF FUZZY LOGIC CONTROLLER

A. FIS Editor

In this paper, presents a methodology for rule base fuzzy logic controller applied to a system. The Fuzzy Logic Controller is to be designed, Before running the simulation in MATLAB/SIMULINK. It is done using the FIS editor. Using the Fuzzy logic toolbox, FIS file is created. To design of a Fuzzy Logic Controller, it requires the choice of Membership Functions. After the appropriate membership functions are chosen, a rule base is created. In a fuzzy Controller, the set of linguistic rules is the most essential part. The various linguistic variables to design rule base for output of the fuzzy logic controller are enlisted in Table I. Using in MATLAB/SIMULINK The response of the fuzzy logic controller is obtained. A two input which is Speed Error (e) & Change in Error (ec) and one – output Change in control, fuzzy controller is created and the membership functions and fuzzy rules are determined.

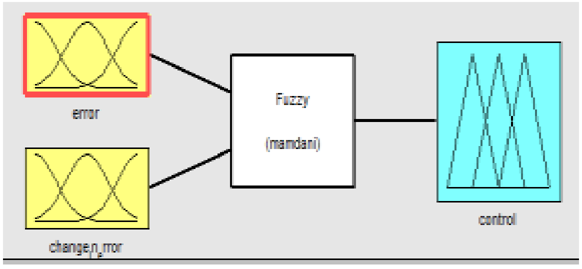

Figure 3. Mamdani Type Fuzzy Controller

B. Membership Function Editor

The Membership Function Editor shares some features with the FIS Editor. In fact, all of the five basic graphical user interface tools have similar menu options. The MF Editor is the tool that let you display and edits all of the membership functions associated with all of the input and output variables for the entire fuzzy inference system [2-3]. When you open the Membership Function Editor to work on a fuzzy inference system that does not already exist in the workspace, there is not yet any membership functions associated with the variables that you have just defined with the FIS Editor.

a) Fuzzy Set Characterizing Input

i. Error [Range (0 to 1)]

TABLE I. CRISP RANGE TABLE FOR ERROR

Fuzzy Variable	MF Used	Crisp Input Range
Error low (el)	Triangular MF	[0 0.04 0.08]
Error Medium (em)	Triangular MF	[0.06 0.1 0.14]
Error High (eh)	Triangular MF	[0.12 0.16 0.2]

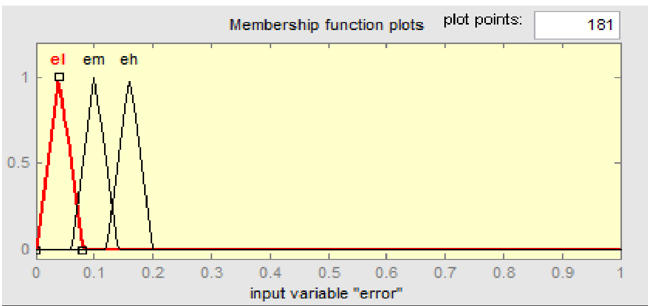

Figure 4. Membership Function Fuzzy Set Characterize Input

ii. Change in Error [Range (0 to 1)]

TABLE II. CRISP RANGE TABLE FOR CHANGE IN ERROR

Fuzzy Variable	MF Used	Crisp Input Range
Output Low (ol)	Triangular MF	[0 0.15 0.3]
Output Medium (om)	Triangular MF	[0.2 0.4 0.6]
Output High (oh)	Triangular MF	[0.5 0.65 0.8]

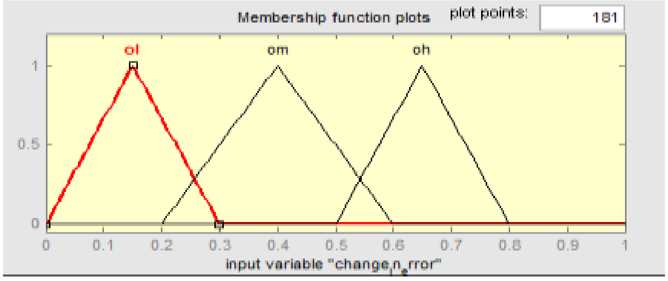

Figure 5. Membership Function Fuzzy Set Characterize Output

b) Fuzzy Set Characterizing Output

Use triangular membership function types for the output. First, set the Range (and the Display Range) to (0 1), to cover the output range. Initially, the negative membership function will have the parameters [0 0.15 0.3], the zero membership function will be [0.203 0.403 .603], for the positive membership function will be [0.5 0.65 0.8].

i. Control [(Range (0 to 1)]

TABLE III. CRISP RANGE TABLE FOR CONTROL

Fuzzy Variable	MF Used	Crisp Input Range
Error Change Low (ecl)	Triangular MF	[0 0.15 0.3]
Error Change medium (ecm)	Triangular MF	[0.203 0.403 .603]
Error Change High (ech)	Triangular MF	[0.5 0.65 0.8]

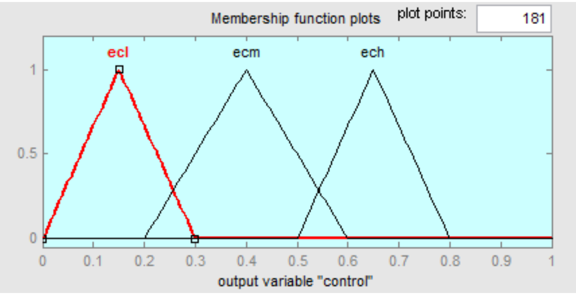

Figure 6. Triangular Membership Function Output

C. Rule Editor

Constructing rules using the graphical Rule Editor interface is fairly self-evident. Based on the input and output variables defined with the FIS Editor, the Rule Editor allows you to create the rule statements automatically [4].

1. If (error is el) and (change in error is ol) then (control is ecl) (1).
2. If (error is el) and (change in error is om) then (control is ecm) (1).
3. If (error is el) and (change in error is om) then (control is ech) (1).
4. If (error is em) and (change in error is om) then (control is ecm) (1).
5. If (error is em) and (change in error is ol) then (control is ecl) (1).
6. If (error is em) and (change in error is oh) then (control is ech) (1).
7. If (error is eh) and (change in error is om) then (control is ecl) (1).

8. If (error is eh) and (change in error is om) then (control is ecm) (1).
9. If (error is eh) and (change in error is oh) then (control is ech) (1).

III. SIMULATION BLOCK DIAGRAM

A. Simulation Model of PID Controller

Simulation model of Conventional PID Controller for set point tuning control as shown in Figure 7.

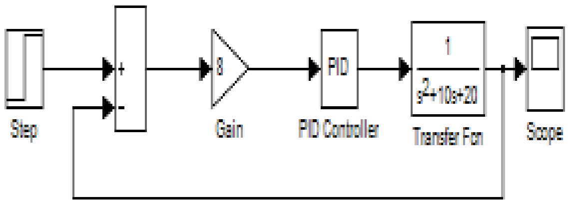

Figure 7. Simulation Model by using PID Controller

B. Simulation Model of Fuzzy Logic Controller

A simulation model of Fuzzy Logic Controller for set point tuning control as shown in Figure 8.

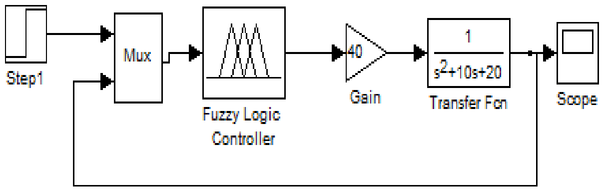

Figure 8. Simulation Model by using Fuzzy Logic Controller

IV. SIMULATION RESULTS & DISCUSSION

A. Simulation Result of PID Controller

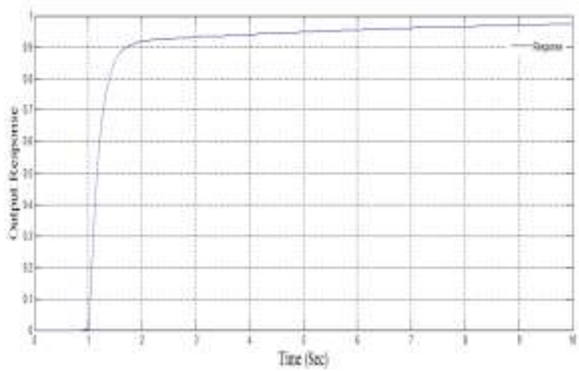

Figure 9. Simulation Result using PID Controller

From Figure 9 it is seen that PID controllers drives the system unstable due to mismatch error generated by the inaccurate time delay parameter used. Steady state error & overshoot are present when PID controller is used to control the set point tuning.

B. Simulation Result of Fuzzy Logic Controller

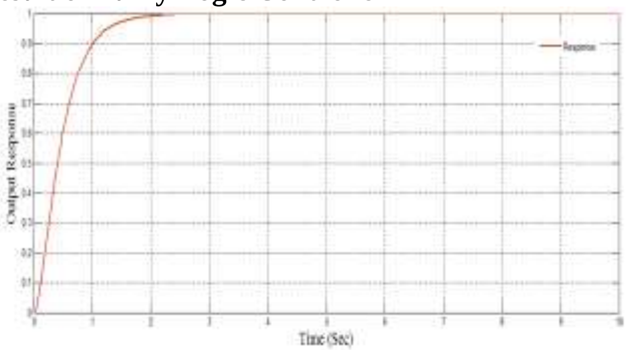

Figure 10. Simulation Result using Fuzzy Logic Controller

From figure 10 Fuzzy Logic Controller provide good performance in terms of oscillations and overshoot in the absence of a prediction mechanism. The FLC algorithm adapts rapidly to longer time delays and provides a stable Response.

C. Discussion

From Figure 9 it is seen that PID controllers drives the system unstable due to mismatch error generated by the inaccurate time delay parameter used. Steady state error & overshoots are present when PID controller is used to control the set point tuning. The Fuzzy Logic Controller is applied to described above in figure 8. Fuzzy Logic Controller simulation results are plotted against with that of conventional controller PID controller for comparison purposes. The simulation results are obtained using a 9 Fuzzy Logic Controller rules.

From the simulations, in the presence of unknown or possibly varying time delay, the proposed Fuzzy Logic Controller shows a significant improvement in maintaining performance and preserving stability over standard PID method. To strictly limit the overshoot, using Fuzzy Controller can achieve a great control effect. Especially it can give more attention to various parameters, such as the response time, the error of steadying and overshoot. Comparison of these two systems indicated that the fuzzy logic controller significantly reduced overshoot and steady state error. Comparison results of PID and FLC are shown in Table IV. The overall performance may be summarized as

TABLE IV. COMPARISON TABLE OF PID & FLC

Parameters	PID Controller	Fuzzy Logic Controller
Overshoot	Present	Not Present
Settling Time	More	Less
Rise Time	Less	More
Steady State Error	Present	Not Present

V. CONCLUSION

In this paper, two different methods regarding the tuning at conventional PID and fuzzy logic controller has been described. Ziegler Nichols method is used for fine-tuning of conventional PID controller. But this method is not suitable for many systems. This method gives the approximate value of any response not the appropriate or exact value and it is having one more disadvantage that the rise time and settling time will be more .For better performance to reduce the settling and rise time for getting better response. To get the better performance it is essential to reduce both the rise time and settling time simultaneously and for this purpose Fuzzy logic technique can be used because it is a type of logic controller (FLC), which will successfully eliminate the whole overshoot from the output response. Alternatively settling time and rise time will be also reduced. The simulation results shows that compared to the traditional PID controller, fuzzy self-tuning PID controller has a better dynamic response curve, shorter response time, small overshoot, high steady precision, good static and dynamic performance. To get the better performance in PID controllers genetic algorithm can be used for further future expansion. In which the ideology of progression, natural selection and genetics from natural biological system in a computer algorithm to simulate evolution can be used.

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