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Position Control of Servo Motor Using Fuzzy Logic Controller

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ABSTRACT: The vast majority of the modern procedures utilize the ordinary PID controllers because of their straightforward and vigorous outline, reasonable cost, and viability for direct frameworks, however routine PID controllers are generally not powerful if the procedures included are higher request and time delay frameworks. For this, Fuzzy Logic controllers were showed up. On the off chance that we consolidate the two shrewd control frameworks, the issue will be determined. The use of FLC's to servo frameworks produces results better than traditional controllers. It is seen that, if there is an adjustment in framework parameters or burden unsettling influences, the reaction of framework because of corresponding necessary subsidiary (PID) controller is significantly influenced and PID controller needs retuning . Be that as it may, FLCs protect the wanted reaction over extensive variety of framework parameters and burden unsettling influences. A FLC more often than not gives preferable results over those of traditional controllers, as far as the reaction time, settling time and especially in strength. The goal of this paper is to analyze the time determination execution between routine controller and Fuzzy rationale controller in position control arrangement of a DC servomotor. This will incorporate configuration and improvement of a controller for position control utilizing Matlab/Simulink. The extent of this work is to apply two sorts of controller in particular PID and Fuzzy rationale controller. The product part incorporates programming ongoing programming utilizing Matlab/Simulink. At long last, the product will be incorporating with equipment for position control of servo framework.

KEYWORDS: PID, fuzzy logic, position control system, servomotor.

I. INTRODUCTION

Servomotors are broadly utilized as a part of numerous programmed frameworks, including drive for printers, recording devices, mechanical controllers, machine instruments, moving machines and so forth. Relative essential subordinate (PID) controllers ordinarily control these engines. Such controllers will be sufficiently compelling if the velocity and precision prerequisites of control frameworks are not basic under shifting situations of the frameworks. Additionally, the typical approach to upgrade the control activity is to tune the PID coefficients, yet this can't adapt to fluctuating control situations coming about because of burden unsettling influences, framework nonlinearities and change of plant parameters. The experience demonstrates that FLC yields better results than those got by ordinary control calculations [3], [4]. Additionally, FLC have, normal component of not requiring a nitty gritty numerical model and prompt much quicker and exact controllers for servo frameworks [5]. Fuzzy Logic Controllers depend on the Fuzzy set and Fuzzy rationale hypothesis initially upheld by Lotfi A. Zadeh. Because of its heuristic nature, Fuzzy rationale control is much closer in soul to human deduction and regular dialect than customary rationale frameworks. The FLC gives a calculation, which can change over the semantic control system, in light of master learning into a programmed control procedure. Specifically, the system of FLC shows up extremely helpful when the plants are excessively mind boggling for investigation by routine quantitative methods or when the accessible wellsprings of data are deciphered

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subjectively, estimated or with instability. The utilization of FLC fundamentally changes the way to deal with control of drives. A customary controller changes the framework control parameters on the premise of an arrangement of the differential mathematical statements, which depicts the model of drive framework. In a Fuzzy controller, the changes are made by a Fuzzy standard based master framework, which is a consistent model of human conduct of the plant administrator [7], [8]. A FLC generally gives preferable results over those of ordinary controllers, regarding the reaction time, settling time and especially in heartiness. The strength of FLC is estimable component in engine drive applications, where, the framework parameters are broadly changing amid plant operation. Because of non-straight structure of the FLC, the primary outline issue lies in the determination of the steady and finish guideline set and the state of enrollment capacities. Nonetheless, FLC's outline is made less demanding by cordial and importance apparatuses of the Fuzzy rationale. In this paper, the idea of Fuzzy rationale has been utilized for position control, utilizing dc servomotor. Subsequent to the presentation of Fuzzy set hypothesis by Zadeh and the primary innovation of a Fuzzy controller by Mamadani, Fuzzy control has picked up a wide acknowledgment, because of the closeness of surmising rationale to human thinking and has discovered applications in numerous force plants and power frameworks. It gives a powerful method for changing over the master sort control information into a programmed control methodology. Two reasons regularly marked for seeking after Fuzzy control are the longing to fuse semantic control rules and the need to outline a controller without adding to an exact framework model. The main Advantages of the fuzzy control systems are as follows-

1. **It is not necessary to build a detailed mathematical model**
2. **Fuzzy controllers have a high strength and a high adjustment.**
3. **They can operate with a high input numbers.**
4. **They can be adapted easily into nonlinear systems**
5. **The human knowledge can be easily applied**
6. **The process development time is relatively lower**

II. NONLINEARITIES INVOLVED IN PLANT

The exhibitions of the servo framework specifically influence the strength, reaction speed and following precision of the machine device. In a servo arrangement of CNC machine device, it confronts a vital issue that it ought to still keep great element attributes and unfaltering state following precision with the impacts of time variety, nonlinearity and burden unsettling influence. Conventional PID controller is generally connected in the servo framework, yet it can't address the issues of parameters conforming capacity and unsettling influence dismissal ability. Fuzzy control is a wise control strategy which impersonates consistent considering human and is free on a precise scientific model of the controlled article. Besides, it is inhumane to parameters Variation, and has solid vigor. It is splendidly connected to beat the impacts of nonlinearity, time variety and coupling of servo framework. To the issue that the consistent state blunder is difficult to be disposed of with a Fuzzy controller, a Fuzzy PID controller is proposed in this paper. The proposed controller fuses in excellences of both control methodologies, which are adaptability, flawless unsettling influence dismissal ability of the Fuzzy control, and the high consistent state accuracy of PID control.

III. DESIGN OF CONTROLLER

In procedure control today, more than 95% of the control circles are of PID sort, most circles are really PI control. PID controllers are today found in all regions where control is utilized. The controllers come in a wide range of structures. There are standalone Systems in boxes for one or a couple circles, which are fabricated by the hundred thousand yearly. Fig. 1 demonstrates the piece chart of PID controller.

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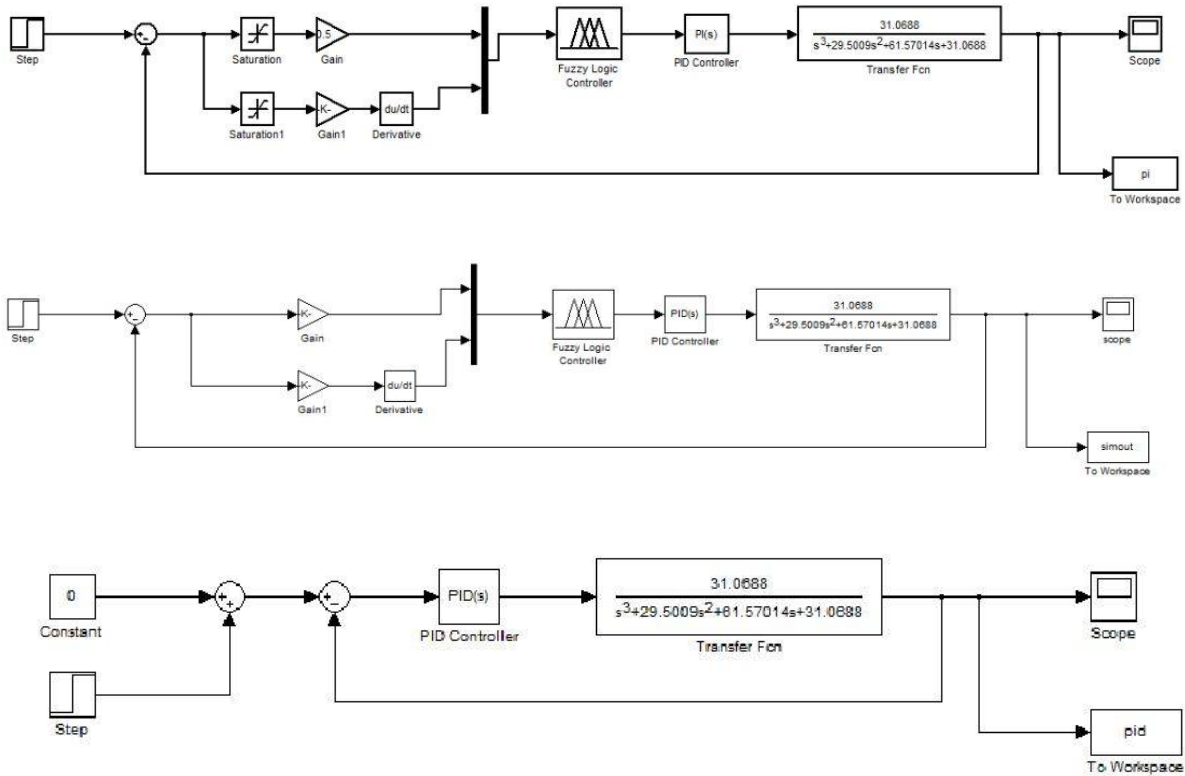


Figure 1: Block Diagram of Fuzzy, PI and PID Controller

1. Ziegler-Nichols Method

Ziegler and Nichols had proposed a famous tuning parameter of PID controller in 1942. Steps involved in this method are as follows:

1. First, note whether the required proportional control gain is positive or negative. To do so increase the step the input under manual control and see that the resulting steady state value of the process output has also increased. If so, then the steady-state process gain is positive and the required Proportional control gain, K_p , has to be positive as well.
2. Turn the controller to P-only mode, i.e. turn both the Integral and Derivative modes off.
3. Turn the controller gain, K_p , up slowly (more positive if K_p was decided to be so in step 1, otherwise more negative if K_p was found to be negative in step (1) and observe the output response. When a value of K_p results in a sustained periodic oscillation in the output, mark this critical value of K_p as K_u , the ultimate gain. Also, measure the period of oscillation, P_u referred to as the ultimate period. Using the

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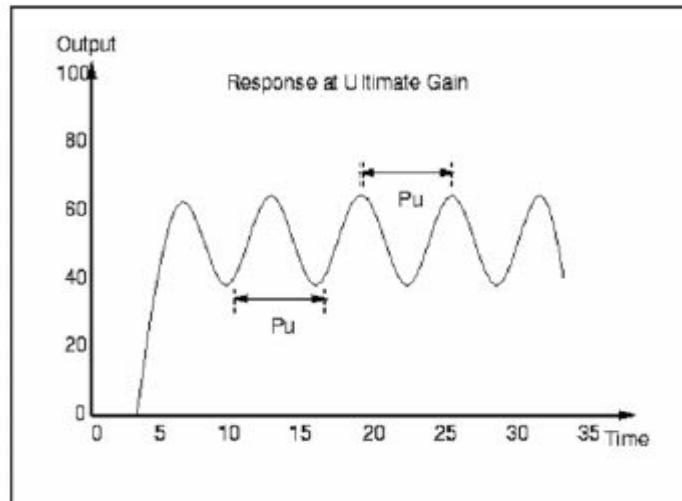


Figure 2: Response of Ultimate Gain

With some real processes the response to a step change or set point disturbance differs depending on the direction or size of the change. In this case it is irrelevant to look at the open-loop response to tune the controller. Instead the closed-loop response i.e. the behavior of the system with control has to be studied. The values of K_p , K_i and K_D are calculated from table 1.

IV. DESIGN OF FUZZY LOGIC CONTROLLER

The Fuzzy Logic Controller is intended to have two Fuzzy state Variables and one control variable for accomplishing position control of the DC Servo Motor. These two info variable are the blunder and change in mistake. It demonstrates the fundamental piece chart of Fuzzyrationale controller with data and yield variables. of a controlled framework is depicted by an arrangement of Fuzzy acquainted memory (FAM) decides that associate a Fuzzy information set to a Fuzzy yield set of the FLC. These principles are given by Mamdani consequently it is called as Mamdani's FIS.

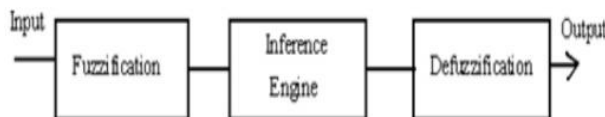


Figure 2: Block Diagram of Fuzzy Inference System

Crisp input information from the sensor is converted into fuzzy values for each input fuzzy set with the fuzzification block. The decision making logic determines how the fuzzy logic operations are performed and together with the knowledge base determines the outputs of each fuzzy IF-THEN rules. These two components are combined into the inference block. All the outputs are combined and converted to crispy values within the defuzzification block. Fuzzy rules can be described as a relational matrix $R, R = E \times EC \times KP \times Ki \times Kd$

Firstly, “min” implication method is used to calculate the matrix R . Then the fuzzy reasoning results of outputs are gained by aggregation operation of fuzzy sets of inputs and matrix R , where “max-min” aggregation method is used. Because definite values of outputs are needed for application, the fuzzy results should be defuzzified. In this paper, the “centroid” method is used for defuzzification to gain the accurate values kp , ki and kd which are then sent to PID controller to control the system.

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The error signal is the difference between the set point and output position of the motor. Following seven linguistic terms are used for the fuzzy sets i.e. negative big, negative medium, negative small, zero, positive small, positive medium, positive big which are denoted NB, NM, NS, ZE, PS, PM, PB respectively. The fuzzy sets are then defined by the triangular membership functions.

TABLE 1 RULE BASE FOR FIS

Δe	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NM	NS	NS	PS	PM	PB
NM		NM	NS	NS	PS	PM	
NS			NS	NS	PS		
ZE	NB	NM	NS	ZE	PS	PM	PB
PS			NS	PS	PS		
PM		NM	NS	PS	PS		
PB	NB	NM	NS	PS	PS	PM	

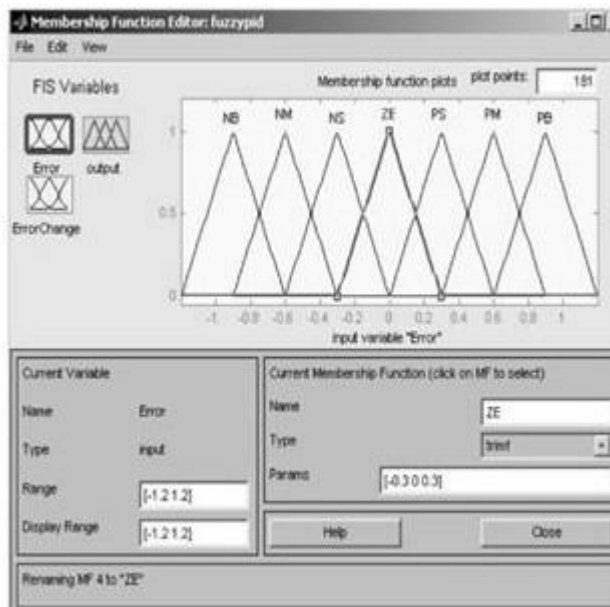


Figure 3: Membership Functions for Error and Change in Error

1. Output of FIS

For membership functions of output signal following seven linguistic terms are used for the fuzzy sets i.e. negative big, negative medium, negative small, zero, positive small, positive medium, positive big which are denoted NB, NM, NS, ZE, PS, PM, PB respectively. The fuzzy sets are then defined by the triangular membership functions as shown in Fig.

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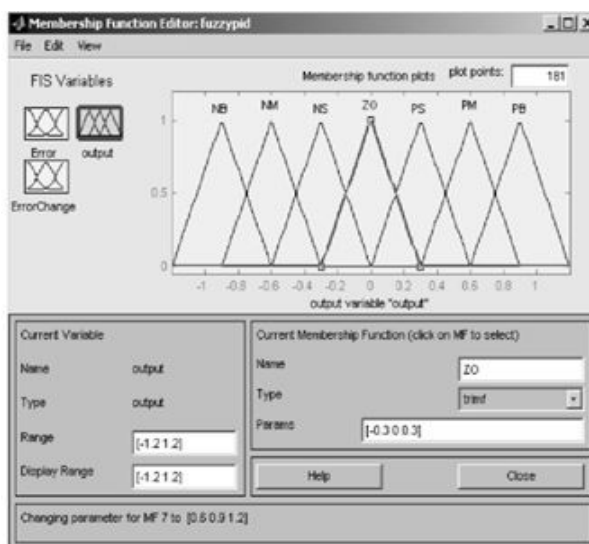


Figure 4: Membership Functions for Output of FIS

V. OVERVIEW OF SERVO SYSTEM

The review of servo system where set point is given through personal computer. The computer program (FIS) output is given to DAC which converts digital to analog signal. This analog signal is given to driver circuit of servo amplifier. From driver circuit output is given to servo amplifier which amplifies current to the motor. A potentiometer is connected to the shaft of the motor and a voltage of 5V is given to it, which is distributed over 360°. Thus the motor shaft position is converted in voltage signal and given back to PC through ADC as feedback signal.

From set point and feedback signal error is calculated the difference between the errors of two conjugative iterations gives change in error and this error and change in error is given as input to FIS which gives the output signal to achieve desired position.

TABLE 2 SYSTEM PARAMETERS

Potentiometer sensitivity (Kp)	5.093 V/rad
Signal amplifier gain (Ka)	1
Back EMF constant (K)	15×10^{-3} V/rad/s
Armature Resistance (R)	2 Ω
Armature Inductance (L _r)	1mH
Motor Torque Constant (K)	15×10^{-3} N-m/A
r	
Combined moment of inertia motor shaft & load referred to the motor shaft side (J _m)	42.6×10^{-6} Kg-m ²
Viscous damping coefficient of the motor referred to the motor shaft side (D _m)	47.3×10^{-6} Nm/rad/s

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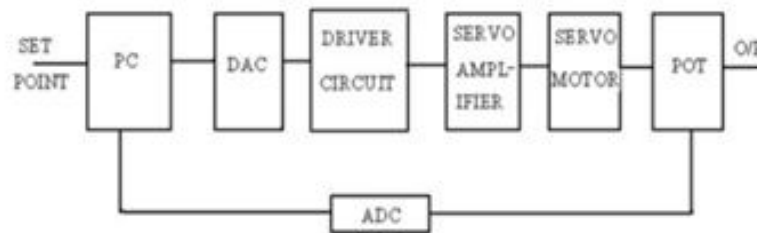
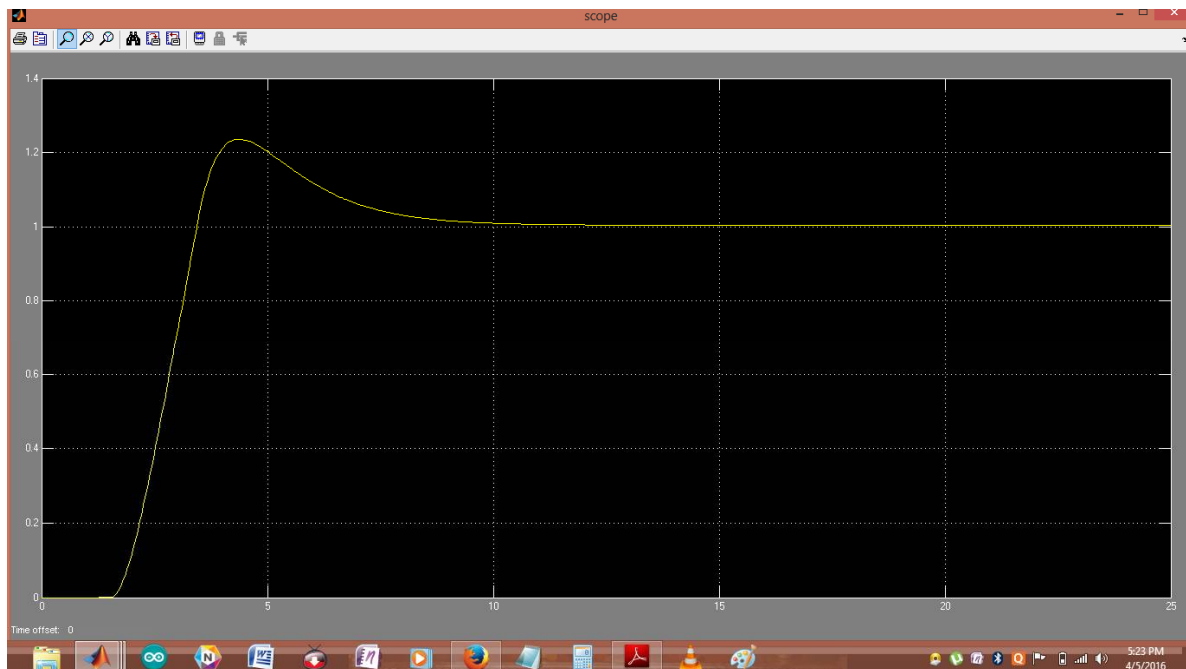


Figure 5: Block Diagram of Servo System

VI. SIMULATION RESULTS

With a conventional PID controller, it will bring about vast overshoot or poor soundness. In this paper, a Fuzzy PID controller is proposed keeping in mind the end goal to enhance the execution of the servo framework. The proposed controller fuses the upsides of PID control which can dispense with the enduring state blunder, and the benefits of Fuzzy rationale, for example, straightforward outline, no need of an exact numerical model and some versatility to nonlinearity and time-variety. The Fuzzy-PID controller acknowledges the mistake (e) and blunder change (ec) as inputs, while the parameters k_p , k_i , k_d as yields. Control standards of the controller are built up in light of experience so that self-regulation of the estimations of PID parameters is accomplished.



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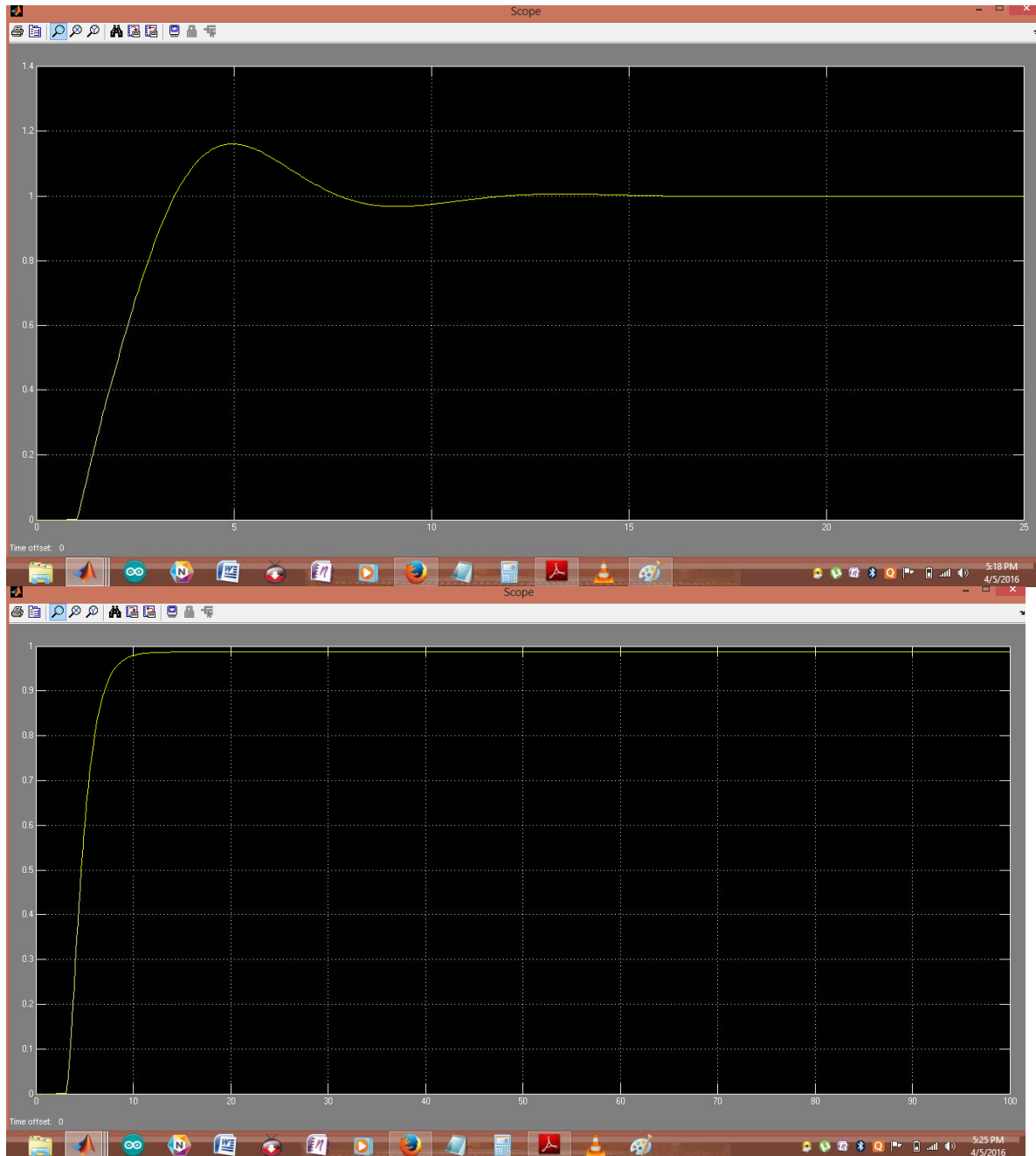


Figure 6: Output Response with Fuzzy, Fuzzy PI and Fuzzy PID Controller

The time response parameters, including rise time (T_r), percent overshoot (M_p), settling time (T_s) and steady state error (E_{ss}) of the PID controller and the fuzzy logic controller (FLC) for the higher order system transfer function of DC servo motor are presented in Table II.

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TABLE 3. TIME RESPONSE PARAMETER

CONTROLLER TYPE	TR (SEC)	MP (%)	TS (SEC)	(ESS) (%)
PID Controller	0,018	9,23	0,07	4
FLC	0,07	0	0,12	0

VII. CONCLUSION

It is seen that the fuzzy controller preserves the desired response, even in the presence of load disturbance and varying control environments. This ensures the controller's robustness. The choice of rules and membership functions has considerable effect on fuzzy

Controller performance, e.g., rise time, settling time, overshoots etc. It is observed that using the superposition of different consequent active at particular region of domain, for the same combinations of antecedents, performance of FLC is improved considerably in terms of settling time and overshoot. The combination of two sets of rules with same antecedents but different consequent reduces the settling time and overshoot.

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