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# Design of PI Controller Using MRAC Technique for the Control of DC Electromotor Drive

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**Abstract:** PID controller is used in most of the applications but it has some limitations like linearity, noise in derivative, etc., PI controller is used in some real life applications to overcome the limitations of PID controller. In this Paper, We implements PI controller for the control of speed of DC motor. It performs a comparative study with the PID controller of MRAC and Fuzzy logic controllers. PI Controller has two main parameters $K_p$ and $K_i$. To find out the optimal values of $K_p$ and $K_i$, Model Reference Adaptive Controller is used. It is observed that the PI controller with MRAC gives superior performance in speed control of DC motor as compared to MRAC PID controller and Fuzzy controller.

**Keywords:** DC Motor, PI Controller, MRAC, Fuzzy Logic Controller.

## I. INTRODUCTION

Drives can be defined as systems used for motion control e.g.-fans, robots, pumps etc. Prime mover is the main part of any drive which provides the movement, so it can be diesel engines, petrol engines, hydro motors, electric motors etc. Drivers using electric motor as the prime movers are known as electrical drives [1]. There are several advantages of electrical drives. Easy to control, High efficiency (switch mode converters and electrical motors are very efficient), Lesser pollution, Easy to store or transport energy. Motors take the power from electrical source and convert that energy into mechanical energy, so it can be considered as energy converters. There are many types of motors which used in electrical drives, choice of motor depends on electrical source and application. A machine that converts dc power into mechanical power is known as a DC motor [2],[3]. Its operation is based on the principle that when a current carrying conductor is placed in a magnetic field, the conductor experiences a mechanical force. The Proportional-Integral-Derivative (PID) controllers have been the most commonly used controller in process industries for over 50 years even though significant development have been made in advanced control theory. According to a survey conducted by Japan Electric Measuring Instrument Manufacturers Association in 1989, 90 % of the control loops in industries are of the PID type . A PID controller calculates an "error" value as the difference between a measured process variable and a desired setpoint. The controller attempts to minimize the error by adjusting the process control inputs. Several limitations are associated with PID controller. Some of these are Feedback controller, Linearity, Noise in derivative. To overcome these limitations, a PI controller is developed using the Model Reference Adaptive Control (MRAC). Fuzzy Logic Controller is also developed to compare the results of MRAC PI with Fuzzy Logic Controller.

## II. DESIGN OF PI CONTROLLER

### PI CONTROLLER:

Like the P-Only controller, the Proportional-Integral (PI) algorithm computes and transmits a controller output (CO) signal every sample time, T, to the final control element (e.g., valve, variable speed pump) [4], [5]. The computed CO from the PI algorithm is influenced by the controller tuning parameters and the controller error, e(t). PI controllers have two tuning parameters to adjust. While this makes them more challenging to tune than a P-Only controller, they are not as complex as the three parameter PID controller. Integral action enables PI controllers to eliminate offset, a major weakness of a P-only controller. Thus, PI controllers provide a balance of complexity and capability that makes them by far the most widely used algorithm in process control applications.

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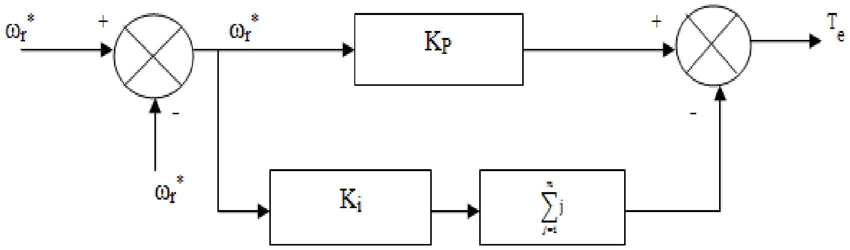

Figure 1: Block diagram of PI speed controller

$$CO = CO_{bias} + Kc \cdot e(t) + \frac{Kc}{Ti}\int e(t)dt \quad (1)$$

Where:
CO = controller output signal (the wire out)
$CO_{bias}$ = controller bias or null value
e(t) = current controller error, defined as SP – PV
SP = set point
PV = measured process variable (the wire in)
Kc = controller gain, a tuning parameter
*T*i = reset time, a tuning parameter

The first two terms to the right of the equal sign are identical to the P-Only controller referenced at the top of this article. The integral mode of the controller is the last term of the equation. Its function is to integrate or continually sum the controller error, e(t), over time. Some things we should know about the reset time tuning parameter, *T*i: It provides a separate weight to the integral term so the influence of integral action can be independently adjusted. It is in the denominator so smaller values provide a larger weight to (i.e. increase the influence of) the integral term. It has units of time so it is always positive. ZN tuning method is used for tuning the PI Controller [6].

| PID TYPE | Kp | $T_i$ | $T_d$ |
|---|---|---|---|
| P | 0.5 Ku | ∞ | 0 |
| PI | 0.45 | Pu/1.2 | 0 |
| PID | 0.6 | Pu/2 | Pu/8 |

Table: ZN Tuning Method

## III. SOFT COMPUTING TECHNIQUES

### 3. A. MODEL REFERENCE ADAPTIVE CONTROLLER:

The general idea behind Model Reference Adaptive Control (MRAC, also known as an MRAS or Model Reference Adaptive System) is to create a closed loop controller with parameters that can be updated to change the response of the system [7], [8]. The output of the system is compared to a desired response from a reference model. The control parameters are update based on this error. The goal is for the parameters to converge to ideal values that cause the plant response to match the response of the reference model. For example, you may be trying to control the position of a robot arm naturally vibrates. You actually want the robot arm to make quick motions with little or no vibration. Using MRAC, you could choose a reference model that could respond quickly to a step input with a short settling time [9], [10].

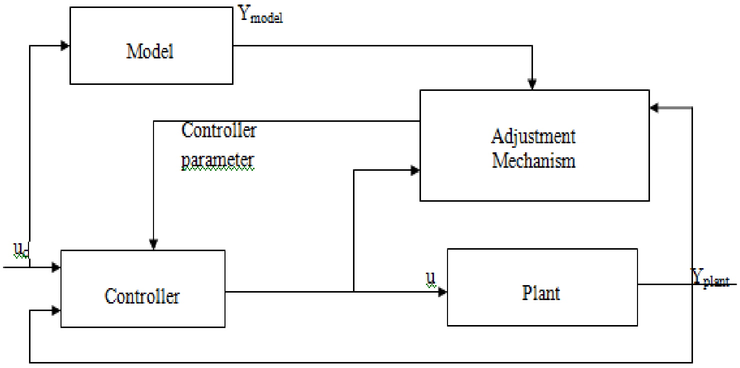

Figure2: Block Diagram of a Model-Reference Adaptive Control (MRAC) System.

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The controller presented above can be thought of as consisting of two loops. The ordinary feedback loop which is called the inner loop composed of the process and controller. The parameters of the controller are adjusted by the adaptation loop on the basis of feedback from the difference between the process output y and the model output $y_m$ . The adaptation loop which is also called the outer loop adjusted the parameter in such a way that makes the difference becomes small. An important problem associated with the MRAC system is to determine the adjustment mechanism so that a stable system that brings the error to zero is obtained. The following parameter adjustment mechanism, called the MIT rule, was originally used in MRAC.

$$\frac{d\theta}{dt} = -\gamma e\frac{\partial e}{\partial \theta}$$

e ($e = y - y_m$) denotes the model error and θ is the controller parameter vector. The components of $\frac{\partial e}{\partial \theta}$ are the sensitivity derivatives of the error with respect to θ. The parameter γ is known as the adaptation gain. The MIT rule is a gradient scheme that aims to minimize the squared model error $e^2$.

### 3. B. FUZZY LOGIC CONTROLLER:

The operation principle of a FL controller is similar to a human operator. It performs the same actions as a human operator does by adjusting the input signal looking at only the system output. A FL based controller consists of three sections namelyfuzzifier, rule base and defuzzifier as shown in fig 3. Two input signals, the main signal and its change for each sampling, to the FL controller are converted to fuzzy numbers first in fuzzifier. Then they are used in the rule table to determine the fuzzy number of the compensated output signal. Finally, the resultant united fuzzy subsets representing the controller output are converted to the crisp values [11], [12].

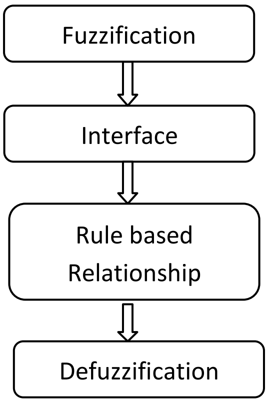

Figure 3: Step by Step Process of Fuzzy Logic Controller

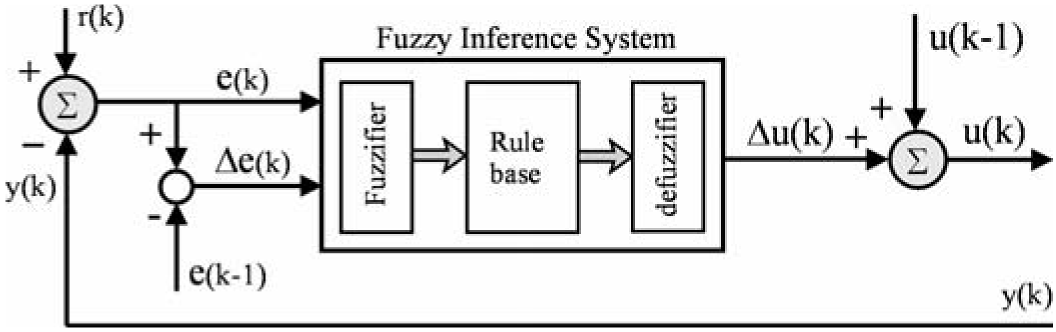

Figure 4: Basic Structure of Fuzzy Logic Based Controller.

The FL based controller is designed to act as an integrator controller, such that the resultant incremental output u(k) is added to the previous value u(k-1) to yield the current output u(k). Recalling the digital solution of an integration using Euler's integration as,

$u(k)=u(k-1)+\Delta u(k)$ (2)

In a digital integration, the term

$\Delta u(k)=k_I T_s e(k)$ (3)

Where $k_I$ is integral constant,$T_s$ is sampling period, and e(k) is the integrated signal. The change Δu(k) on the output of an integrated becomes zero when the input e(k) is zero. Therefore output of an integrator retains the previous value.

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Hence (1) can be used for both an integrator and fl controller. The difference between an integrator and fl controller is the method that is used to obtain ^u(k), which is obtained using (2) for an integrator, and using fuzzy inference system shown in fig.4 for FI Controller.

## IV. DESIGN OF PI CONTROLLER USING MRAC TECHNIQUE

Consider a process with a first order transfer function

$$G(s) = \frac{b}{p+a} \tag{4}$$

Where ‘a’ is assumed to be positive and ‘b’ non negative.

The PI controller is given by

$$u(t) = \left\{kp\,[uc(t) - y(t)] + \frac{ki}{p}[uc(t) - y(t)]\right\} \tag{5}$$

In the time domain, using the differential operator $p = \frac{d}{dt}$

$$y(t) = \frac{b}{p+a}\,u(t) = \frac{b}{p+a}\left\{kp\,[uc(t) - y(t)] + \frac{ki}{p}[uc(t) - y(t)]\right\} \tag{6}$$

$$y(t) = \frac{b}{p+a}[k_p u_c(t) + \frac{ki}{p}u_c(t)] + \frac{b}{p+a}[\,-k_p - \frac{ki}{p}\,]y(t) \tag{7}$$

$$y(t)[\,1+ \frac{b}{p+a}(k_p + \frac{ki}{p})] = \frac{b}{p+a}(k_p + \frac{ki}{p})\,u_c(t) \tag{8}$$

$$y(t)[\,p^2 + ap + bk_p p + bk_i] = b(k_p p + k_i)\,u_c(t) \tag{9}$$

$$y(t) = \{b(k_p p + k_i)/[\,p^2 + ap + bk_p p + bk_i]\}u_c(t) \tag{10}$$

zero is $bk_p p + bk_i = 0$

$$p = s = -(k_i/k_p) \text{ i.e., real zero} \tag{11}$$

We select a second order oscillating system as the reference model.

$$G_m(s) = (y_m(s)/u_m(s)) = [\beta s+\omega_n^2]/[s^2+2\xi\omega_n s+\omega_n^2] \tag{12}$$

$(-\omega_n^2/\beta)$ is the real zero to match equation (11)

Using MIT rule, $\frac{d\theta}{dt} = -\gamma e\frac{\partial e}{\partial\theta}$

$$\frac{\partial e}{\partial\theta} = \frac{\partial(y-ym)}{\partial\theta} = \frac{\partial y}{\partial\theta} \tag{13}$$

$$\frac{d\theta}{dt} = p\theta = -\gamma e\frac{\partial e}{\partial\theta} \tag{14}$$

Using MIT rule,

$$\frac{dkp}{dt} = -\gamma_p\frac{\partial J}{\partial kp} = -\gamma_p\left(\frac{\partial e}{\partial y}\right)\left(\frac{\partial e}{\partial y}\right)\left(\frac{\partial y}{\partial kp}\right) \tag{15}$$

$$e = y - y_m,\ \left(\frac{\partial e}{\partial y}\right) = 1 \tag{16}$$

$$\left(\frac{\partial e}{\partial y}\right) = e \tag{17}$$

$$\frac{dkp}{dt} = -\gamma_p e\left(\frac{\partial y}{\partial kp}\right) \tag{18}$$

Partially differentiating the equation (10) w.r.t $k_p$, we get

$$k_p = \frac{-\gamma p}{p}\,\frac{b}{m(p)}\,e\,p\,(u_c - y) \tag{19}$$

where $m(p) = p^2 + p(a+bk_p) + k_ib$ and similarly we get parameter of $k_i$ as,

$$k_p = \frac{-\gamma p}{p}\frac{b}{m(p)} e \ (u_c - y) \tag{20}$$

comparing m(p) with denominator of general second order equation, we get

$$2\xi\omega_n = a + bk_p \tag{21}$$

$$\omega_n^2 = k_ib \tag{22}$$

## V. PROGRAMMING RESULTS

Figure 5: shows the simulated system in Matlab /Simulink to verify the proposed concept.

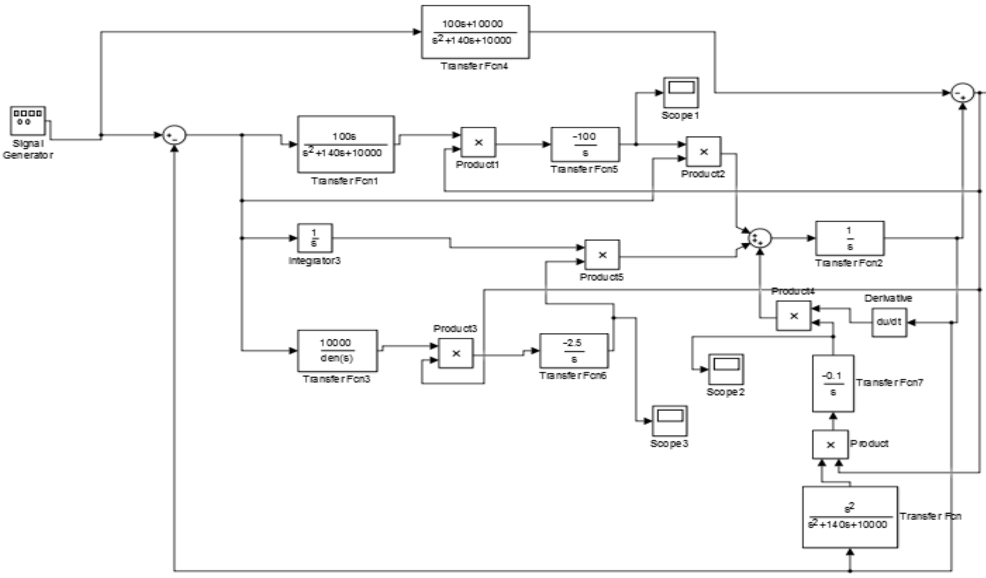

Figure 5: Matlab / Simulink Model of control scheme for of MRAC PID

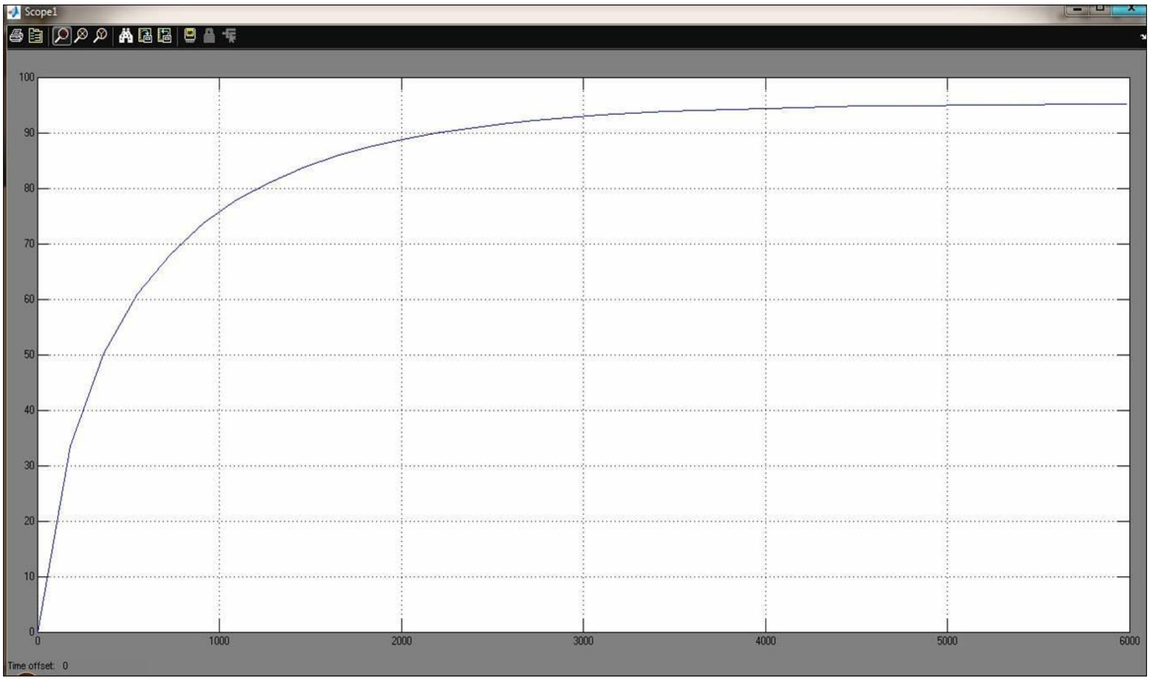

Figure 6a: Proportional Gain response of MRAC PID Controller

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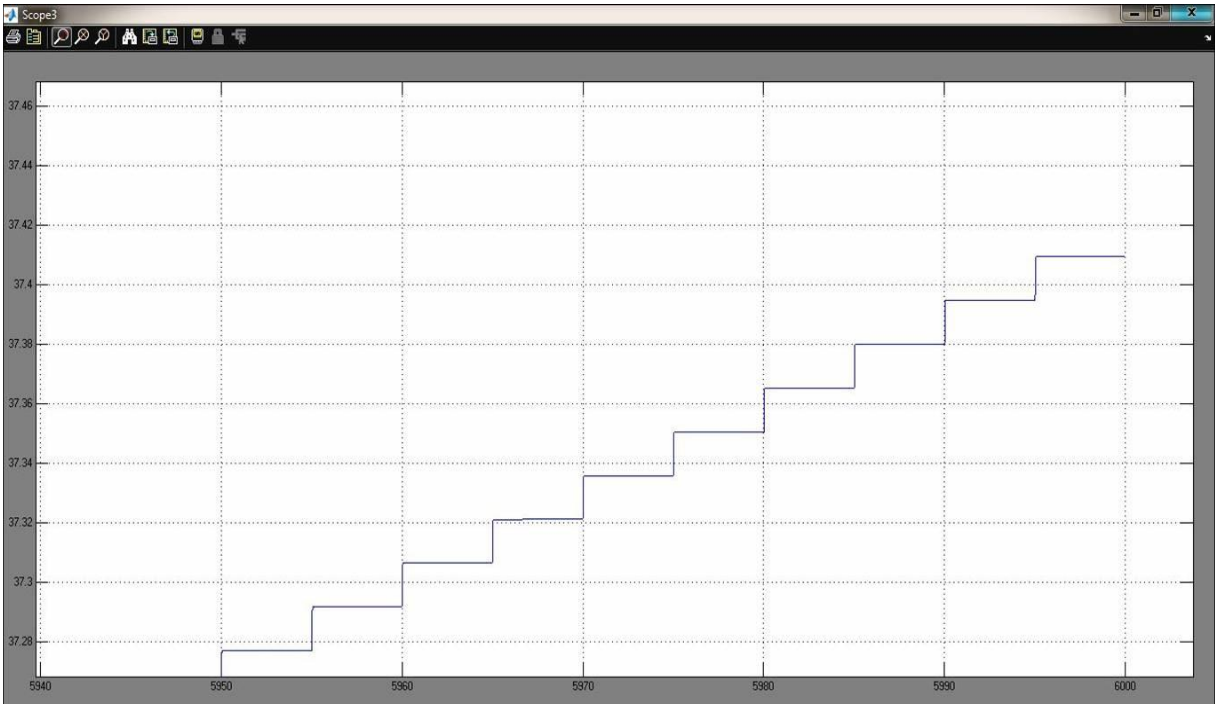

Figure 6b: Integral response of MRAC PID Controller

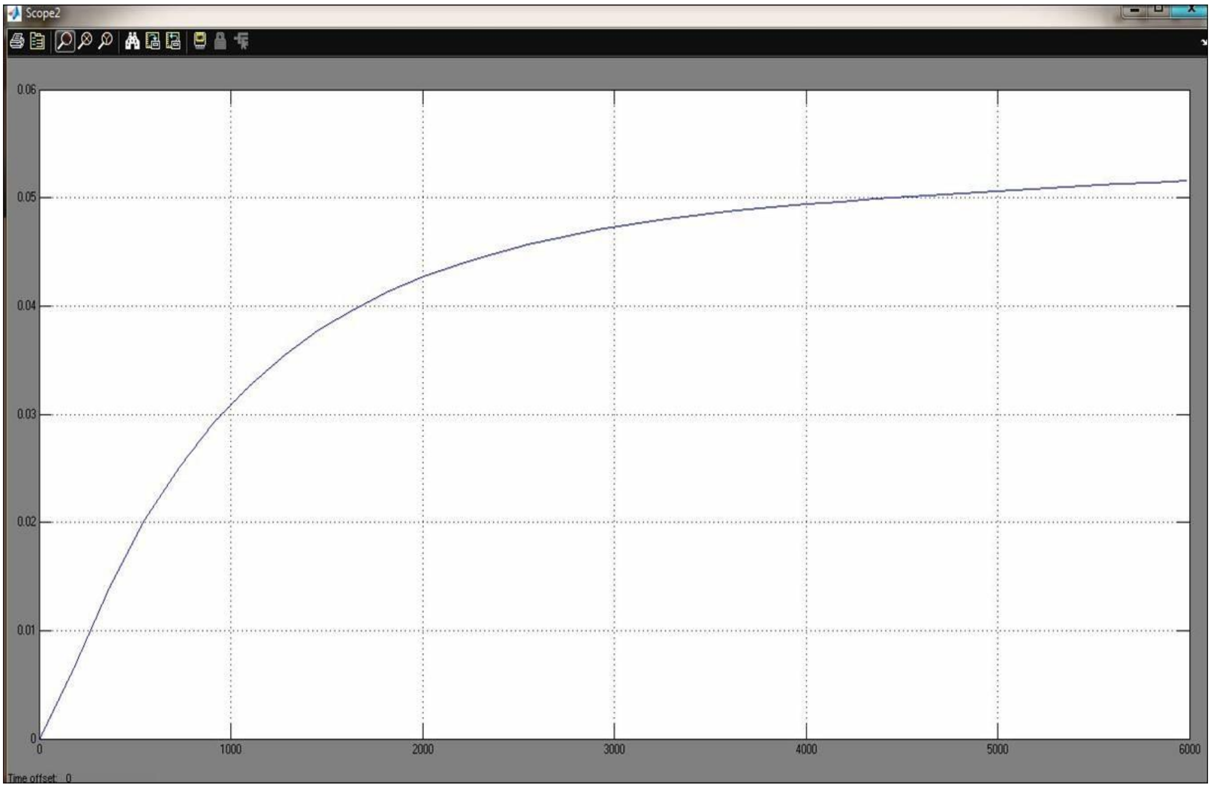

Figure 6c: Derivative response of MRAC PID Controller

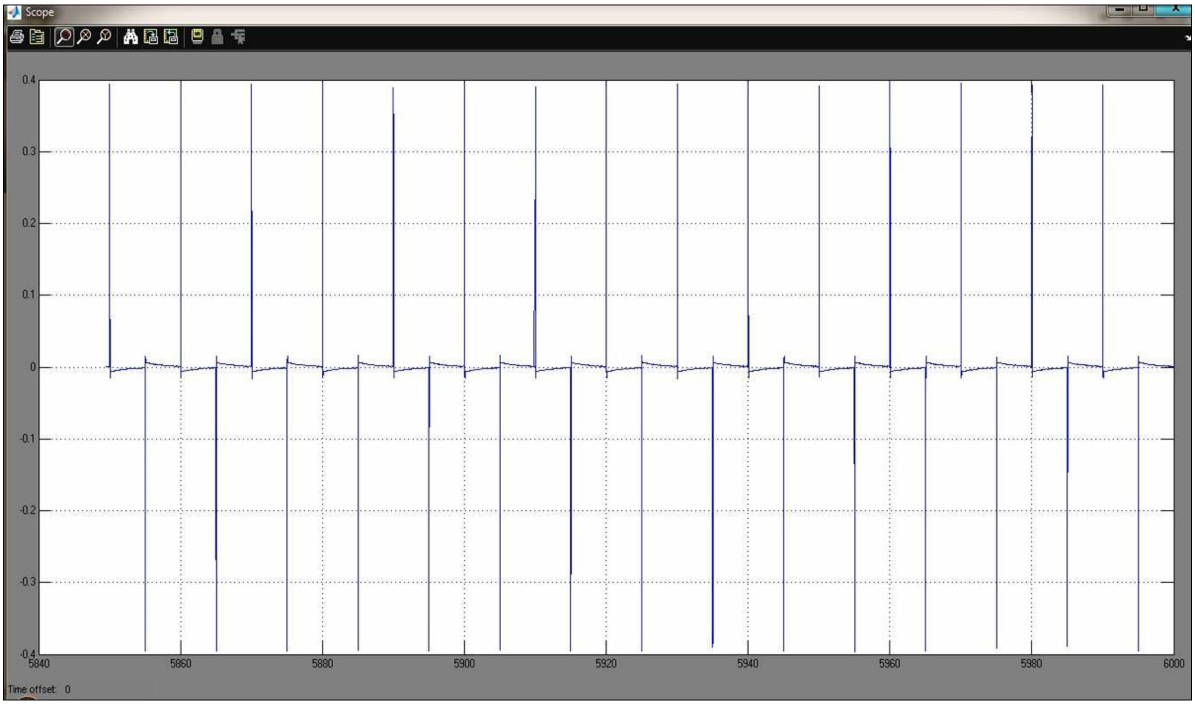

Figure 7: Error of the MRAC PID Controller

The error with the MRAC PID Controller is infinity.

## MATLAB / SIMULINK RESULTS:

The proposed concept is tested with two controllers namely

1. Fuzzy logic controllers

2. Proportional integral (PI) controller

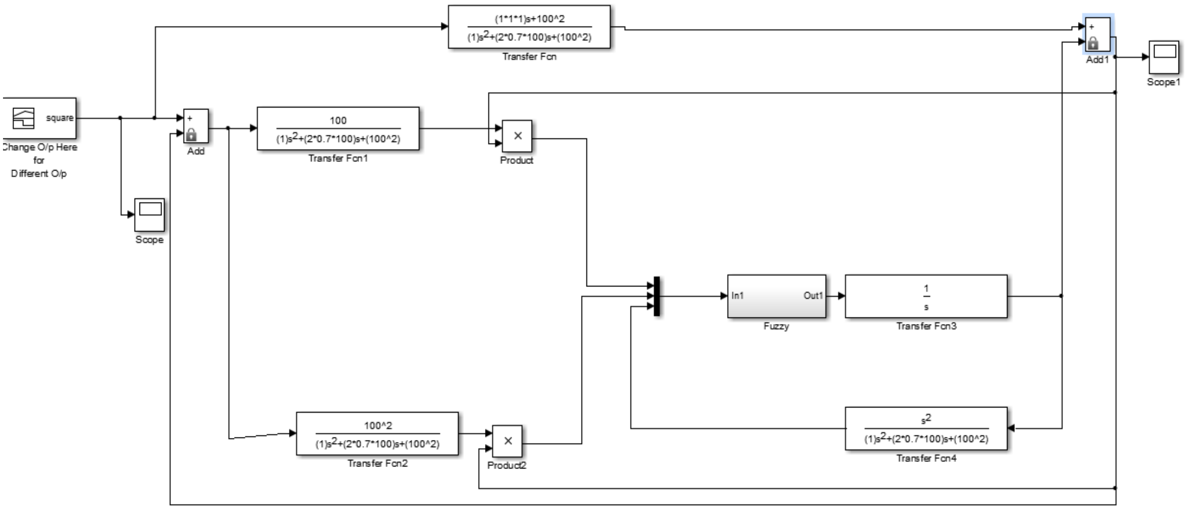

Figure 8: Simulation with Fuzzy Logic Controller

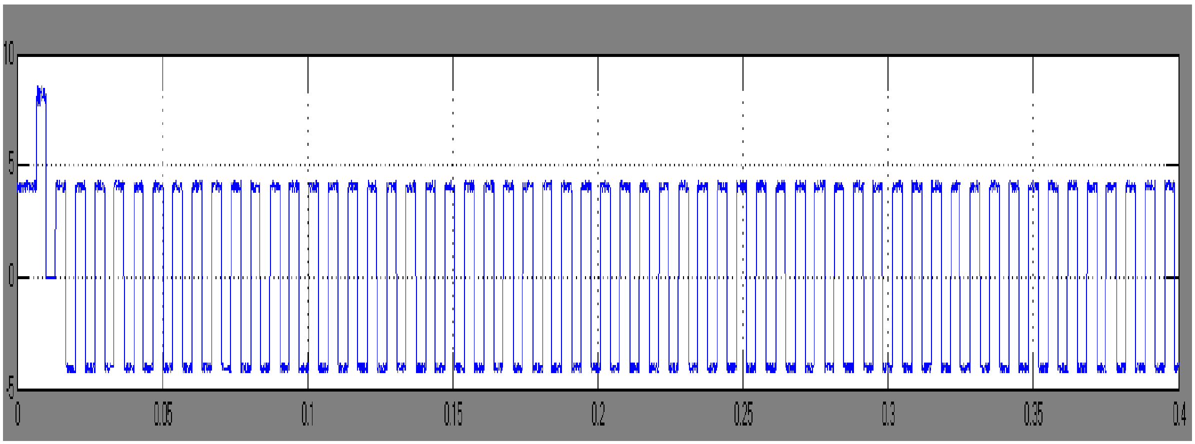

Figure 9: Error with Fuzzy Logic Controller

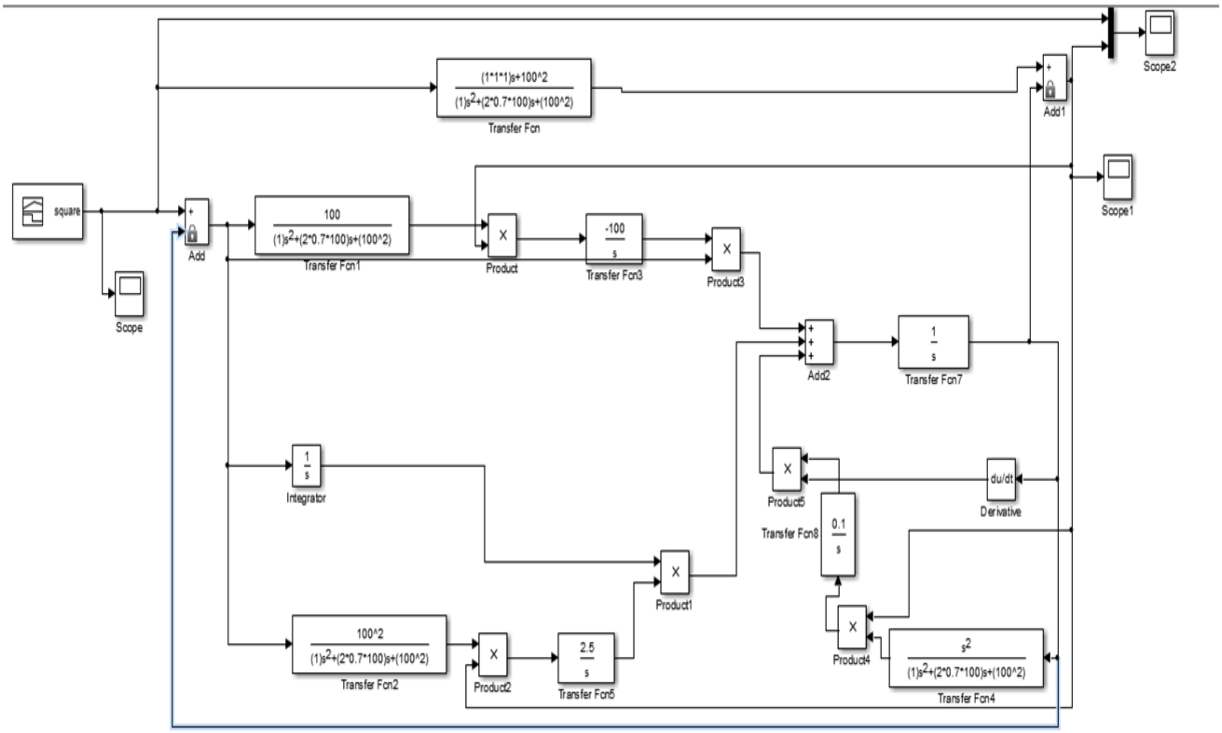

Figure 10: Simulation with MRAC PI Controller

## VI. CONCLUSION

In this paper, we considers a DC motor model with unity feedback to control speed of DC motor using feedback controller. The primary goal of the controller is to control the speed of DC motor while manipulating the parameters of controller .This thesis designs a PI controller and optimization of PI controller using MRAC Technique. The gain values $K_p$ and $K_i$ obtained using MRAC Technique. The error with MRAC PID is very high and not coming to steady state and the error with the Fuzzy Logic Controller is better than the MRAC PID but tends to oscillations at the beginning. The error with the MRAC PI Controller is almost zero and better than the both MRAC PID and the Fuzzy Logic Controller.

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