

DC Motor Modelling and Control using Fuzzy Logic Controller (FLC)

¹ESMAIL. S. Mohammed, ²SedatNazlibilek, ³FATHI SH BENKOURA

¹Lecturer, Mechatronics Engineering, the Higher Institute of Science and Technology, Zawia, Libya

²Electrical And Electronics Engineering, Baskent University, Ankara, Turkey

³Lecturer, Electrical Engineering, the Higher Institute of Science and Technology, Zawia, Libya

Corresponding Author: Esmail. S. Mohammed

ABSTRACT: DC motor position control widely used in industrial applications. This paper was focuses on the design of a PID controller, fuzzy logic control (FLC) systemis used with PID fuzzy controller and compared between them for controlling the position of a DC motor. The motor is modelled and simulated. Moreover the (PID) controller was designed tuned by using a Matlab/Simulink block instead of conventional tuning methods such as hand-tuning or Ziegler-Nichols method. Then, the fuzzy logic controller (FLC) was designed and the system responses of (FPID) with different defuzzification methods were investigated. The signal is angle position (teta) was created by Simulink and applied to the input control system. FPID controller succeeded to reduce the error between signal input andsignal output is better than conventional tuning methods.

KEY WORDS: DC motor, position control, hand-tuning method, Fuzzy logic control, FPID controller.

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I. INTRODUCTION

Recently, DC motor control to control the motion (speed and position) has become widespread. The control systems of motors speed and position is very necessary and important because DC motor is widely used in industrial applications, and many other fields of control systems such as industrial homes place and robotics where speed and position control of DC motor are required [1-3]. Two major problems encountered in DC motor control are the noise in the system loop and the varying time of the motor parameters under operating conditions. The PID widespread use of control it is highly desirable to have efficient manual and automatic methods of tuning the controllers. A good insight into PID tuning is also useful in developing more schemes for automatic tuning and loop assessment [4]. These methods have successful results but they need more time and effort to get a good system response. The mathematical model to present of DC motor does not give accurate of the real system because approximated it to linear system that is main problem [5]. To avoid this problem, fuzzy logic control (FLC) can be used. The (FLC) does not dependent on the model, also it is insensitive to changing of parameters [6]. The most important advantages of (FLC) is that it can be successfully applied to control nonlinear systems using an operator experiences or control engineering knowledge without any mathematical model of the system[7]. There are many searches and studies about DC motor fuzzy control system design, compared PID with FLC for position control and observed that FLC performed better than PID methods and shown that FLC is less sensitive than PID to load variations [8,9]. In generally some methods realized of DC motor control by such as adjusting the field resistance, putting a resistor in series with the armature circuit or adjusting the terminal voltage applied to the armature [10].

1.1 DC motor model

In DC motors armature control the voltage was applied to the field winding (separately excited), the voltage applied to the armature of the motor is adjusted without changing the voltage applied to the field. Figure.1 shows a separately excited DC motor equivalent model.

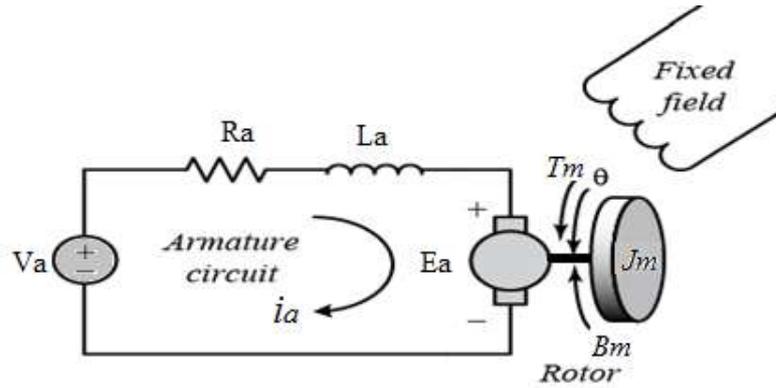


Figure 1: Schematic Diagram of DC Motor

The differential equation for the armature circuit is

$$v_a(t) = R_a \cdot i_a(t) + L_a \cdot \frac{di_a(t)}{dt} + e_a(t) \quad (1)$$

$$e_b(t) = K_b \cdot w(t) \quad (2)$$

The equation for torque equilibrium is

$$T_m(t) = K_T \cdot i_a(t) \quad (3)$$

$$T_m(t) = J_m \cdot \frac{dw(t)}{dt} + B_m \cdot w(t) \quad (4)$$

By combining the upper equations together:

$$v_a(t) = R_a \cdot i_a(t) + L_a \cdot \frac{di_a(t)}{dt} + K_b \cdot w(t) \quad (5)$$

$$K_T \cdot i_a(t) = J_m \cdot \frac{dw(t)}{dt} + B_m \cdot w(t) \quad (6)$$

By taking Laplace transforms to (5) and (6) are:

$$V_a(s) = R_a \cdot I_a(s) + L_a \cdot I_a(s) \cdot s + K_b \cdot W(s) \quad (7)$$

$$K_T \cdot I_a(s) = J_m \cdot W(s) \cdot s + B_m \cdot W(s) \quad (8)$$

The armature voltage is

$$V_a(s) = W(s) \cdot \frac{1}{K_T} \cdot [L_a \cdot J_m \cdot s^2 + (R_a \cdot J_m + L_a \cdot B_m) \cdot s + (R_a \cdot B_m + K_b \cdot K_T)] \quad (9)$$

Then the relation between armature voltage and angular speed of the shaft can be presented by transfer function as

$$\frac{W(s)}{V_a(s)} = \frac{K_T}{L_a \cdot J_m \cdot s^2 + (R_a \cdot J_m + L_a \cdot B_m) \cdot s + (R_a \cdot B_m + K_b \cdot K_T)} \quad (10)$$

The position can be found as

$$\theta(s) = \frac{1}{s} W(s) \quad (11)$$

The transfer function between armature voltage as input and the position of the shaft as output when the motor without load is:

$$\frac{\theta(s)}{V_a(s)} = \frac{K_T}{L_a \cdot J_m \cdot s^3 + (R_a \cdot J_m + L_a \cdot B_m) \cdot s^2 + (K_T \cdot K_b + R_a \cdot B_m) \cdot s} \quad (12)$$

The DC motor model is built in Simulink/MATLAB as shown in figure.2, the inputs are armature voltage (V_a) and load torque (T_{load}).The outputs are angular speed in (ω) and position (θ).

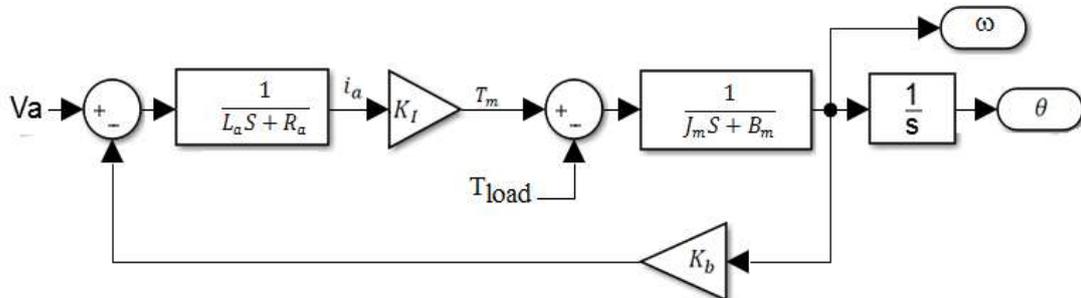


Figure 2. DC motor model in Simulink/MATLAB

The following characteristic of the DC motor was used:.

Performance specifications:

Torque continuous = 0.95 N-m

Peak torque =5.22 N-m

Maximum speed =5000 rpm

Rated power =200 w

Electrical specification

Torque constant = 0.17 N-m/ Amp

Terminal resistance = 1.4 Ohms

BEMF constant = 18.2 V/krpm

Armature inductance = 4.9 m-H

Moment of inertia = 0.00092 kg/m²

Recommended Bus Voltage = 80 VDC

Maximum Terminal voltage =104 VDC

1.2 Proportional-integral-derivative (PID) controller

The PID controllers are used mostly in industrial control applications due to their simple structures, completely control algorithms and low costs. Figure.3 shows the schematic model of a control system with a PID controller.

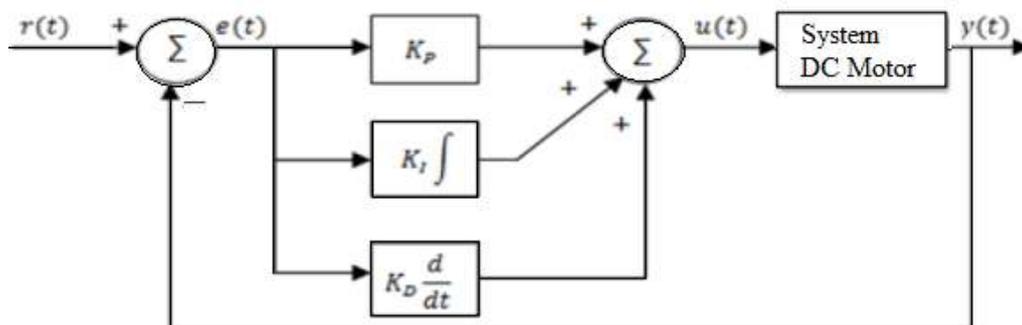


Figure 3. PID controllers system

Where

K_p = proportional gain

K_i = integral gain

K_d = derivative gain

1.3MATLAB/Simulink

The simulation was performed by using Simulink to present the model, the simulation begins with the motor at the zero degree position. The desired position was 36 degree. There is deferent between input and output signal without controller as shown in figure 4.

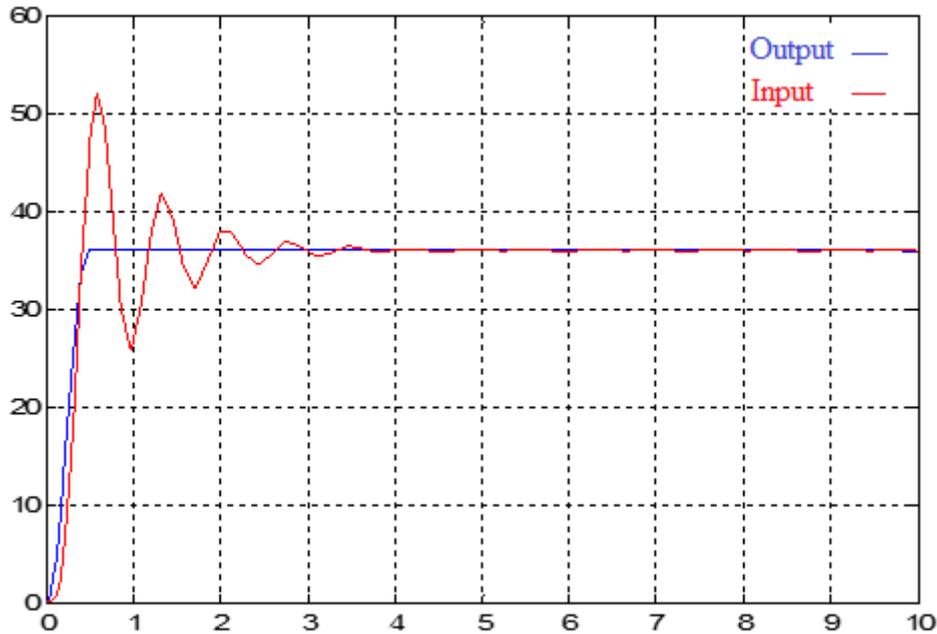


Figure4.Input and output signal without controller

To reduce this deferent, the PID controller was used as shown in Figure.5. By using Hand Tuning, the parameters was done to reduce the deferent between input signal (position 36°) and output signal (position). The values of the parameters which gated the best results as shown in figure.6 are:

$$K_p = 1.3 \quad K_i = 0.5 \quad K_d = 0.5$$

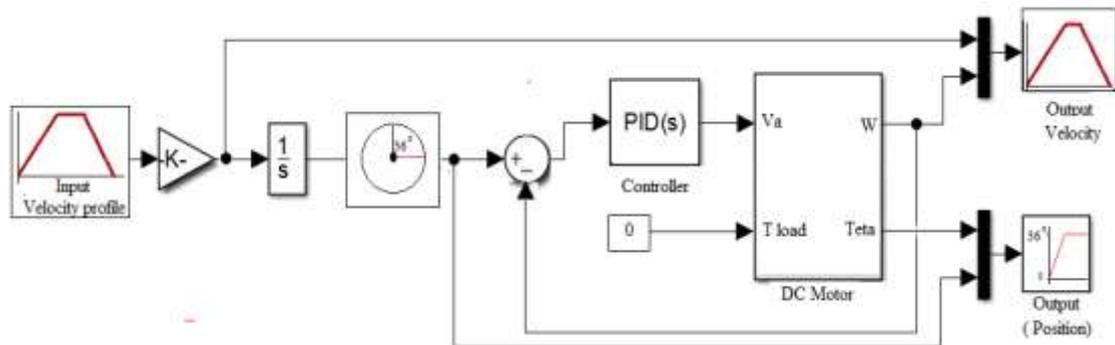


Figure5.Simulink Block Diagram of DC Motor with PID controller

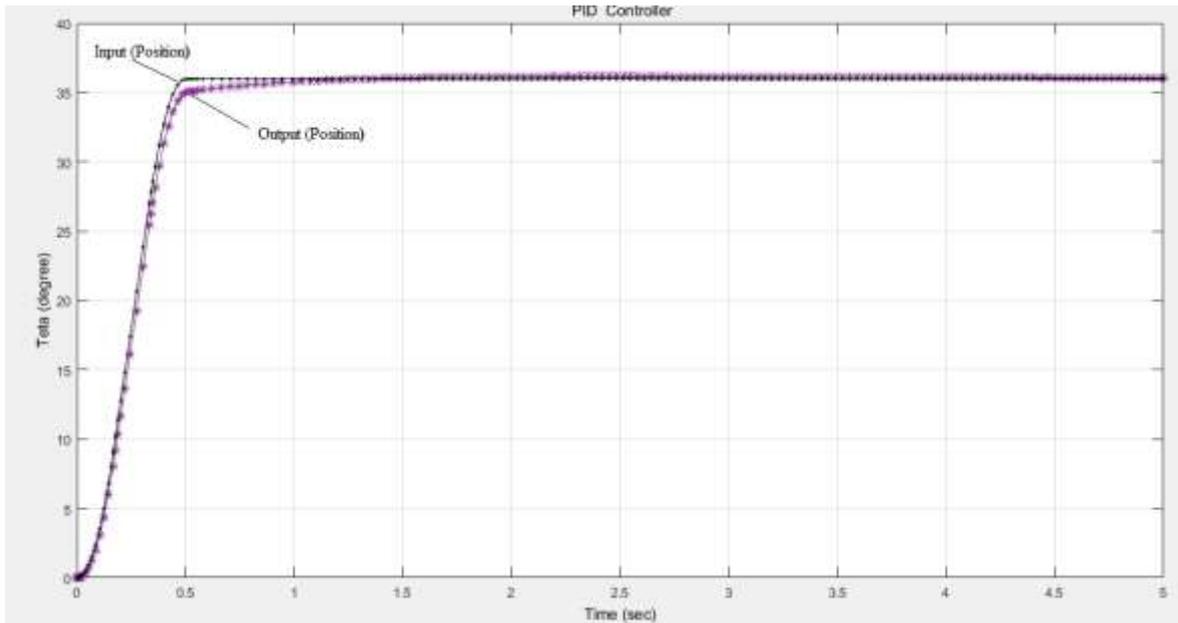


Figure6. Figure 6. The output response with PID controller

II. Fuzzy logic controller (FLC)

The main components of fuzzy logic controller is fuzzification interface, rule base, inference mechanism, and defuzzification interface. The fuzzy controller converts a linguistic control strategy into controller strategy, and fuzzy rules are constructed by expert experience or knowledge database. Firstly, set the error $e(t)$ and the error variation $de(t)$ of the angular position to be the input variables of the fuzzy logic controller. The control voltage $u(t)$ is the output variable of the fuzzy logic controller. The linguistic variables are defined as {NB, NS, Z, PS, PB}, where NB means negative big, NS means negative small, Z means zero, PS means positive small and PB means positive big.

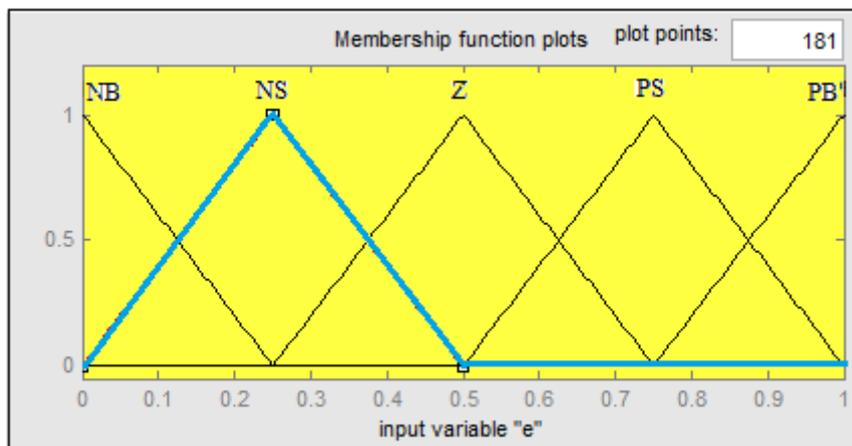


Figure7. Membership function for (e) normalized input

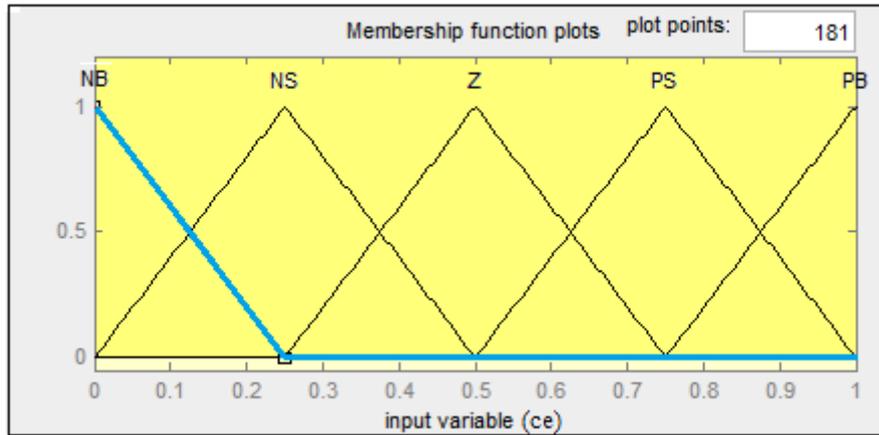


Figure 8. Membership function for (ce) normalized input

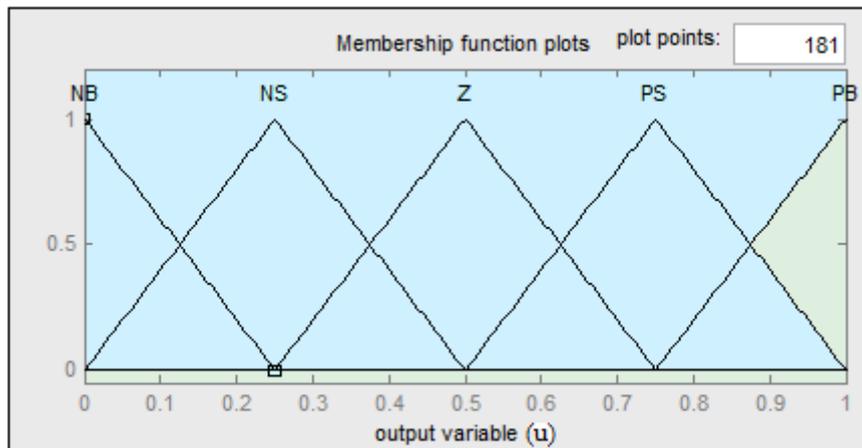


Figure 9. Membership function for (u) normalized output

Here max-min type decomposition is used and the final output for system is calculated by using center of area gravity method.

$$\mu_B(u(t)) = \max[\mu_{A_1j}(e(t)), \mu_{A_2j}(ce(t)), \mu_{Bj}(u(t))] \quad 13$$

Where;

$\mu_{A_1j}(e(t))$ = the membership function of $e(t)$

$\mu_{A_2j}(ce(t))$ = the membership function of $ce(t)$

$\mu_{Bj}(u(t))$ = the membership function of $u(t)$

j is an index of every membership function of fuzzy set, m is the number of rules and is the inference result. Fuzzy output $u(t)$ can be calculated by the center of gravity defuzzification as:

$$u(t) = \frac{\sum_{i=1}^m \mu_B(u_i(t)) \cdot u_i}{\sum_{i=1}^m \mu_B(u_i(t))}$$

III. SIMULINK IMPLEMENTATION

Inputs of FPID are (e) error and (ce) change of error where the output is control. The fuzzy rules are summarized in Table I. Figures (9-10) shows Fuzzy input variables error (e) and change of error (ce) and Fuzzy output variable (control) respectively. (a) and (b) consist of seven fuzzy sets namely NB (negative big), NM (negative medium), NS (negative small), Z (zero), PS (positive small),

PM (positive medium) and PB (positive big) . The fuzzy PID control system designed in Simulink as shown in Figure 11.

Table I. The fuzzy rules are summarized

| E CE | NB | NM | NS | Z | PS | PM | PB |
|-------------|----|----|----|----|----|----|----|
| NB | NB | NB | NB | NB | NM | NS | Z |
| NM | NB | NB | NB | NM | NS | Z | PS |
| NS | NB | NB | NM | NS | Z | PS | PM |
| Z | NB | NM | NS | Z | PS | PM | PB |
| PS | NM | NS | Z | PS | PM | PB | PB |
| PM | NS | Z | PS | PM | PB | PB | PB |
| PB | Z | PS | PM | PB | PB | PB | PB |

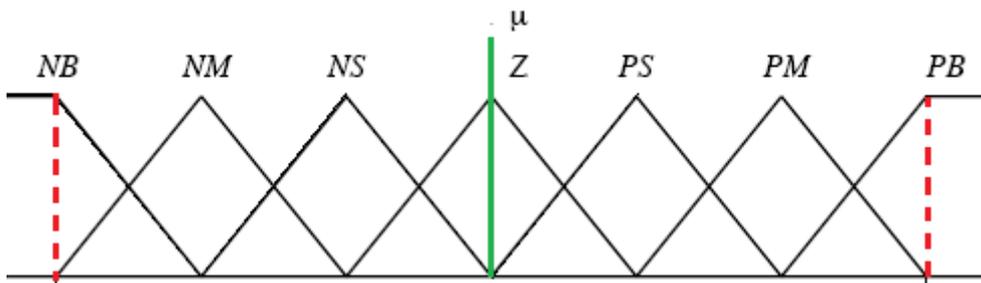


Figure 9. Fuzzy input variables error (e) and change of error (ce)

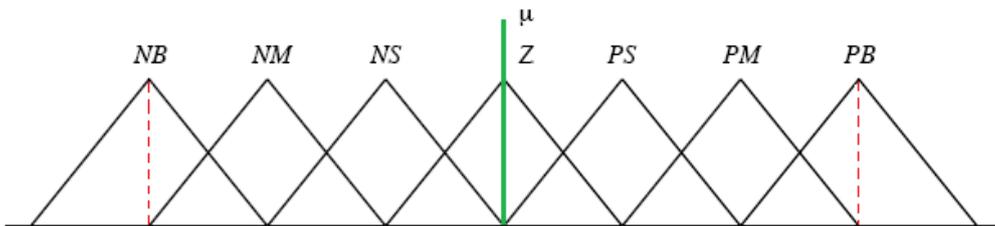


Figure 10 . Fuzzy output variable (control)

The figure.11 shows that, the output fuzzy logic controller and output the PID controller. The optimal performance in tracking the reference input (θ) when fuzzy logic controller FPID was used when compared with PID controller.

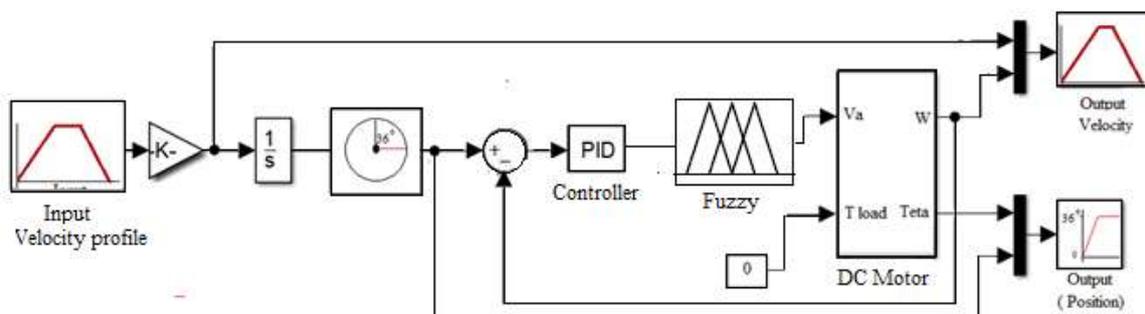


Figure 11. Simulink Block Diagram of DC Motor with fuzzy logic controller

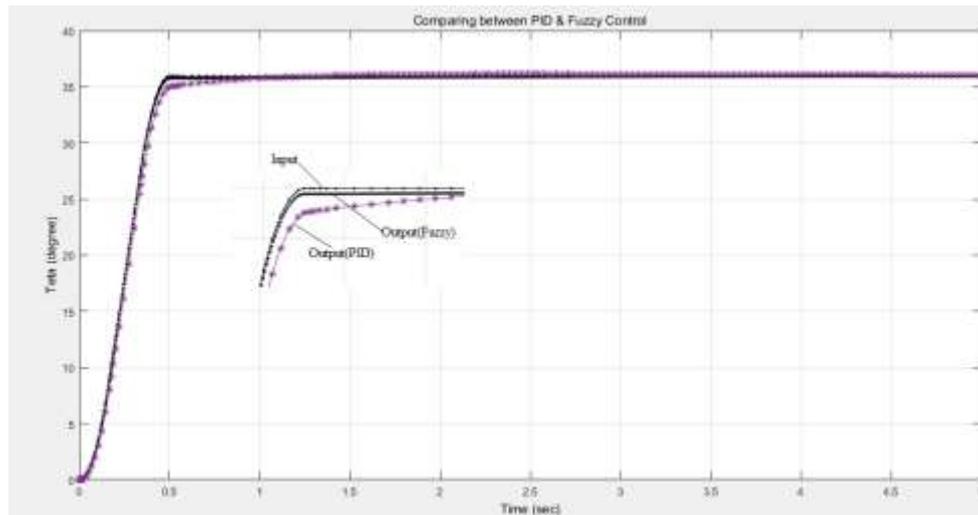


Figure 12. Comparing between PID and fuzzy controller

IV. CONCLUSIONS AND RECOMMENDATIONS

The position control of DC motor, PID controlling techniques used Ziegler-Nichols hand tuning and fuzzy logic controller FPID was presented. The controller shows optimal performance in tracking the reference input (θ) when fuzzy logic controller FPID was used. Fuzzy Logic Controller provides performance characteristics and improve the control of DC motor better than conventional tuning method. Hence it is concluded that the proposed Fuzzy Logic Controller can be used.

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