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SPEED CONTROL OF DC MOTOR USING PID AND FUZZY LOGIC CONTROLLER

P.Balaram[1],P.Tulasi ram[2], D.Akhila[3], K.Vamsi[4]
[1,2,3,4]*Student, Department of Electrical and Electronics Engineering, Aditya Institute of Technology and Management, Tekkali, India*

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ABSTRACT

In this project, we have designed a DC motor whose speed is controlled by PID controller and Fuzzy logic controller . The Proportional , Integral and Derivative gains are adjusted manually till the appropriate response will obtain. In case of FUZZY, controller is designed according to the all 25 rules for auto-tuning the each parameters. The study shows the comparison between responses of PID and Fuzzy. The ultimate result will be speed control of DC motor using Fuzzy logic controller will precise.

INTRODUCTION

We have different types of methodologies in the field of automation, in which we have mainly used Proportional Integral Derivative (PID) controllers. This project proposes a new methodology for tuning PID controllers for processes with the underdamped response. It allows determining the proportional, integral, and derivative gains through a fuzzy inference system. The main objective of this methodology is to improve the performance of the system in terms of setpoint tracking, i.e. to decrease the rise time, overshoot, and response time. The fuzzy logic controller was adopted to improve PID control and it seems appropriate to use it also in this case. context, since the design of the tuning procedure, can be done intuitively, reflecting the typical experience of the operator.

MODELLING OF THE DC MOTOR

The electrical equivalent of a DC motor is illustrated below. It can be represented by a voltage source (V) in series with an inductance (L) and a resistor (R) and this in series with an induced voltage (e) of opposite direction to our voltage generator. The induced voltage is generated by the rotation of the electric coil through the fixed flux lines of the permanent magnets. This voltage is called electromotive force.

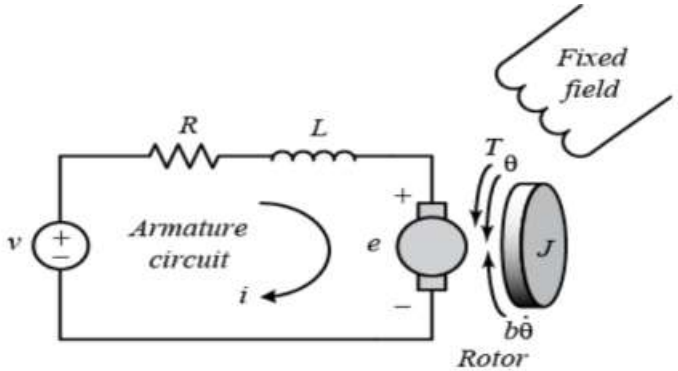

Fig: DC Motor Representation

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In general, the torque generated by a DC motor is proportional to the armature current and the magnetic field strength. Suppose the magnetic field is constant and therefore the motor torque (T) is proportional to armature current (i) alone by a constant factor (Kt) called the torque constant, as shown in equation (1). This is called an armature-driven motor.

$$T = Kt \times i \quad \text{_____(1)}$$

The back electromotive force emf (e) is proportional to the angular velocity of the shaft (θ) by a constant factor (Kb) called the electromotive force constant, as shown in Figure 1.

$$e = Kb \times \theta \quad \text{_____(2)}$$

We derive the following governing equations based on Newton's second law in equation (3) and Kirchhoff's mesh law in equation (4).

$$J\ddot{\theta} + b\dot{\theta} = Kt \times i \quad \text{_____(3)}$$

$$La \times di/dt + Ra \times i = V - Kb \times \dot{\theta} \times b \quad \text{_____(4)}$$

(J) is the moment of inertia of the rotor, (b) is the viscous friction constant of the motor, (La) is the electrical inductance, (Ra) is the electrical resistance, and (V) is the voltage source. By applying the Laplace transform, the modeling equations can be expressed in terms of Laplace variables as follows as shown in equations (5) and (6).

$$s(J.s + b) \times \Theta(s) = Kt \times I(s) \quad \text{_____(5)}$$

$$s(La.s + Ra) \times I(s) = V(s) - Kb \times s.\Theta(s) \quad \text{_____(6)}$$

The open-loop transfer function below was obtained by eliminatig I(s) in equations (7), where the rotational seed is considered as the output and the armature voltage as the input.

$$G(s) = \frac{\Theta(s)}{V(s)s} = \frac{Kt}{(j.s + b)(La.s + Ra) + K \times K} \frac{rad/sec}{V} \quad \text{_____(7)}$$

Parameters	Value
Torque constant (Kt)	0.5 Nm/A
Electromotive force constant (Kb)	1.25 V/rad/sec
Electrical resistance (Ra)	5 Ω
Viscous friction constant of the motor (b)	0.008 N.m/rad/sec
Electrical inductance (La)	0.2 H
Moment of inertia of the rotor (J)	0.1 kg.m²

Table: DC Motor Parameters

Using the parameters of our engine which are in the table above in equation (7), we obtain the following equation:

$$G(s) = \Theta(s)/V(s) = \frac{0.5}{(0.1s + 0.008)(0.2s + 5) + 0.5 \times 1.25} \frac{rad/sec}{V}$$

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We can then translate the previous equation by the Simulink diagram shown below :

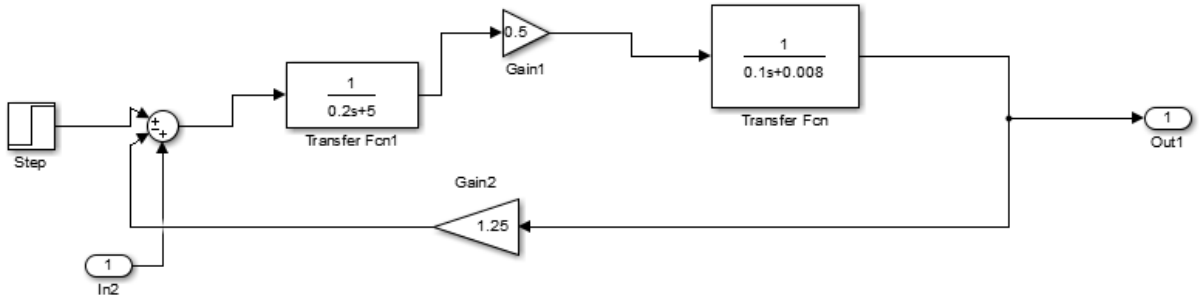

Fig: SIMULINK representation of DC motor

PID CONTROLLER

The function of the PID controller is mainly to adjust an appropriate proportional gain (KP), integral gain (KI), and differential gain (KD) for optimal control performance. There are several methods to adjust the PID parameters, in our case, we will use the "Manual adjustment" method. Manual tuning of the PID controller is done by setting the reset time to a maximum value and the rate to zero and increasing the gain until the loop oscillates at a constant amplitude. First, we set the ki and KD values to zero. We ramp up until the loop output oscillates, so KP should be set to about half that value for a "quarter amplitude decay" response. Then ki is increased until any mismatch is corrected in sufficient time for the process. However, too high a value will cause instability. Finally, Kd is increased, if necessary, until the loop is fast enough to reach its set point after a load disturbance. However, an excessive increase in Kd will cause over-response and overshoot. Fast tuning of the PID loop usually results in a small overshoot to reach the setpoint faster; however, some systems cannot accept overruns, in which case an over-damped closed-loop system is required, which will require tuning well below half the setting that was causing the oscillation. The values obtained are: Kp = 30, ki=12 ,Kd=1.

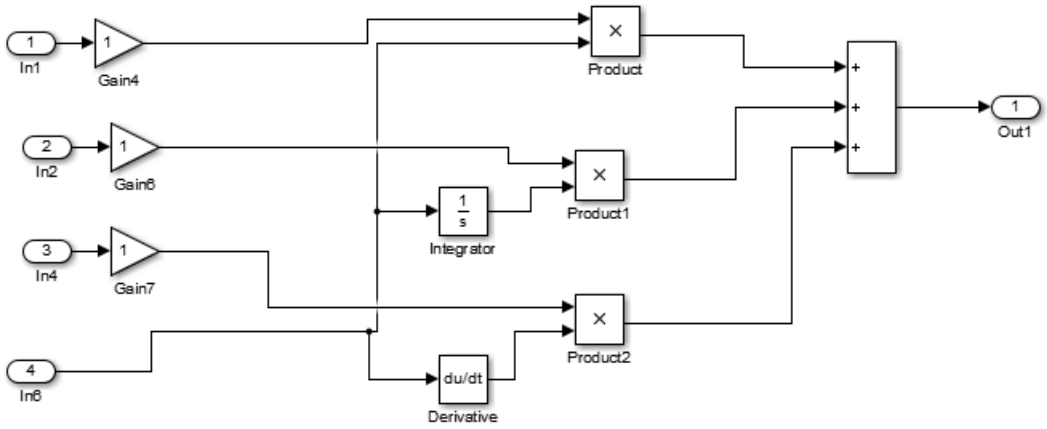

Fig: SIMULINK diagram of the PID controller

Let us put this PID controller design in series with our DC motor, we then obtain the SIMULINK diagram below :

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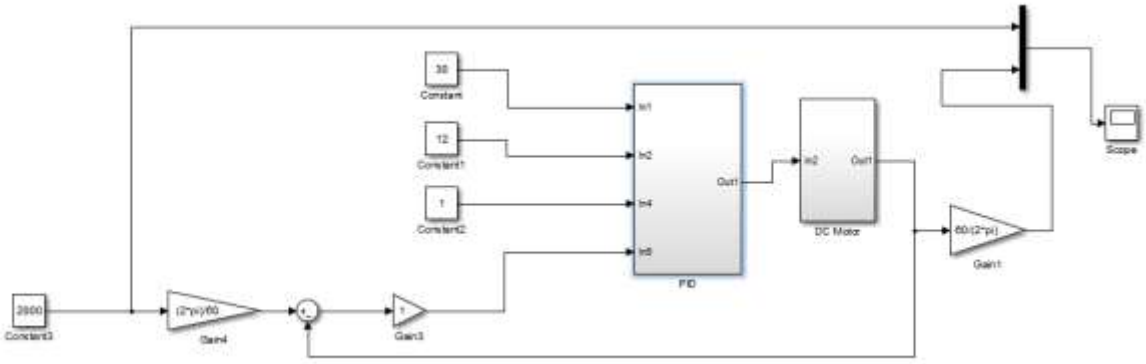

Fig: SIMULINK diagram of the DC Motor using PID controller in series

FUZZY LOGIC CONTROLLER

Fuzzy logic controller (FLC) is the most active research area in the application of fuzzy set theory. Fuzzy reasoning and fuzzy logic. A control system is an agreement of physical components designed to alter an other physical system. The output of the physical system under control is adjusted by the help of an error signal. The difference between the actual response (calculated) of the płant and the desired response gives the error signal. For obtaining satisfactory responses and characteristics for the closed-loop control system, an additional system, called as compensator or controller, can be added to the loop. The basic block diagram of the closed-loop control system is shown in Figure 1. The fuzzy control rules are basically IE-THEN rules.

FUZZY CONTROL DESIGN

In designing a fuzzy logic controller, the process of forming fuzzy rules plays a vital role. There are four structures of the fuzzy production rule system (Weiss and Donnel, 1979) which are as follows:

1. A set of rules that represents the policies and heuristic strategies of the expert decision-maker.
2. A set of input data that are assessed immediately prior to the actual decision.
3. A method for evaluating any proposed action in terms of its conformity to the expressed rules when there is available data.
4. A method for generating promising actions and determining when to stop searching for better ones

The various steps involved in designing a fuzzy logic controller are as follows:

Step 1: Locate the input, output, and state variables of the plane under consideration. I

Step 2: Split the complete universe of discourse spanned by each variable into a number of fuzzy subsets, assigning each with a linguistic label. The subsets include all the elements in the universe.

Step 3: Obtain the membership function for each fuzzy subset.

Step 4: Assign the fuzzy relationships between the inputs or states of fuzzy subsets on one side and the output of fuzzy subsets on the other side, thereby forming the rule base.

Step 5: Choose appropriate scaling factors for the input and output variables for normalizing the variables between [0, 1] and [-1, I] interval.

Step 6: Carry out the fuzzification process.

Step 7: Identify the output contributed from each rule using fuzzy approximate reasoning.

Step 8: Combine the fuzzy outputs obtained from each rule.

Step 9: Finally, apply defuzzification to form a crisp output.

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The Simulink diagram of our MCC in series with the fuzzy PID controller is shown in the following figure:

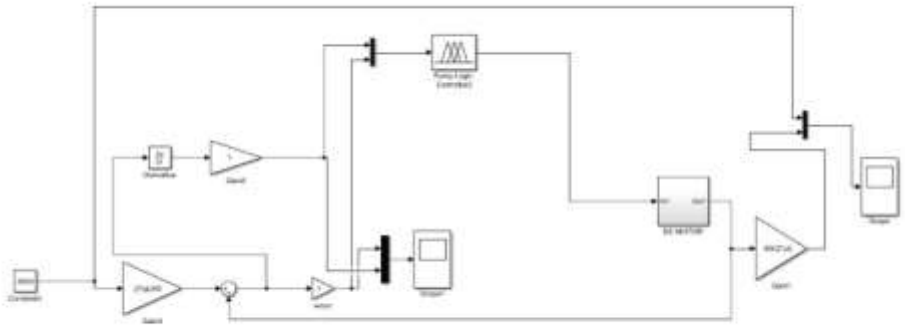
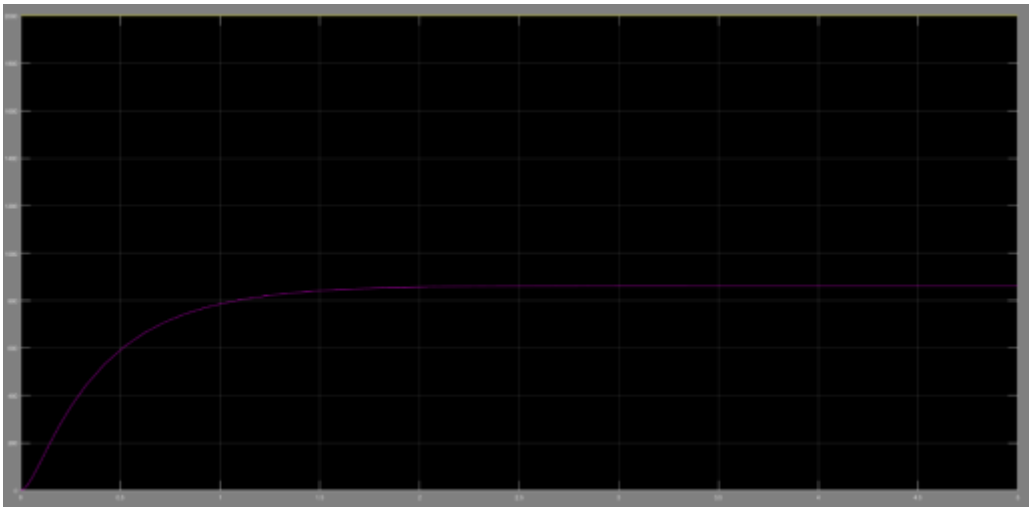


Fig: Simulink diagram of the DC motor in series with a Fuzzy Controller

SIMULATION

1. SYSTEM WITHOUT USING PID CONTROLLER

Before performing the control, we must first see the motor output in rpm. In this case, the step response does not reach the desired value, the rise time is too high and the steady state error is very high.



2. SYSTEM USING PID CONTROLLER

In this case, we observed that the step response reaches the desired value, with a very short rise time with an appropriate settling time. Steady-state error, in this case, is very low.

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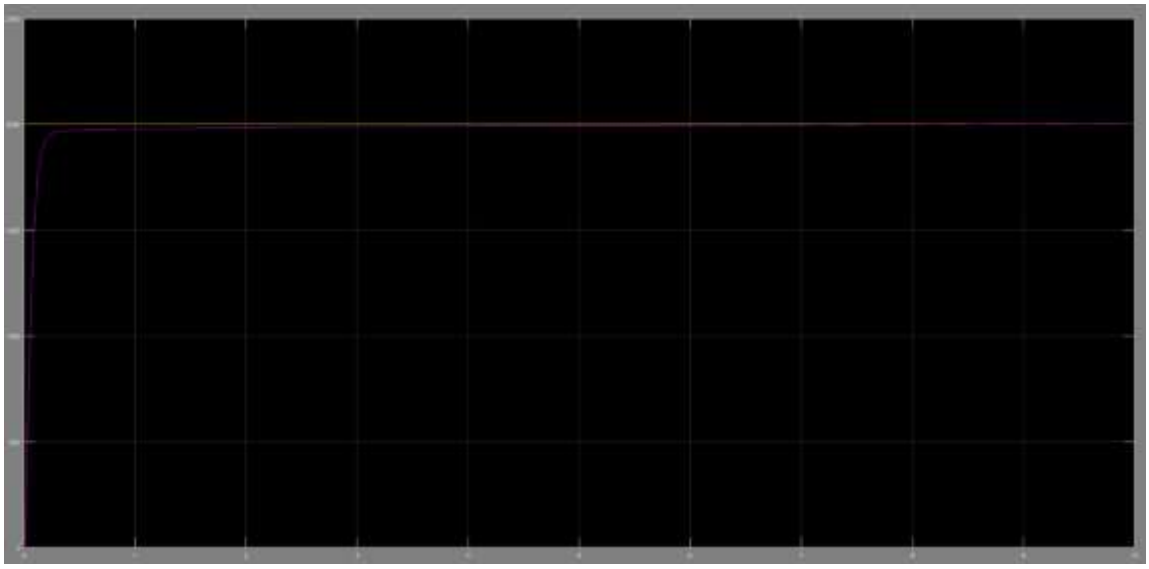

3. SYSTEM USING FUZZY CONTROLLER

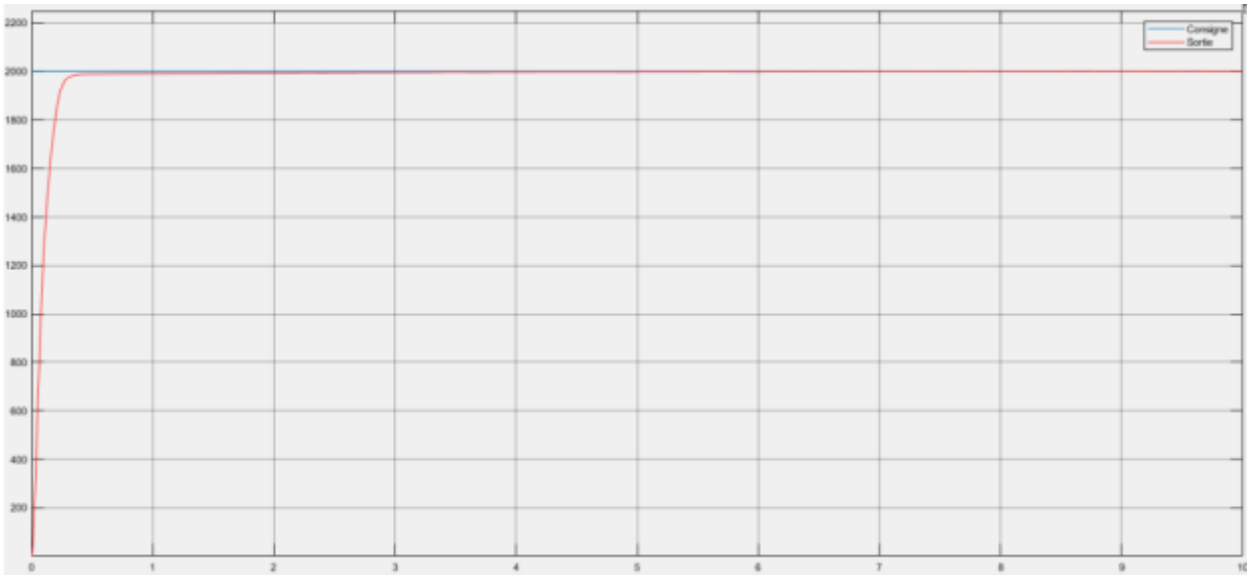

Fig : DC output with Fuzzy controller

CONCLUSION

From the table we notice that,

- Overshoot is zero in case of both PID controller and Fuzzy logic controller.
- PID controller shows the better performance than using Fuzzy controller in terms of rise time.
- If we not used any controller, the steady state error will be very large. Using PID it will be negligible and zero with Fuzzy controller.
- In case of settling time, Fuzzy controller offers precise value than with using PID controller.

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Parameters	Using PID	Using Fuzzy
Overshoot (%)	0 %	0
Rise time (sec)	55.791 ms	170.16 ms
Steady state error	1.5	0
Settling time (sec)	1.19	0.274

Table: Comparison between step responses of PID and Fuzzy

DC motor alone offers unreliable performance. The classical PID is faster in rise time than the fuzzy but it takes much longer to reach its final value. The fuzzy has the best compromise between rise time and response time, it also offers a very accurate output.