

DESIGN AND IMPLEMENTATION OF SPEED CONTROL OF DC MOTOR USING WITHOUT CONTROLLER & WITH PI CONTROLLER MPC CONTROLLER

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Abstract— In this paper the Growing need of industry for higher productivity is placing new demands on mechanisms connected with electrical motors. There are three methods for speed control of a DC motor without a controller, with a Proportional-Integral (PI) controller, and a Model Predictive Control (MPC) controller. The objective is to compare the performance of these approaches in terms of speed regulation, response time, and efficiency. The first method investigates a basic open-loop control strategy where speed is controlled by varying the applied voltage to the motor. The second method employs a PI controller to regulate motor speed by adjusting the input voltage based on the difference between the desired and actual speeds. Lastly, the third method utilizes an MPC controller, which employs a predictive model of the system dynamics to optimize control actions over a finite time horizon.

Keywords— DC Motor, PI Controller, MPC Controller

1. INTRODUCTION:

Nowadays DC Motors are widely used in many industrial applications, home appliances, robot manipulators, rolling mills, and steel mills. In industrial appliances it is speed control of DC motors is required. This paper the comparison between the without a controller, PI controller, and MPC controller for which MATLAB /

SIMULINK software has been used. A close loop controller known as a PI controller is frequently used to regulate the speed of DC motors. P-I controllers are capable of producing zero steady-state error whenever the reference speed changes stepless. Model predictive control (MPC) has been used in the chemical and oil industries since the 1980s where the desired reference does not change frequently. This control technique became popular and later was introduced in power electronics. MPC controller is an advanced method for speed regulation of any electrical drive The MPC controller has a better performance in the speed controlling of DC Motor while compared with another controller comparing with other controller.

2. DC MOTOR:

A DC motor, or direct current motor, is a type of electrical machine that converts electrical energy into mechanical energy through the interaction of magnetic fields.

2.1 MODELING OF SEPARATELY EXCITED DC MOTOR:

The DC motor serves as a fundamental torque transducer, where the torque produced on the motor shaft is directly proportional to both the field flux and the armature current. When modeling any physically active element like a DC motor, it's imperative to derive its

transfer function, which encapsulates the mathematical representation of the element. By testing an idealized mathematical model under various input conditions and fine-tuning it with controllers, we can effectively capture the dynamic behavior of the system.

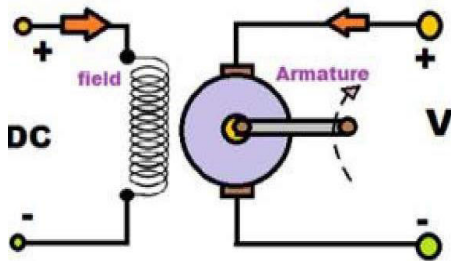


Fig 2.1. Separately excited DC motor

The input is the armature voltage

V = Armature Voltage (volts)

R = Armature Resistance (Ω)

L = Armature Inductance (H)

I = Armature current (amp)

b = damping (friction)

coefficient V_b = Back emf (volts)

T = Torque

2.2 Equations:

To derive the Transfer Function of the DC Motor between motor voltage and rotational speed.

Motor torque T_m is related to armature current I by the constant factor K_t :

$$T_m = K_t i \dots\dots\dots(1)$$

$$em = K_e \theta \dots\dots\dots(2)$$

According to Newton’s Law combined with Kirchhoff’s Law, the mechanical equation of motion for the motor is given by:

$$J \ddot{\theta} + b \dot{\theta} = K_m i - T_L \dots\dots\dots(3)$$

$$L_m \frac{di}{dt} + R_m i = V - K_M \dot{\theta} \dots\dots\dots(4)$$

Assuming load torque $T_L=0$ and friction torque $T_f=0$ for simplicity, the above equations can be simplified. Using Laplace Transforms, we get:

$$S(Js + b) \theta (s) = K_m I(s) - T_L (s)$$

$$(L_m s + R_m) I s = V s - K_m s\theta$$

Here Transfer function describes the relationship between voltage and speed in the motor.

$$\theta (s) /V(s) = K_m / (Js+b (Lm s+ Rm)+ K_m$$

2.3 Transfer Function of DC Motor Block Diagram:

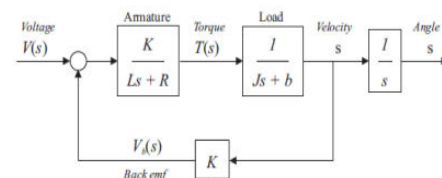


Fig.2.3. Block diagram of DC Motor with Transfer Function

2.4 Parameters:

DC Motor	5hp 1750 rpm Supply voltage=240v $V_f = 150$
Moment of inertia of the rotor (J_m)	0.054kg.m ²
The damping ratio of the mechanical system (b_m)	0.04 Nms
Electromotive force constant ($K=K_e=K_t$)	0.55 Nm/Amp
Electric resistance (R)	0.2 Ω
Electric inductance (L)	0 H

Table 2.4. Parameters of DC Motor transfer function

3. WITHOUT CONTROLLER:

In this simulation diagram, the IGBT is used as a switch for the best performance of speed control, fast switching. We are using 5HP, 240V, and 1750 rpm separately excited DC motors, and additionally, 150V DC supply is given to the field. Here we see taken constant load of the circuit considering its load of 10kg. In this simulation, there are five motor parameters monitored by using displays, such as armature current, electrical torque, field current, speed w (rad/sec), and speed of the DC Motor.

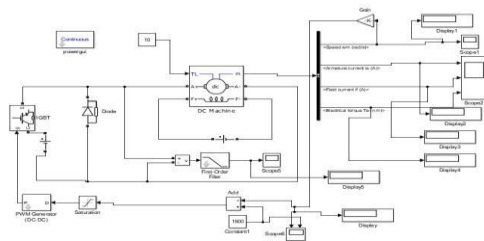


Fig 3. Simulation diagram of Speed control of DC Motor without controller

Here the rotation speed output is in radians per second. Here to convert rad/sec to rpm we use a $60/\pi$ value in this model. The diode is to maintain a continuous current path in the armature. The saturation block is a fundamental element used to limit the amplitude of signals within a specified range. The pwm dc-dc generator is more effective at controlling motor speeds at low rpm than linear methods. Hence IGBT is connected to a DC Motor.

4. Proportional-Integral (PI) Controller:

A Proportional-Integral (PI) controller, often referred to as a PI controller, is a type of feedback control system widely used in engineering and industrial applications for regulating processes and systems. It is a combination of two basic control strategies: proportional control and integral control.

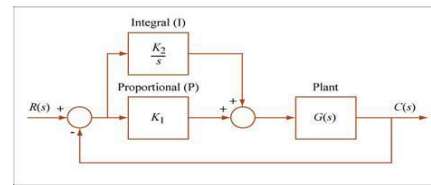


Fig.4. Block diagram of PI speed controller

4.1 Transfer Function code:

We can define a PI controller in MATLAB using a transfer function model directly, for example:

$$J = 0.054;$$

$$b = 0.04;$$

$$K = 0.55;$$

$$R = 0.2;$$

$$L = 0;$$

$$s = tf('s');$$

$$P_motor = K / ((J*s+b)*(L*s+R)+K^2)$$

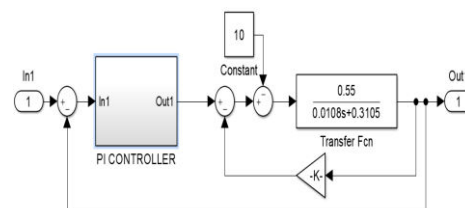
$$0.55$$

$$P_motor = \frac{0.55}{0.0108 s + 0.3105}$$

Continuous-time transfer function.

4.2 Tuning of PI Controller:

By using the above parameters and code we tuned the PI controller with the transfer function of speed control of DC Motor.



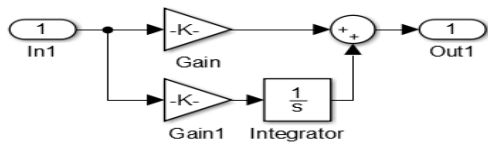


Fig.4.2.1. Transfer Function with PI controller simulation diagram

The proportional and integral term reduces the rise time and eliminates the steady state error, but it increases overshoot. After running the necessary code in MATLAB, the response has been generated.

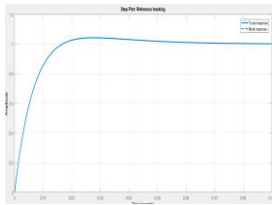


Fig.4.2.2. Step response of PI Controller

It is observed from the graph that the rise time is 0.0107 seconds, settling time is 0.049 seconds. Steady-state error is 0(zero). It will eliminate the steady state error to zero. The controller increased the overshoot.

4.3 Simulation of Speed control of DC Motor with PI controller:

In this model, the IGBT is used as a switch for the best performance of speed control, fast switching, and low losses. Here 5HP, 240V, 1750 rpm separately excited DC motor and additionally 150V DC supply are given to the field. The constant load of the circuit considers its load of 10kg constantly. In this simulation, there are five motor parameters monitored by using displays, such as armature current, electrical torque, field current, speed ω (rad/sec), and speed of the DC Motor.

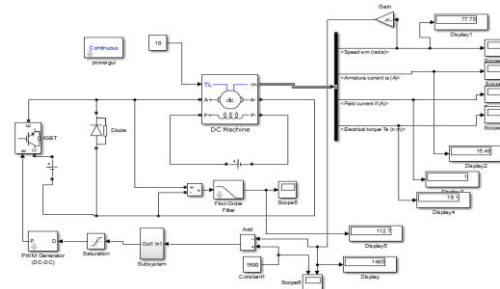


Fig.4.3. Simulation Block Diagram with PI Controller

Here the rotation speed output is in radians per second. We need this in RPM to give feedback to the PI controller. Hence we use a $60/\pi$ converter for this purpose. The diode is to maintain a continuous current path in the armature. The PI controller gain is chosen by the trial-and-error method. The PWM dc-dc generator is more effective at controlling motor speeds at low RPM than linear methods when the carrier signal voltage is more than the reference voltage that time IGBT goes to OFF or 0 state.

5. MPC Controller

Model Predictive Control (MPC) is an advanced control strategy used in various industries such as manufacturing, automotive, aerospace, and process control. It is a type of control algorithm that predicts future system behavior based on a mathematical model of the system and optimize

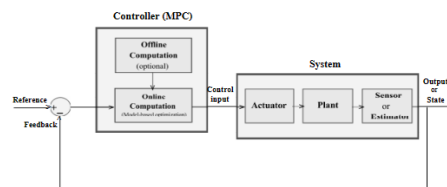


Fig.5. Block Diagram of MPC Controller

5.1 Tuning of Transfer Function with MPC Controller:

By using the above data like source code, and parameters we tuned the MPC

controller with the transfer function of the DC motor.

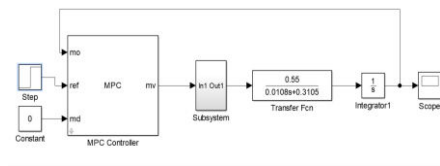


Fig.5.1. Simulation Diagram of Transfer Function with MPC Controller

In this block step input is given to reference of MPC controller, and the subsystem is taken from the model variable of the controller. Transfer function element input is connected to the subsystem and the other end is connected with the integrator; it is taken from the model output of the controller.

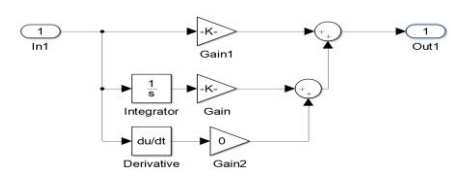


Fig.4.8. Block Diagram of Sub System

5.2 Tuning Process of MPC Controller:

By using the above tuning data we can tune the MPC controller as shown in the below figures.

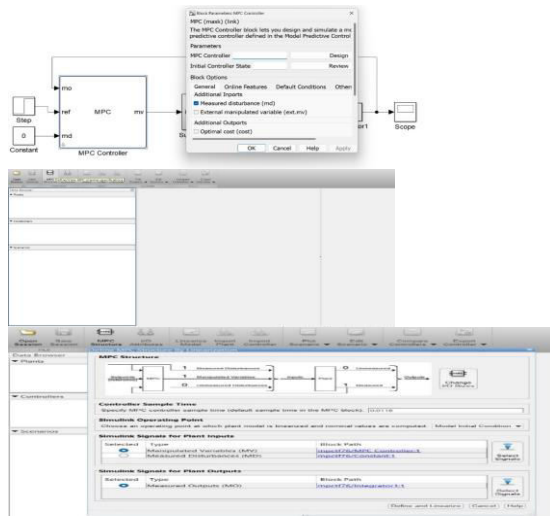


Fig.5.2. Linearization of MPC Structure

Before going to define and linearize the MPC structure we selected the controller sample time is 0.0118, the Input signal for the plant is manipulated variables (MV) and the output signal for the plant is measured output (MO).

5.3 Tuned output of MPC Controller:

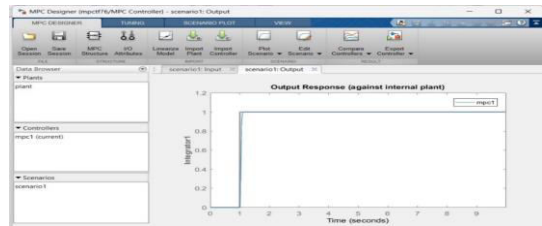


Fig.5.3.1. Output Response of MPC Structure

After defining and linearizing the MPC structure the mpc1 controller is generated and we will export the controller to the MPC controller block element.

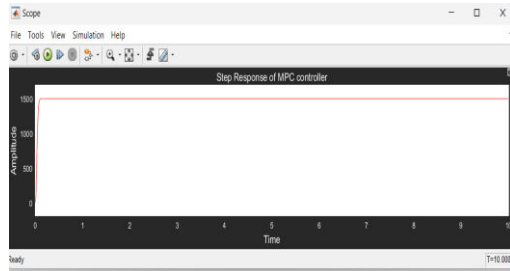


Fig.5.3.2. Step Response of MPC Controller with Kp=3.250, Ki=154.126

5.4 Speed Control of DC Motor with MPC Controller:

In this simulation model, the IGBT is used as a switch for the best performance of speed control, fast switching, and low losses. Here 5HP, 240V, 1750 rpm separately excited DC motor and additionally 150V DC supply are given to the field. To take the constant load of the circuit consider its load 10kg constantly. In that simulation, there are five motor parameters

monitored by using displays, such as armature current, electrical torque, field current, speed w (rad/sec), and speed (RPM) of the DC Motor.

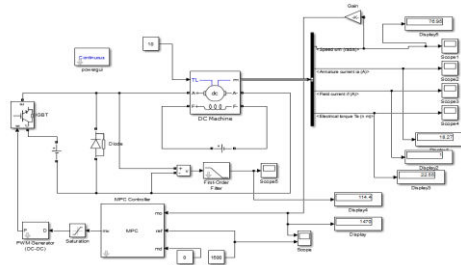


Fig.5.4. Simulation Block Diagram with MPC Controller.

Here the diode is to maintain a continuous current path in the armature. The MPC controller model output (m_o) is taken from speed (rad/sec), the Reference speed of the controller is 1500rpm, and model disturbance (MD) is zero (0) because of external disturbances like temperature, pressure, and also wind disturbances Measured variable (mv) is connected to the saturation element. The saturation block is a fundamental element used to limit the amplitude of signals within a specified range The PWM dc-dc generator is more effective at controlling motor speeds at low RPM than linear metho

6 Simulation Result:

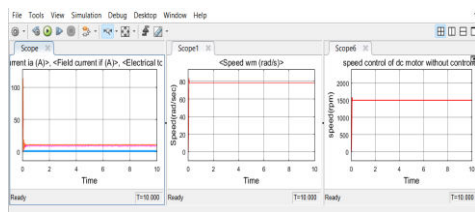


Fig.6.1. Simulation output of speed control of DC motor without controller

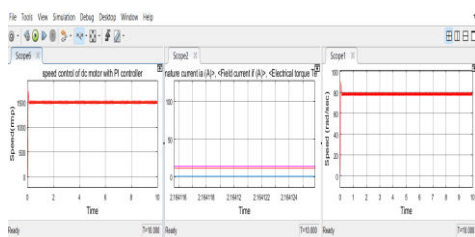


Fig.6.2. Simulation output of speed control of DC motor using PI controller

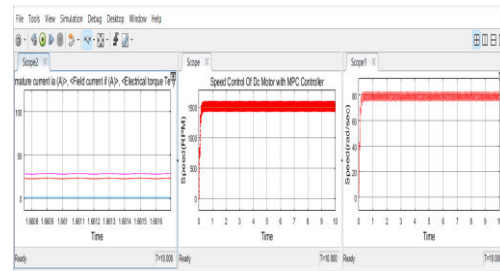


Fig.6.3. Simulation output of speed control of DC motor using MPC controller

Parameter	With- out control ler	PI control ler	MPC control ler
Speed(rpm)	1500	1485	1470
Speed(rad /sec)	78.52	77.75	76.95
Armature current	8.37	15.48	18.27
Field current	1	1	1
Electrical torque	10.33	19.1	22.55

Table 6.4. Comparisons of Speed control of DC Motor using without controller, PI controller, and MPC controller.

7 CONCLUSIONS:

In this paper, comparative studies of the performance of without controller, PI controller, and MPC controller have been studied. According to the comparison of results of the simulations, it is found that the MPC controller is better than conventional controllers like without controller and PI controller.

Hence it is concluded that the proposed MPC controller provides better performance in speed regulation, armature current, field current, and electrical torque of the DC Motor.

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