Control Systems Lab

Experiment 5

PD Control

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Contents

5.1 Objective:

To control the DC motor speed using PID controller under MATLAB Simulink environment.

5.2 Pre Requisites:

1. Mathematical modelling of DC motor.
2. Knowledge on creating the subsystem block.
3. PID Controller basics

5.3 DC Motor Model:

The mathematical equations of the DC Motor are given by the following equations,

$$\text{Electromechanical torque, } Tm = J\frac{d\mathrm{Wm}}{dt} + (\mathrm{Bm} \times \mathrm{Wm}) + \mathrm{T_L} \qquad (1)$$

$$\text{On solving equation (1), } \mathrm{Wm} = \frac{1}{J}\int\big((Tm - \mathrm{T}_L) - (\mathrm{Bm} \times \mathrm{Wm})\big)\mathrm{dt} \qquad (2)$$

Where, Wm = speed of the motor,

$$\text{Effective torque, } \mathrm{Te} = Tm - \mathrm{T}_L = \mathrm{Ka} \times \mathrm{Ia} \qquad (3)$$

$$V_{dc} - (Ia \times Ra) - L\frac{dIa}{dt} = Eb \qquad (4)$$

$$\text{Back EMF, } \mathrm{E_b} = \mathrm{Ka} \times \mathrm{Wm} \qquad (5)$$

On solving equation (3),

$$\text{We get, } Ia = \frac{1}{L}\int(Vdc - (Ia \times Ra) - (\mathrm{Ka} \times \mathrm{Wm}))\mathrm{dt} \qquad (6)$$

By applying Laplace transform for equations (2,3 & 6), the Simulink model in figure 2 is obtained.

The DC Motor specifications are given below,

Table 1: DC Motor specifications

Motor Specifications		
(J)	Moment of inertia of the rotor	0.05 kg.m^2
(Bm)	Motor viscous friction constant	0.01 N-m.s
(Ka)	Motor torque constant	0.5 V-s/rad
(R)	Armature resistance	0.5 Ohm
(L)	Armature inductance	100 mH
(Wm)	Rated motor speed	188 rpm
(V_{dc})	DC voltage source	100 V
(T_L)	Load torque	4 N-m

5.4 PID Controller:

The proportional (P), integral (I), and derivative (D) controller can be expressed mathematically as follows

$$u(t) = k_p e(t) + k_i \int_0^t e(\tau) d(\tau) + k_d \frac{de(t)}{dt} \tag{7}$$

The corresponding block diagram is given in figure 1. The control action is thus a sum of three terms referred to as proportional (P), integral (I) and derivative (D). To convert the integral and differential equation into algebraic equation controller equation 7 can also be described by the transfer function.

$$U(S) = k_p E(S) + \frac{k_i}{S} E(S) + k_d S E(S) \qquad (8)$$

The PID controller described by equation 7 or equation 8 is the ideal PID controller without any disturbances.

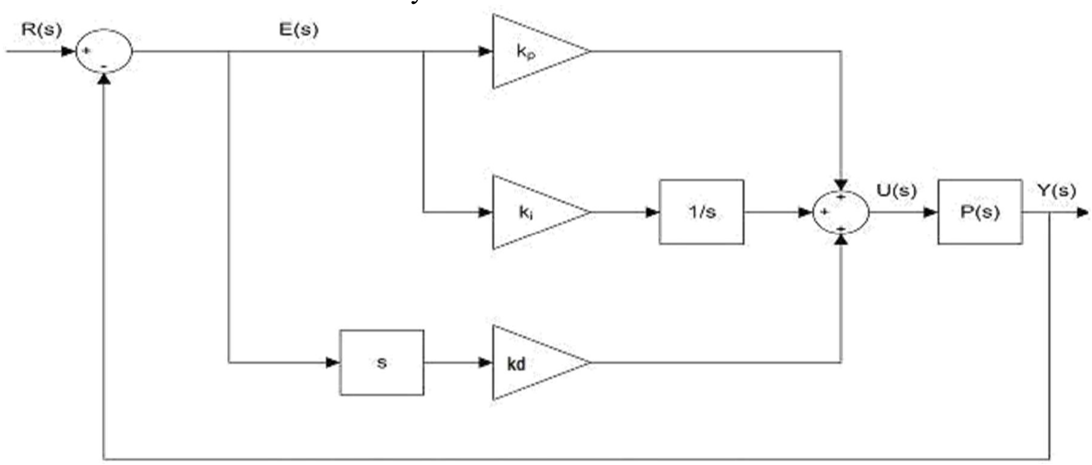

Figure 1: MATLAB Simulink model of PID controller.

5.5 Procedure to build the model with MATLAB Simulink:

Build the DC Motor model with MATLAB Simulink as shown in the figure 2.

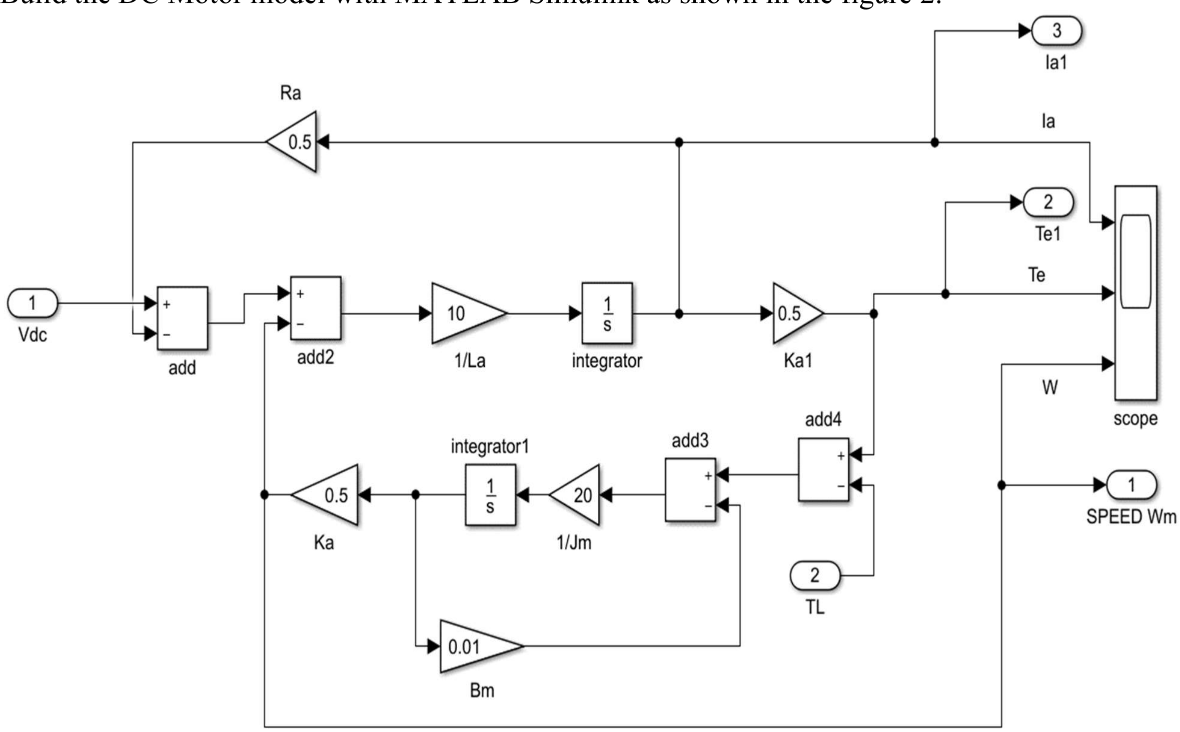

Figure 2: DC motor MATLAB Simulink model

5.6 Creating a subsystem of DC Motor and PID controller blocks:

In order to save all of these components as a single subsystem block, first select all of the blocks, then select **Create Subsystem from Selection** after right-clicking on the selected portion. Name the subsystem as DC Motor. Then delete the input and output ports and add PID controller blocks, constant blocks for reference speed and load torque and scope bloc for output. Now your model should appear as shown in figure 3. Save the model and run it to get the graph as shown in figure 4

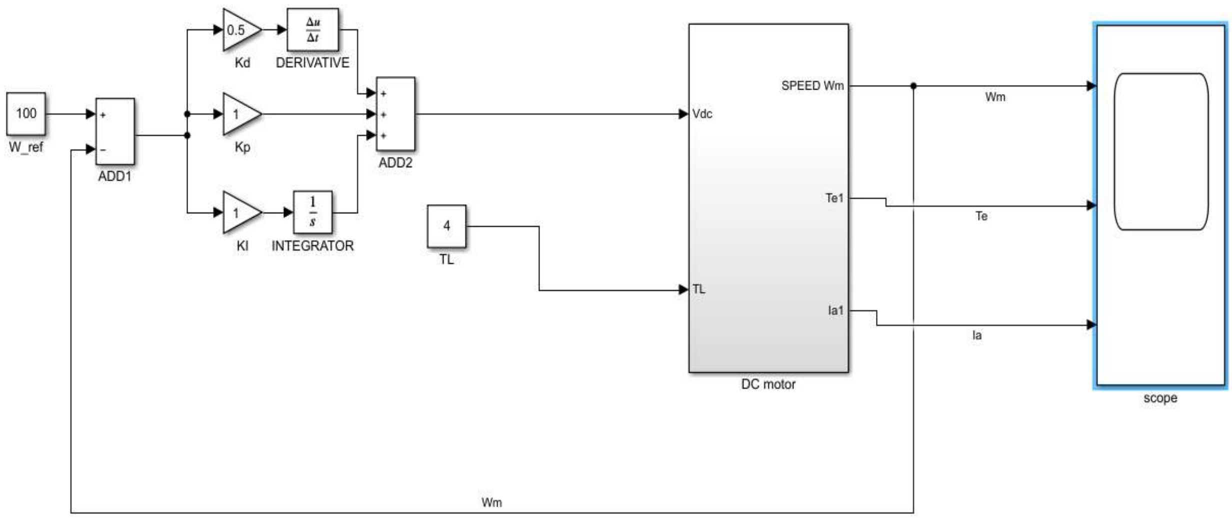

Figure 3: Single subsystem DC motor block with PID controller

5.7 Result:

Figure 4 shows the expected results of the given DC Motor with PID controller.

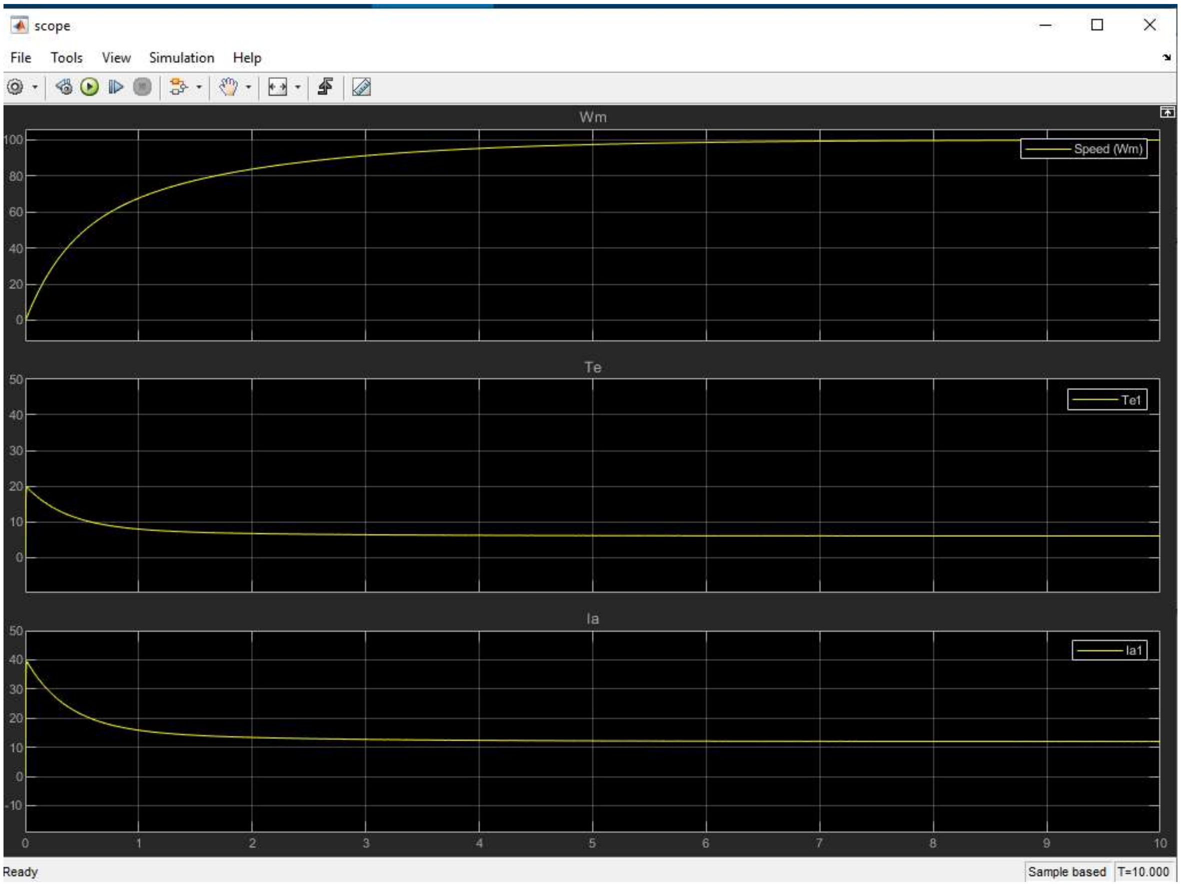

Figure 4: Expected results of DC motor responses using PID controller