EXPERIMENT-II

Modelling, Analysis and Simulation of a DC motor using MATLAB-SIMULINK

Objective: Modeling of P-controller based d.c. motor in Simulink using state space model (using differencial equations) and transfer functions based model.

Equipment/Software: Matlab-Simulink.

Theory: This experiment will illustrate about the modeling and design of separately excited d.c. motor using state space model and transfer function block diagram. Thereafter, a P-controller will be designed to control the speed of the motor.

Two methods are mainly used to control the speed of d.c. motor which are briefly discussed below.

A. **Voltage control method**
   By varying input voltage, the speed of of separately excited d.c. motor can be controlled as expressed in relation given below. ϕ (Flux/pole) is kept constant in this method.

$$\omega = K_e(V_a - I_aR) \qquad , e = V_a - I_aR = back\ emf$$
$$K_e = \frac{K}{\phi}$$

B. **Field current control**
   By decreasing/increasing the flux, the speed can be increased/decreased and vice versa. Input voltage is kept constant while flux is varied.

$$\omega = \frac{e}{\phi}$$

The **Voltage control method** will be used to control d.c. motor in this experiment.

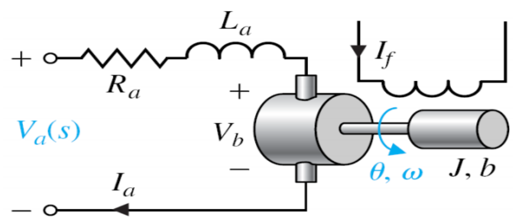

Figure 10: Circuit diagram of DC motor armature-controlled rotational actuator.

Modeling of DC motor in Simulink

1. **Basic mathematical relations**

Electro-mechanical torque, $T = K_t i$ (1)

Back-emf, $e = K_e \frac{d\theta}{dt}$ (2)

Motor shaft angular position, $$\iint \frac{d^2\theta}{dt^2} = \int \frac{d\theta}{dt} = \omega \quad (3)$$

Armature current, $$\int \frac{di}{dt} = i \quad (4)$$

2. **Model of d.c. motor** (state variables: ω, θ, i)

$$\frac{d\omega}{dt} = \frac{1}{J}(K_t i - \omega) \quad (5)$$

$$\frac{di}{dt} = \frac{1}{L}(-Ri + V - K_e\omega) \quad (6)$$

$$\frac{d\theta}{dt} = \omega \quad (7)$$

ω=speed, rotation angle=θ, i=armature cuurent, R=armature resistor, L=inductance of armature coil, J=Moment of inertia, b=Friction constant, Ke=Back-emf proportion constant, Kt=Torque constant, V =Input voltage

For dc motor:

(J)	Moment of inertia of the rotor (J)	0.01 kg.m^2
(b)	Motor viscous friction constant (b)	0.1 N.m.s
(Ke)	Electromotive force constant (Ke)	0.01 V/rad/sec
(Kt)	Motor torque constant (Kt)	0.01 N.m/Amp
(R)	Electric resistance (R)	1 Ohm
(L)	Electric inductance (L)	0.5 H

First Method: Steps to design the mathematical model of DC motor (given by equations 5-7) using set of equations (1 to 7)

- Choose number of intergrators equal to independent variables of plant called 'state variables'. For hint, see snapshots 1,2,3.

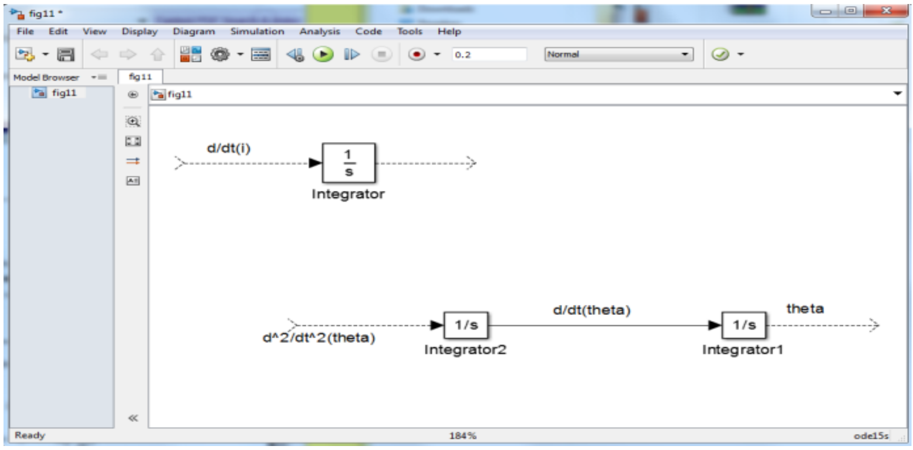

Figure 11: snapshot1

- Select and place blocks required for design, from Simulink library i.e., add, subtract, gain, integrator, step, scope etc.

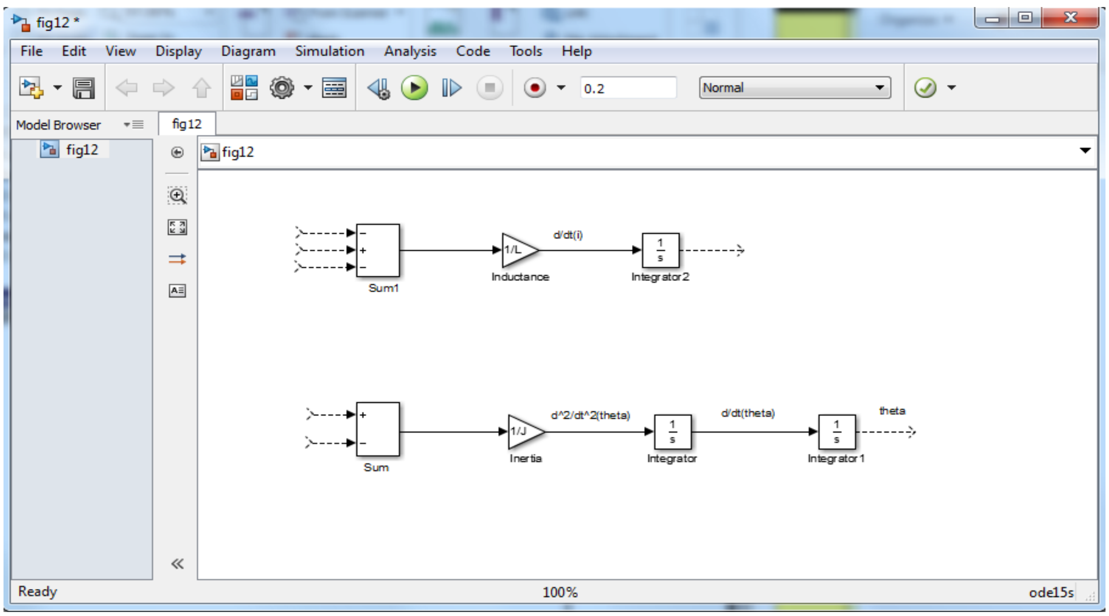

Figure 12: snapshot2

- The final simulink model is show in snapshot3. A step signal (v) is used as a input voltage source.

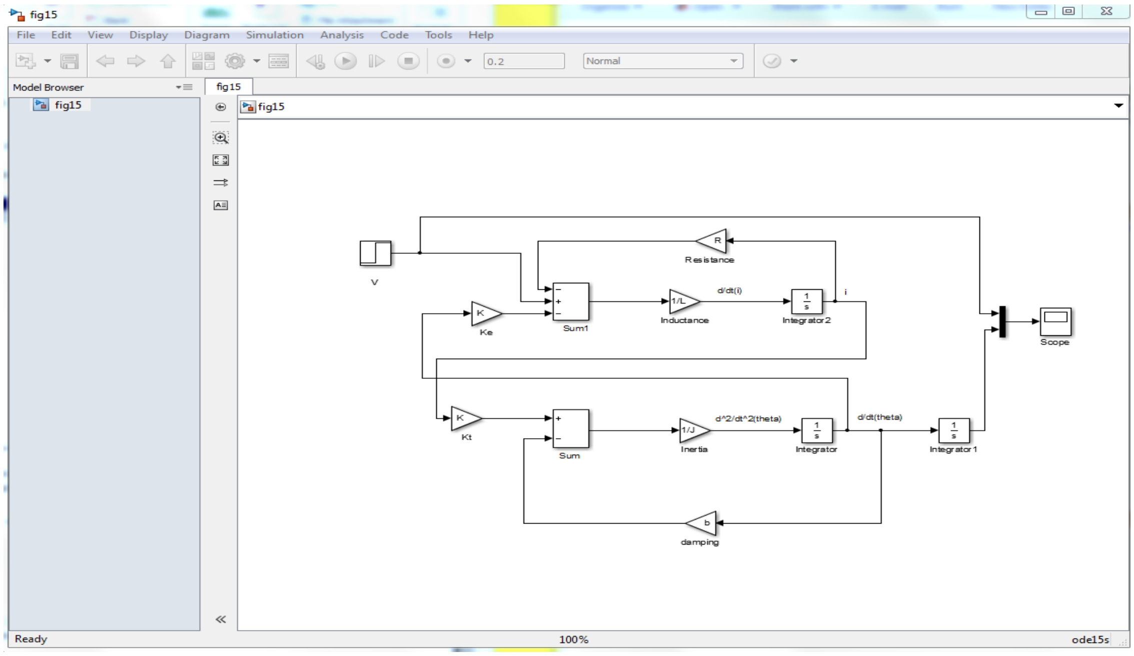

Figure. 13 snapshot3

- After compeleting model goto 'simulation' and select ode15s (stiff/NDF) and stop time 10 seconds.
- Run the model and see the step response.

Now, our motive is to control the speed of the motor using P-controller. For controlling speed (ω) of the motor, we will use a proportional controller. P controller regulates a constant gain say K_P in a feedback control system. This gain regulates the speed error, $e_\omega = \omega_{desired} - \omega$. The speed error passes from the P-controller and becomes the input voltage, v. The final simulink model of the dc motor with the proportional controller is shown in Fig.14.

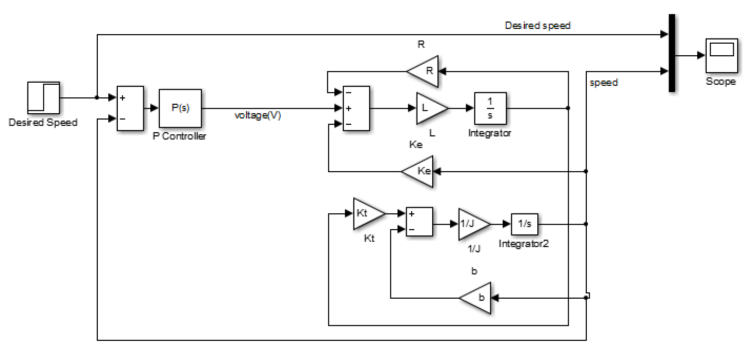

Fig.14 Speed control of DC motor using P-Controller

Set the value of the K_P of proportional controller such that you get desired speed. The desired speed and actual speed are shown in Figure below.

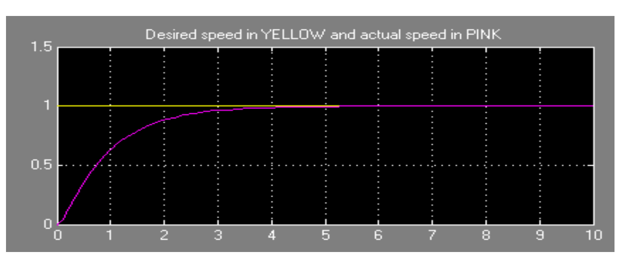

Fig. 15 Desired speed (in Yellow) and actual speed (in Pink)

Second Method: Modelling and control of the DC motor using transfer functions

Using Laplace transform, the model represented by equations (5) to (7) can be modeled as shown below. Use transfer function block of simulink and prepare simulink model as shown in Fig.16.

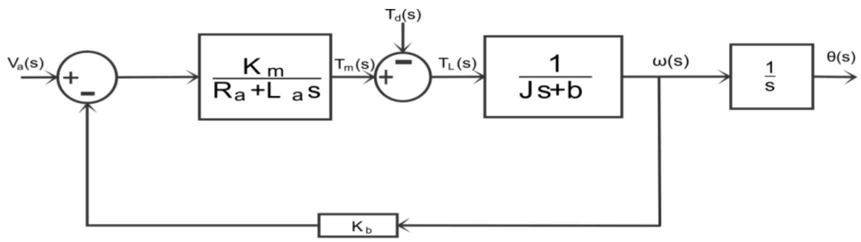

Figure 16: Basic block diagram of the armature-controlled DC motor.

Now, use P-Controller to control the speed of the motor. See the Fig.17 for designing your final model in simulink with P-controller.

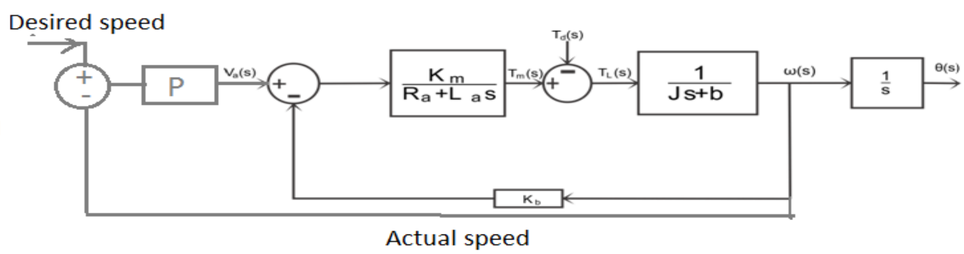

Figure 17: P-Controller based speed control of dc motor

Prepare the Table-I using First Method of the speed control of motor.

Table-I

Parameters	**Values**
Settling Time of speed	
Value of the Kp	
Error between desired and actual speed	
Is there any speed overshoot or undershoot?	Yes or No

POST LAB WORK: Use the linear dynamic model of the dc-dc boost converter given below,

$$\frac{di}{dt} = \frac{1}{L}(V_{in} - i * r_L - (1 - D) * v + d * V)$$

$$\frac{dv}{dt} = \frac{1}{C}((1 - D) * i - d * I - \frac{v}{R})$$

The inductor current (i) and the output voltage (v) are the state variables. ‘d’ is the control input. Vin is input voltage. V is steady state output voltage. I is the steady state inductor current. D is the steady state duty.

Design a P-Controller to control output voltage of the converter using First Method.

Note: Follow the first method and make a simulink model of boost converter using linear dynamic model. As we want to control output voltage (v). Pass the difference of the desired output voltage (use step signal) and actual output voltage (v) through P-controller. The output of the P-controller will be control input (d).

Also, V is different from v and I is different form i also. Use the parameters given in Table-II for simulation.

Table-II

Parameters	Values
Vin	50 V
L, C	1 mH, 500 mF
R and r_L	100 Ohms, 0.05 Ohms
V	100 V
Duty, D	0.5
Inductor current	I=V/(R(1-D))

Prepare the Table-III given below,

Table-III

Parameters	**Values**
Value of the Kp	
Settling time of voltage	
Error between desired and actual voltage	
Is there any speed overshoot or undershoot?	Yes or No