Permanent Magnet DC Machine Simulation in MATLAB Simulink

PMDC machines are found in a wide variety of low-power applications. The field winding is a permanent magnet. Permanent magnets offer a number of useful benefits such as, they do not require external excitation, less space requirement and they are cheaper. The equivalent circuit of permanent magnet dc machine is as in fig. 1. and the equations are given by (1), (2) and (3).

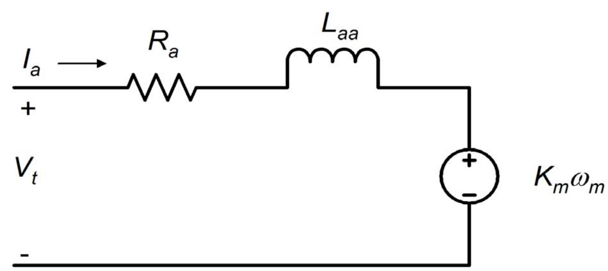

Fig. 1 equivalent circuit of a permanent-magnet dc machine.

$$V_t = I_a R_a + L_{aa}\frac{dI_a}{dt} + K_m\omega_m \tag{1}$$

$$T_e = K_m I_a \tag{2}$$

$$J\frac{d\omega_m}{dt} = T_e - T_L - B_m\omega_m \tag{3}$$

Where V_t DC source voltage (6V)

I_a Armature current (A)

R_a Armature resistance (7Ω)

L_{aa} Armature inductance (120mH)

K_m Torque constant (0.0141 V.s/rad)

ω_m Motor speed (rpm)

T_e Electromagnetic torque (Nm)

T_L Load torque (Nm)

B_m Constant (6.04 x 10^{-6} N.m.s)

J Inertia constant (1.06 x 10^{-6} Kg. m^2)

Equations (1), (2) and (3) can be re-arranged as in (4) and (5) (for construction of the block diagram)

$$\frac{dI_a}{dt} = \frac{1}{L_{aa}}(Vt - I_a R_a - K_m\omega_m) \tag{4}$$

$$\frac{d\omega_m}{dt} = \frac{1}{J}(T_e - T_L - B_m\omega_m) \tag{5}$$

Steps for construction of Permanent Magnet DC (PMDC) machine model in MATLAB Simulink

1. Open a new window for creating the model, drag the following blocks required for the construction.

Menu	Block
Sources	Constant
Math Operations	Sum
Math Operations	Gain
Continuous	Integrator
Sinks	Scope

2. Arrange the blocks in the order shown in Fig. 2 (Duplicate blocks wherever required). Consider T_L (load torque) initially to be zero.

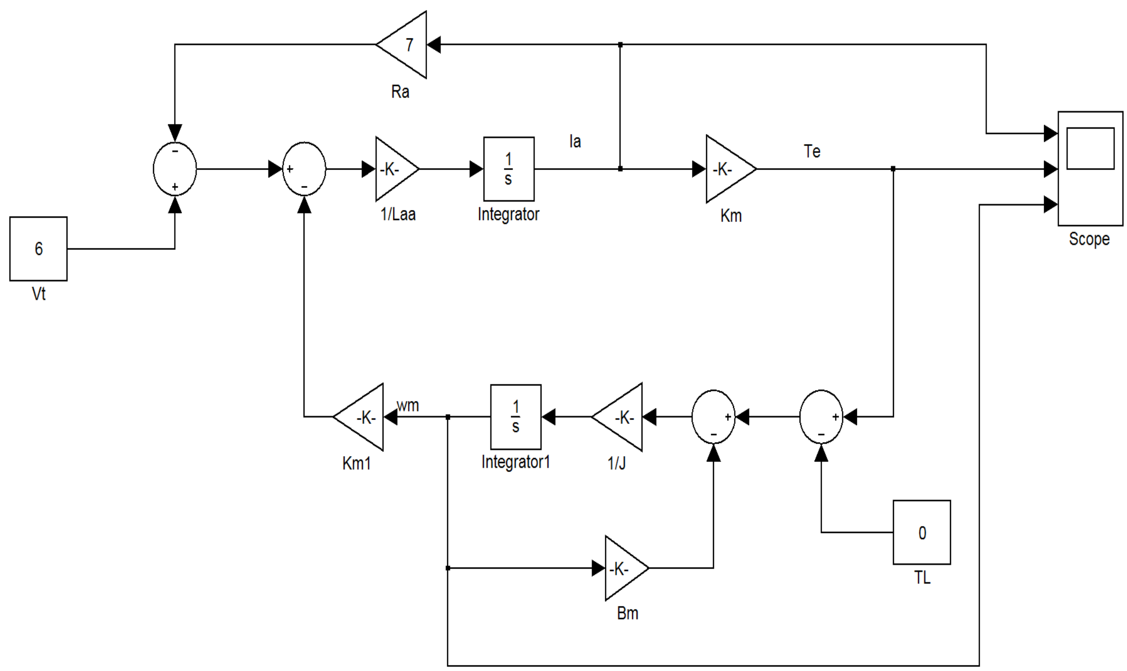

Fig. 2 Simulation diagram of permanent-magnet dc machine under no load.

3. Set the following simulation parameters

Stop time: 0.5s

Type: Variable-step

Ode45 (Dormand-Prince)

Max step size: 0.01s

Relative tolerance: 1e-7

4. Run the simulation. Set the range of the first trace from 0 to 0.7, second trace from 0 to 0.01 and the third trace from 0 to 400. The traces on the scope are the armature current (I_a), electromagnetic torque (T_e) and the motor speed (ω_m). The graph looks like as shown in fig. 3.

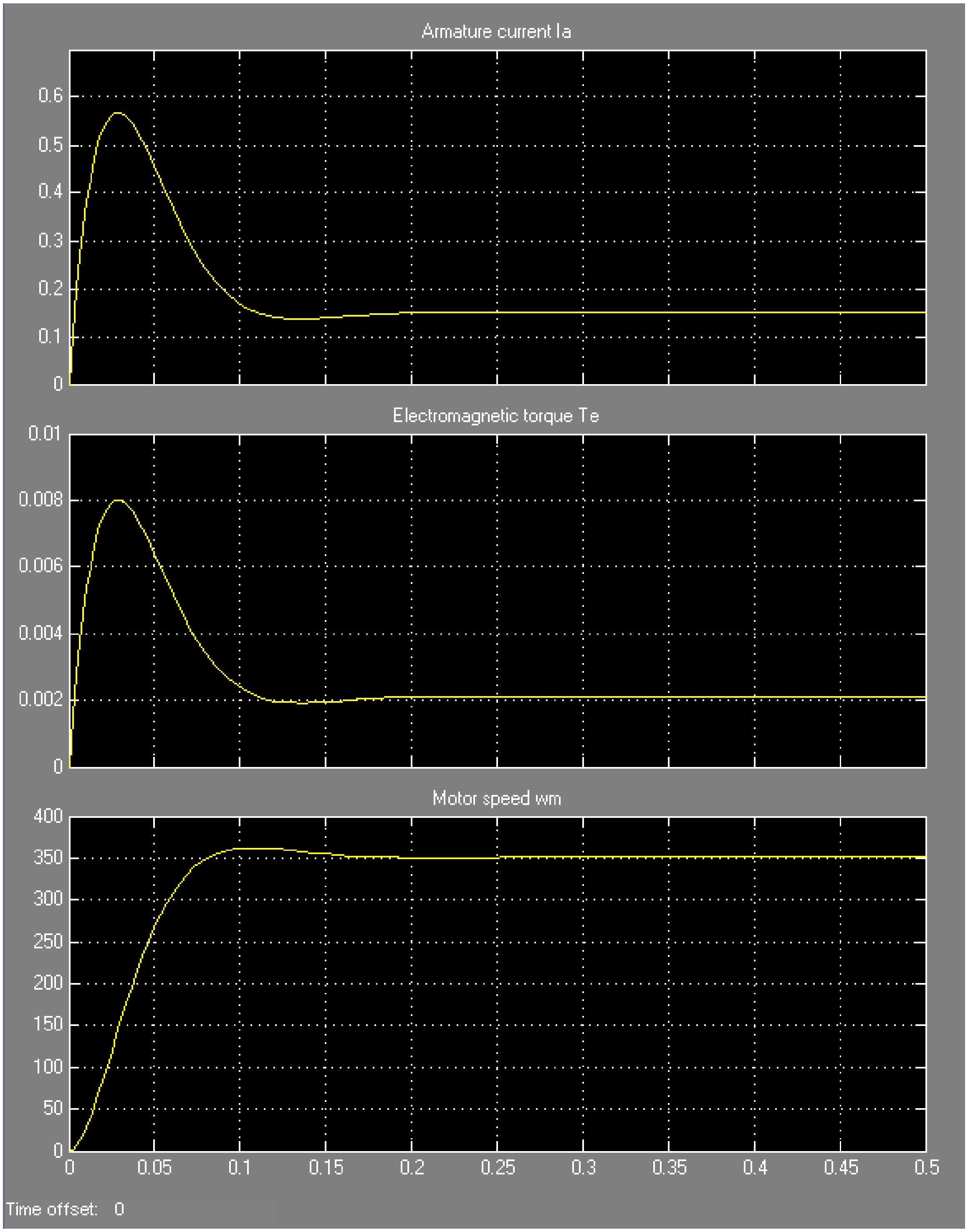

Fig. 3 Simulation results of permanent-magnet dc machine under no-load.

5. In the above simulations, the simulation time was 0.5s and the load torque (T_L) was zero. At 0.5s apply a ramp load in such a way that the speed drops to zero at 1s. Following are the steps for applying the ramp load:

(i) Drag the **switch** block from the **Signal Routing** menu. Flip the block. Double-click on the block to open the block parameters.

(ii) Select criteria for passing first input to **u>= Threshold**. Select the threshold value to 0.5. Enable zero crossing detection.

(iii) Drag the **clock**, **constant** and **ramp** blocks from the source menu. Flip the blocks and connect as shown in fig 4.

(iv) Set the ramp parameters as follows:

Slope: 0.025

Start time: 0.5

Initial output: 0

(v) Change the **Number of axes** to 4 in the scope block and connect the load torque to the 4th input of the scope block.

(vi) Change the simulation time to 1s and run the simulation. Set the range of the first trace from 0 to 1, second trace from 0 to 0.015, third trace from 0 to 400 and fourth trace from 0 to 0.015. The graph looks like as shown in fig. 5.

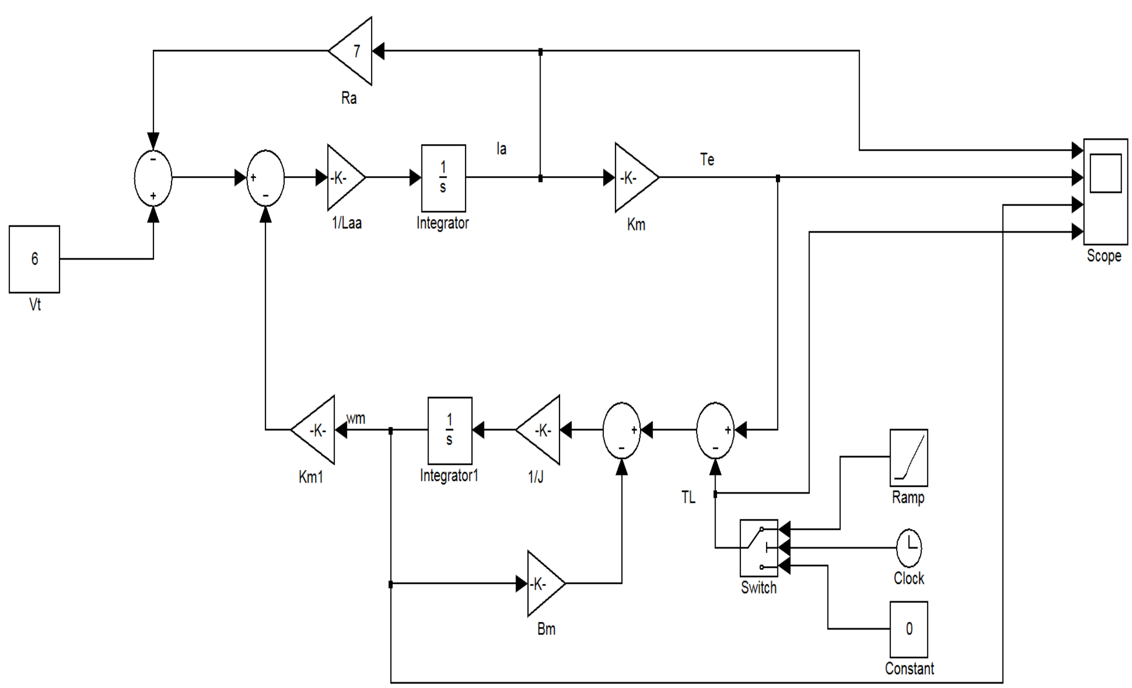

Fig. 4 Simulation diagram of permanent-magnet dc machine with load torque included.

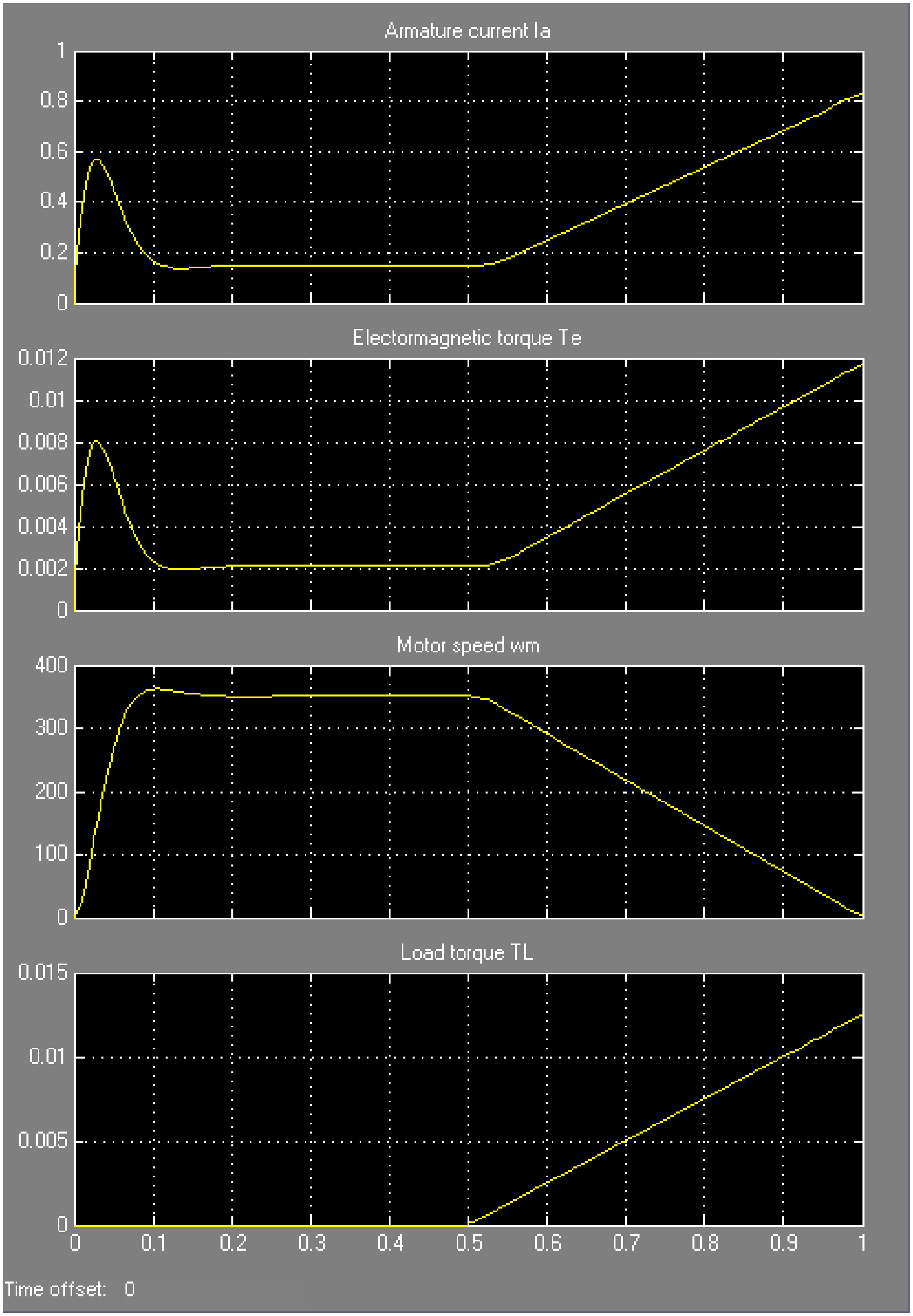

Fig. 5 Simulation results of permanent-magnet dc machine with load torque.

6. Drag the two block **XY graph** from the sinks library. Connect the electromagnetic torque (T_e) to X input and the speed (ω_m) to Y input of the first graph . Change the X settings to 0 and 0.01 and the y settings to 0 and 400. similarly connect the load torque (T_L) to X input and armature current to the Y input of the second graph. Change the X settings to 0 and 0.01 and the Y settings (y-max) to 1. With the XY graphs the block diagram is as shown in fig. 6. The plot are as shown in fig. 7 **.**

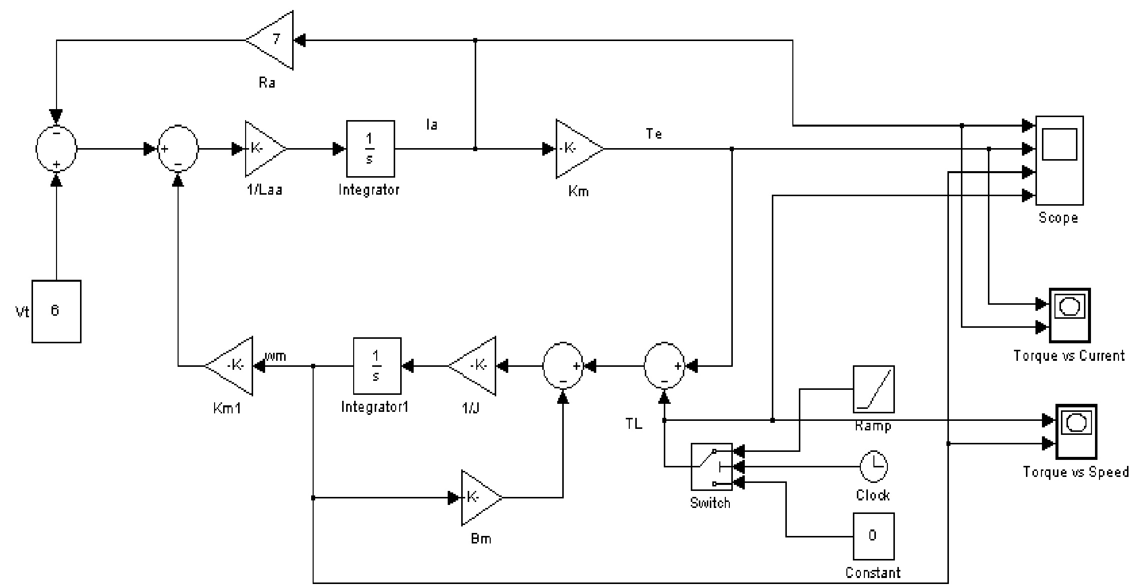

Fig. 6 Simulation diagram of permanent-magnet dc machine with load torque showing XY Plots.

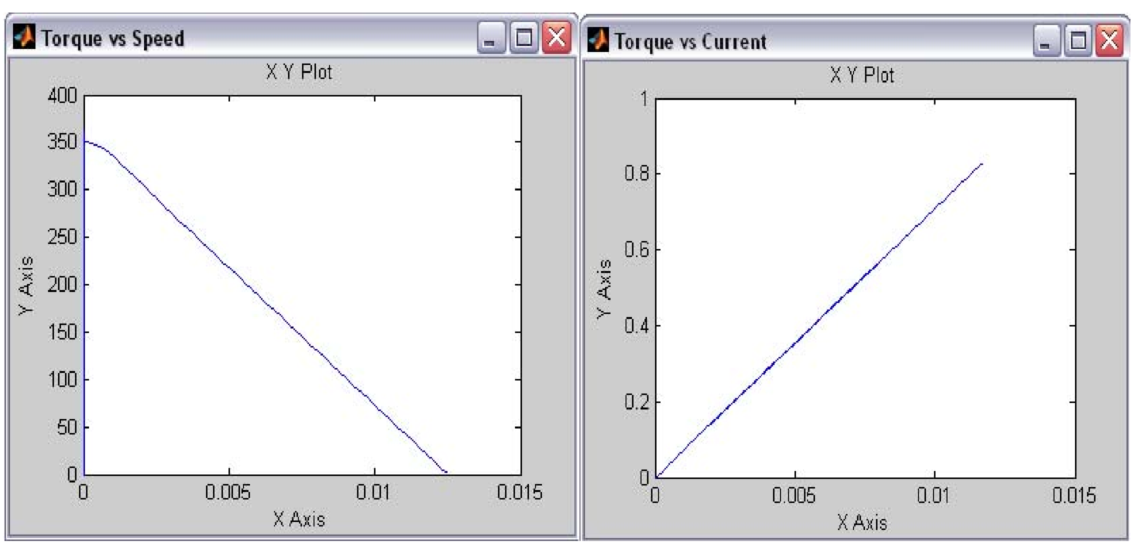

Fig. 7 XY plots of torque vs. speed and torque vs current.