AN INTRODUCTION TO DC MOTOR USING MATLAB/SIMULINK

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Abstract: ***This paper presents the generalized mathematical modelling and state space model of dc motor. The performance of dc motor under various conditions is simulated using MATLAB/SIMULINK environment and simulation result demonstrates the feasibility of the proposed system.***

Key words: ***DC Motor, MATLAB/SIMULINK, State Space, motor speed***

I. INTRODUCTION

Direct current machines are the most versatile energyconversion devices. Their outstanding advantage is that the volt-ampere or speed torque characteristic of these machines are very much flexible and easily adaptable for both steady state and dynamic operations. DC motors provide an attractive alternative to AC servo motors in high-performance motion control applications. The torque generated by a DC motor is proportional to the armature current and the strength of the magnetic field. In this example we will assume that the magnetic field is constant and, therefore, that the motor torque is proportional to only the armature current i by a constant factor K_t as shown in the equation below. This is referred to as an armature-controlled motor.

DC motors are popular in low-power and high precise servo applications due to their reasonable cost and ease of control. Traditionally motor controls in industrial applications employ a cascade control structure. When a wide range of speed control and torque output are required, dc motor is an obvious choice [1].

The state space approach is a generalized time domain method for modeling, analyzing and designing a wide range of control systems and is particularly well suited to digital computational technique. In this paper armature current and speed of the dc motor are taken as state variables.

This paper is structured as follows: Section 2 describes the mathematical modeling of the DC Motor. The state-space model of the DC motor derived from electromechanical relationships along with the model identification is described in Section 3. Section 4 details the state model simulation of DC motor using MATLAB. Finally, Section 5 summarizes the major conclusions of the paper.

MATHEMATICAL MODELING OF DC MOTOR

The different equations related to DC motor are given below

$$e_m(t) = K_m \frac{d\theta(t)}{dt} \quad (1)$$

$$e_a(t) = L_m \frac{di_a(t)}{dt} + R_m i_a(t) + e_m(t) \quad (2)$$

$T(t) = K_t i_a(t)$ (3)

$J\frac{d\theta^2(t)}{dt^2} + B\frac{d\theta(t)}{dt} = T(t)$ (4)

Where $e_a(t)$ = armature voltage, e_m (t) = back emf, $i_a(t)$ = armature current, $T(t)$ =developed torque, $\Theta\theta(t)$ = motor shaft angle, $\frac{d\theta(t)}{dt} = \omega(t)$ θ= shaft speed, J= moment of inertia of the rotor, B = viscous frictional constant, L_m= inductance of armature windings, R_m= armature winding resistance, K_t= motor torque constant, K_m= motor constant.

III. STATE SPACE MODEL OF DC MOTOR

Here the motor speed ω(t) is controlled by varying the armature voltage $e_a(t)$. Hence $e_a(t)$ is the input variable and ω(t) is the output variable.

We chose as the state variables $x_1(t) = \omega(t) = \frac{d\theta(t)}{dt}$ and $x_2(t) = i_a(t)$ (5)

The state equations will now be derived by using above equations.

$\frac{dx_1(t)}{dt} = -\frac{B}{J}x_1(t) + \frac{K_t}{J}x_2(t)$ (6)

$\frac{dx_2(t)}{dt} = -\frac{K_m}{L_m}x_1(t) - \frac{R_m}{L_m}x_2(t) + \frac{1}{L_m}e_a$ (7)

$y(t) = \frac{d\theta(t)}{dt} = \omega(t) = x_1(t)$. (8)

Hence state model of dc motor is derived from equations (6), (7) and (8) as follows

$$\begin{bmatrix} \frac{dx_1(t)}{dt} \\ \frac{dx_2(t)}{dt} \end{bmatrix} = \begin{bmatrix} -\frac{B}{J} & \frac{K_t}{J} \\ -\frac{K_m}{L_m} & -\frac{R_m}{L_m} \end{bmatrix} \begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{1}{L_m} \end{bmatrix} u(t) \quad (9)$$

$$y(t) = \begin{bmatrix} 1 & 0 \end{bmatrix} \begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix} \quad (10)$$

The below simulation model has been used to check the feasibility of the proposed model

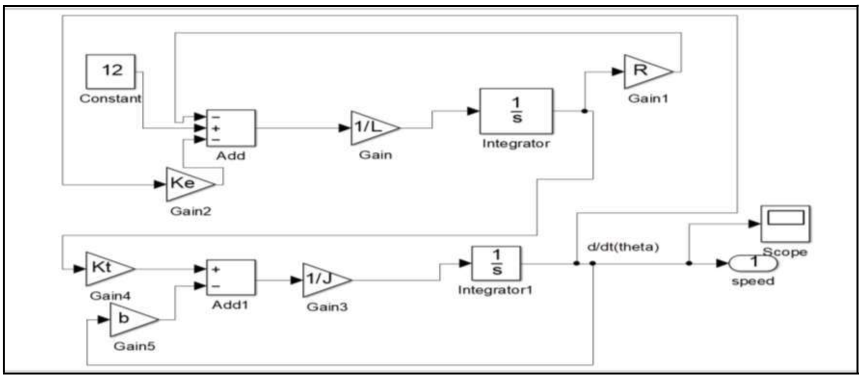
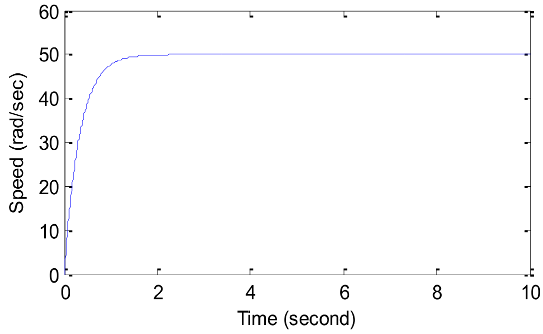


Figure 1 Simulink Model of DC Motor

IV. RESULTS

Let, the motor parameters (coefficient of differential equations) are assigned to be $L_m = 0.01$ H, K_t=0.21 N-m/A, K_m=0.2 V-sec/rad, J=0.004 kg-m2, B=0.0013 N-m-sec/rad, R_m= 3 Ω. The system models given by equations ((6), (7) and (8)) are solved to compute the instantaneous values of the performance variable of the system. The simulated results are shown in following figs.



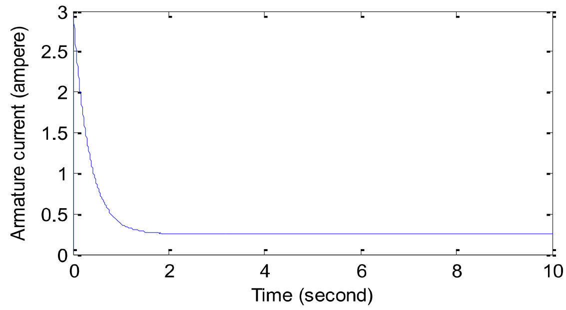


Figure 2 Speed of dc motor

Figure 3 Armature current of dc motor

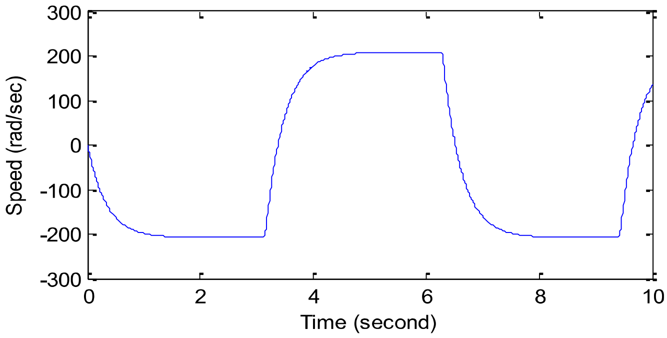


Figure 4 Speed and Armature current of dc motor with e_a(t) = 50 square (t) V

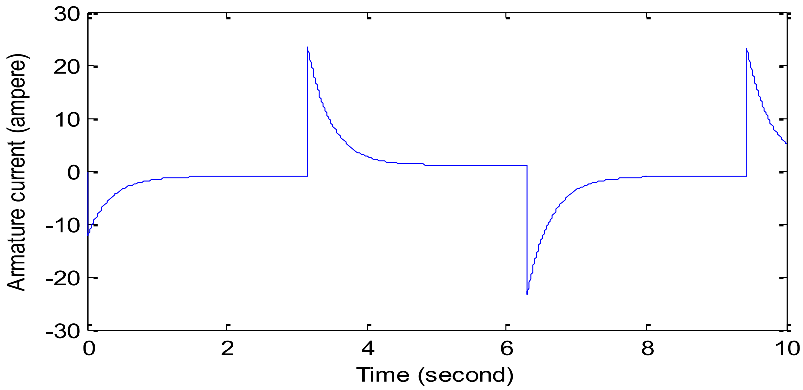


Fig 5: Speed and Armature current of dc motor with e_a(t) = 50 square (t) V

Thus the state model of dc motor is derived using motor parameters and equation (9) and (10) as follows:

$$\begin{bmatrix} \frac{dx_1(t)}{dt} \\ \frac{dx_2(t)}{dt} \end{bmatrix} = \begin{bmatrix} -0.25 & 50 \\ -22 & -400 \end{bmatrix} \begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix} + \begin{bmatrix} 0 \\ 100 \end{bmatrix} u(t) \qquad (11)$$

$$y(t) = \begin{bmatrix} 1 & 0 \end{bmatrix} \begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix} \quad (12)$$

So, the value of A= $\begin{bmatrix} -0.25 & 50 \\ -22 & -400 \end{bmatrix}$, B=$\begin{bmatrix} 0 \\ 100 \end{bmatrix}$, C= $\begin{bmatrix} 1 & 0 \end{bmatrix}$ and D=0

V. CONCLUSION

The state model of dc motor has been developed and simulation has been carried out for the proposed system which can be used further to check system performance in control engineering and system engineering. By keeping the motor parameters constant, we have plotted the speed for different voltages and can conclude that the speed has increased with the increase in voltage.

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