Assignment: Dynamic Modelling of DC Electric Machines

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Task:

Implement the dynamic model of the separately-excited DC motor with the following specifications on MATLAB/SIMULINK:

$R_a = 0.5\ \Omega$, $L_a = 0.003$H, and

$K_b = 0.8$ V/rad/sec, is driving a load of $J = 0.0167\,\text{kg-m}^2$, $B_1 = 0.01$ N·m/rad/sec

(a) Plot the output speed from no-load starting until it reaches its steady state. The motor is supplied with a DC voltage source of 220-V.

(b) Repeat part (a) when the starting torque is 100 N.m.

Solution:

To apply its dynamic model in Simulink, the differential equations are needed to be restated:

$$\begin{cases} V_{in} = E_a + R_a i_a + L_a \dfrac{di_a}{dt} \\ J\dfrac{d\omega_m}{dt} + B_1\omega_m = T_e - T_l \end{cases} \tag{1}$$

where $E_a = K_a\varphi\omega_m = K_e\omega_m$, $T_e = E_a i_a / \omega_m = K_e i_a = K_t i_a$.

Therefore, we can implement the dynamic model as shown in Figure 1:

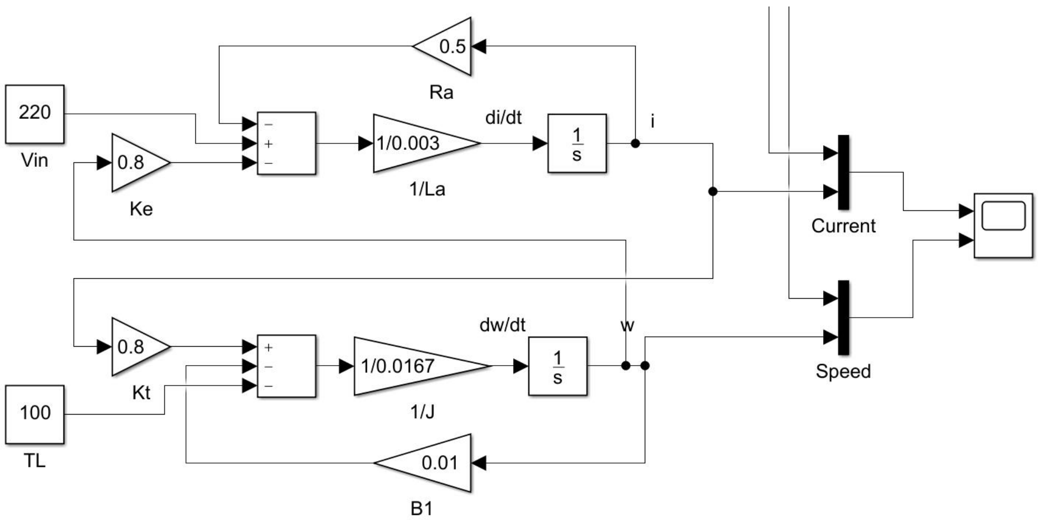

Fig.1: the dynamic Simulink model of DC electric machines

The curves of current and speed are shown as Figure 2:

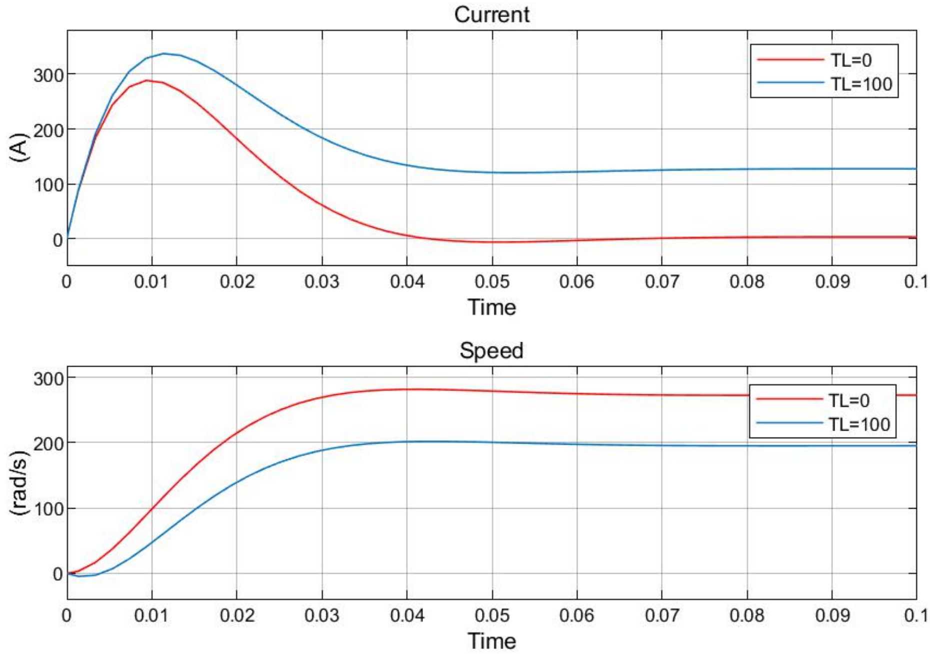

Fig.2: simulation results

1. It can be observed that when the load torque is 0, the steady-state current is 0 as well, while it is a certain positive value when the load torque is 100Nm. This is because the structure of the motor is invariant, and also it is separately excited, which means the field current is independent from the changes of armature current and load torque. Thus the electromagnetic torque is simply proportional to armature current, furthermore, armature current is proportional to load torque in steady state.

2. Last statement can also imply why there is always an overshoot of current response in transient state. During the starting of motor, an electromagnetic torque, which is supposed to be greater than load torque, is needed to accelerate the rotor. Meanwhile, the magnitude of current will be greater than the one in steady state.

3. In this way, the speed keeps increasing (in some cases it might also has an overshoot) until the response of current arrives at steady state, when the electromagnetic torque is equal to load torque.

4. In steady state, one can find that for the motor which bears greater load torque, it rotates in a lower speed. It can be well explained in the view of power. Since the power of the motor is constant, it will produce less electromagnetic torque when the speed is higher.