DYNAMIC MODELLING OF A SEPARATELY-EXCITED DC ELECTRIC MOTOR

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OBJECTIVE

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

R_a = 0.5 Ω, L_a = 0.003H, and K_b =0.8 V/rad/sec, drives a load of J = 0.0167 Kg-m^2, B = 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.

METHODOLOGY

The dynamic equations governing the separately-excited DC motor were implemented in MATLAB/Simulink. The motor's electrical and mechanical behavior was modeled using differential equations, which describe the relationships between input voltage, armature current, motor speed, and load torque.

Mathematical Model:

a) Electrical Equation:

$$V_{in} = E_a + R_a i_a + L_a \frac{di_a}{dt}$$

Since the back electromotive force (EMF) is given by:

$$E_a = K_e \omega_m$$

Substituting for E_a:

$$\frac{di_a}{dt} = \frac{1}{La}(V_{in} - K_e\omega_m - R_a i_a)$$

b) Mechanical Equation:

The equation of motion for the rotor is:

$$J\frac{d\omega_m}{dt} + B\omega_m = T_e - T_L$$

where the electromagnetic torque T_e is:

$$T_e = K_t i_a$$

Substituting for T_e:

$$\frac{d\omega_m}{dt} = \frac{1}{J}(K_t i_a - T_L - B\omega_m)$$

Simulink Implementation:

The above equations were implemented in Simulink using fundamental building blocks such as:

- Integrator Blocks to solve the first-order differential equations.
- Gain Blocks to represent constants like $\frac{1}{La}$, $\frac{1}{J}$, and K_e.
- Sum Blocks to model the algebraic expressions.
- Constant Blocks for fixed parameters such as input voltage and load torque.
- Scope Blocks to visualize the motor speed response.

a) Simulation Conditions

The model was simulated under two conditions:

1. No Load Condition: The motor was supplied with a constant DC voltage of 220 V while the load torque T_L was set to zero.

2. Loaded Condition: The simulation was repeated with an initial load torque of 100 N.m applied to the motor.

b) Solver Configuration

To ensure numerical stability and accuracy, the solver settings in Simulink were configured as follows:

- Solver: ode23tb (suitable for stiff electrical systems)
- Simulation Time: 0.1 seconds

This implementation allowed for an accurate representation of the motor's dynamic response, providing insights into its speed variation from startup to steady-state operation.

The dynamic model is shown in Figure 1:

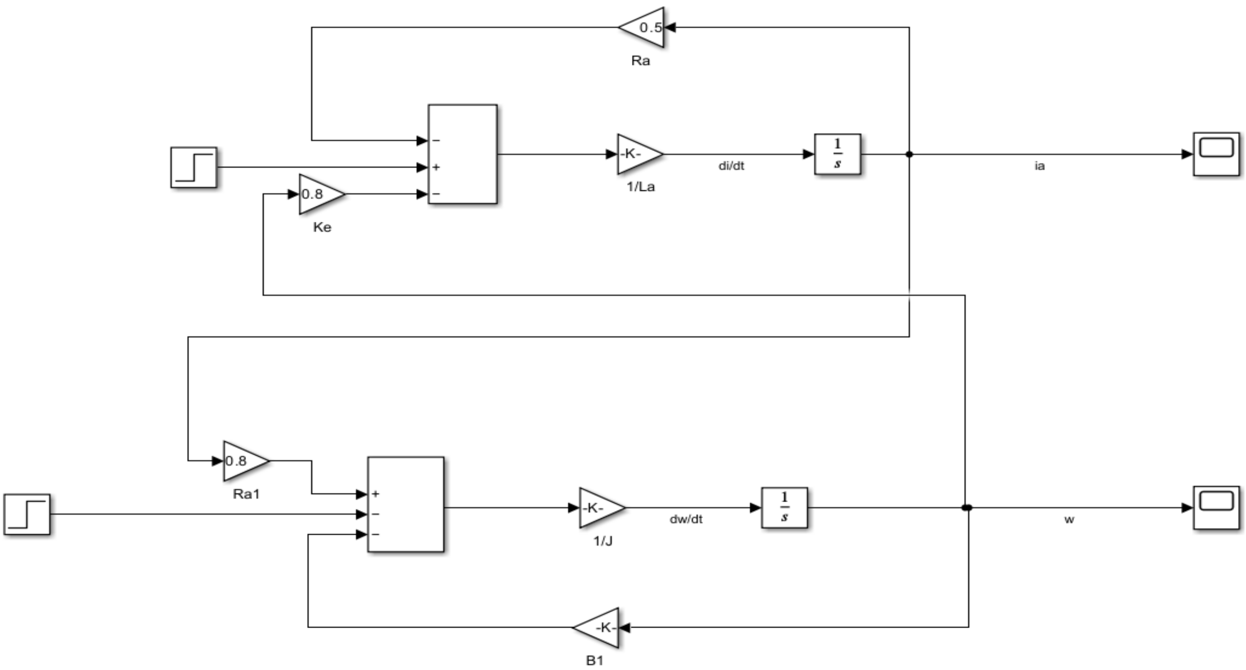

Fig. 1: Simulink Model of a DC Electric Machine

RESULTS:

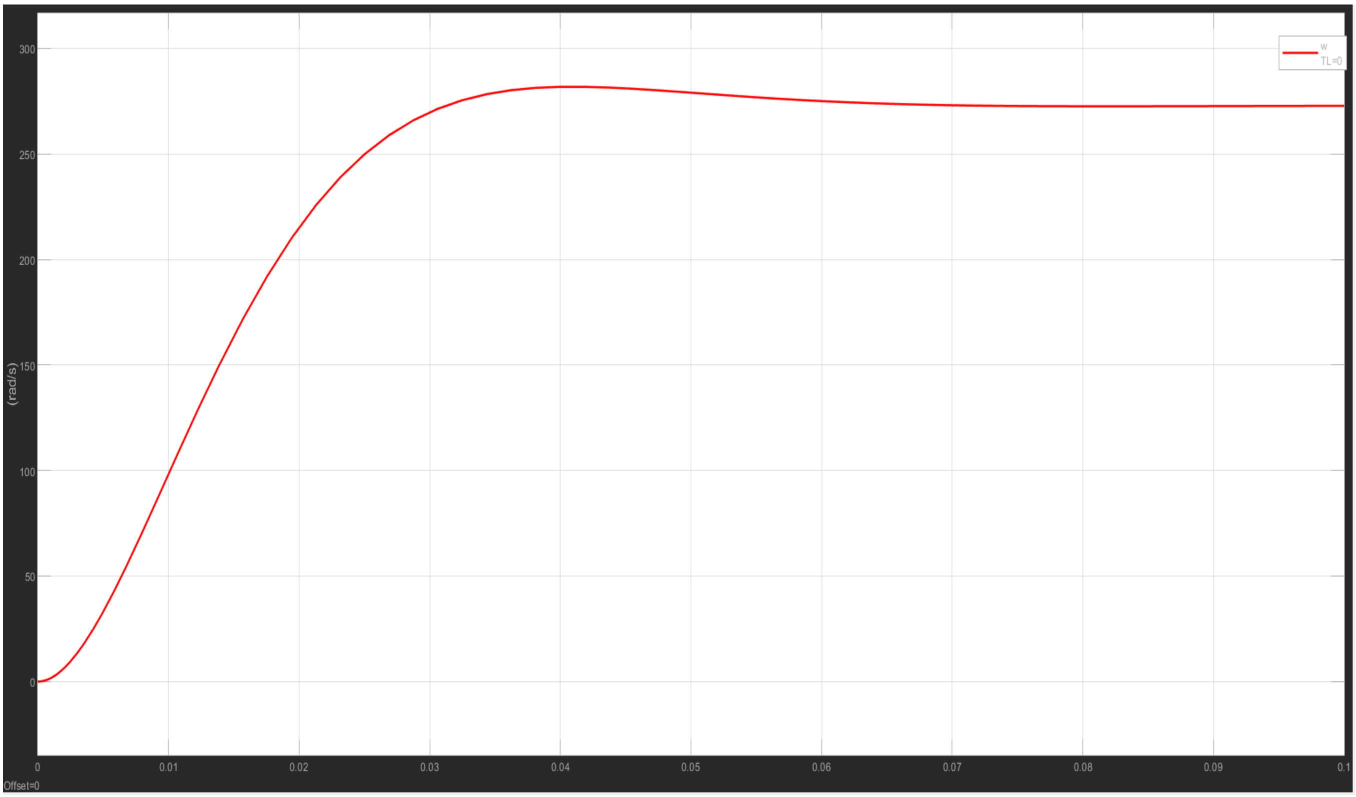

Fig. 2: The output speed from no-load starting until it reaches its steady state.

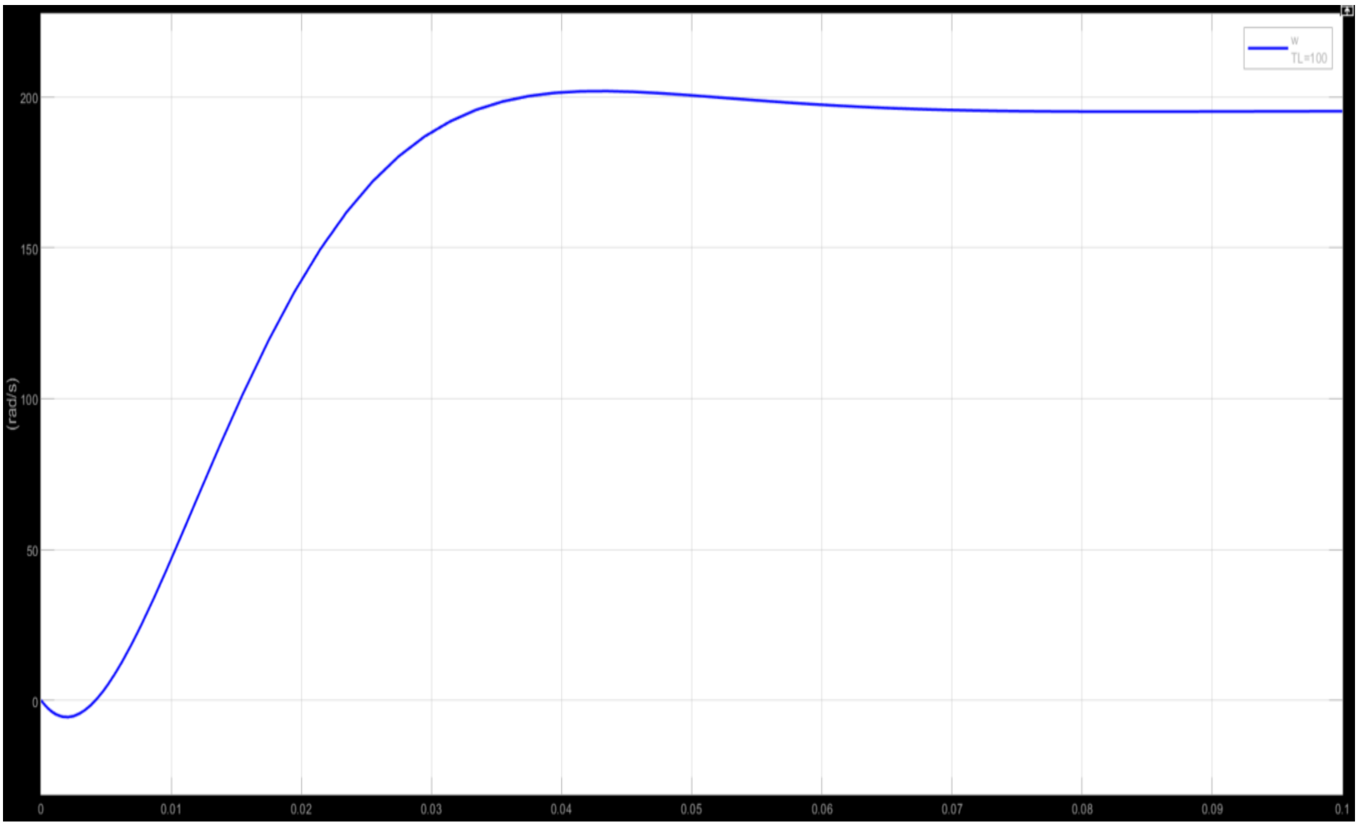

Fig. 3: The output speed when the starting Torque is 100N.m

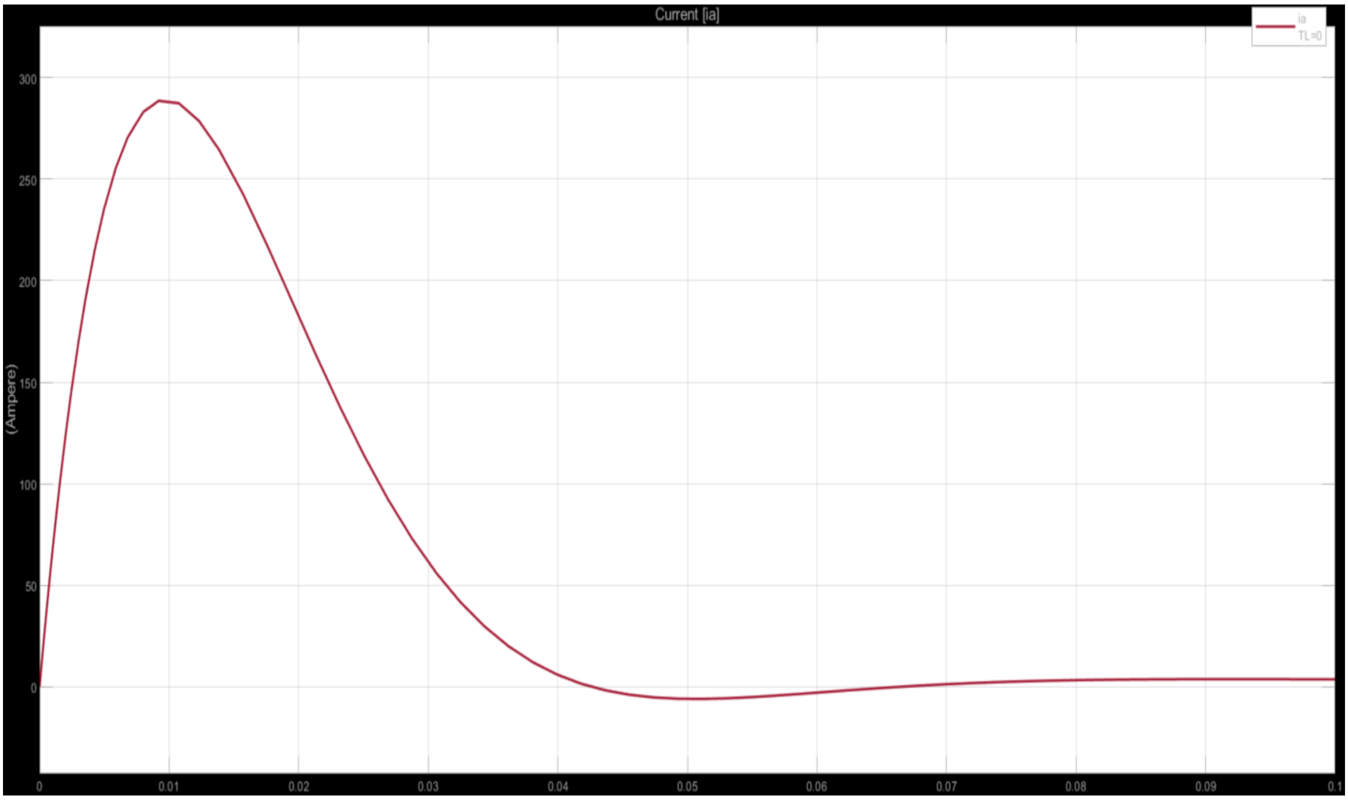

Fig. 4: Armature current at no-load condition

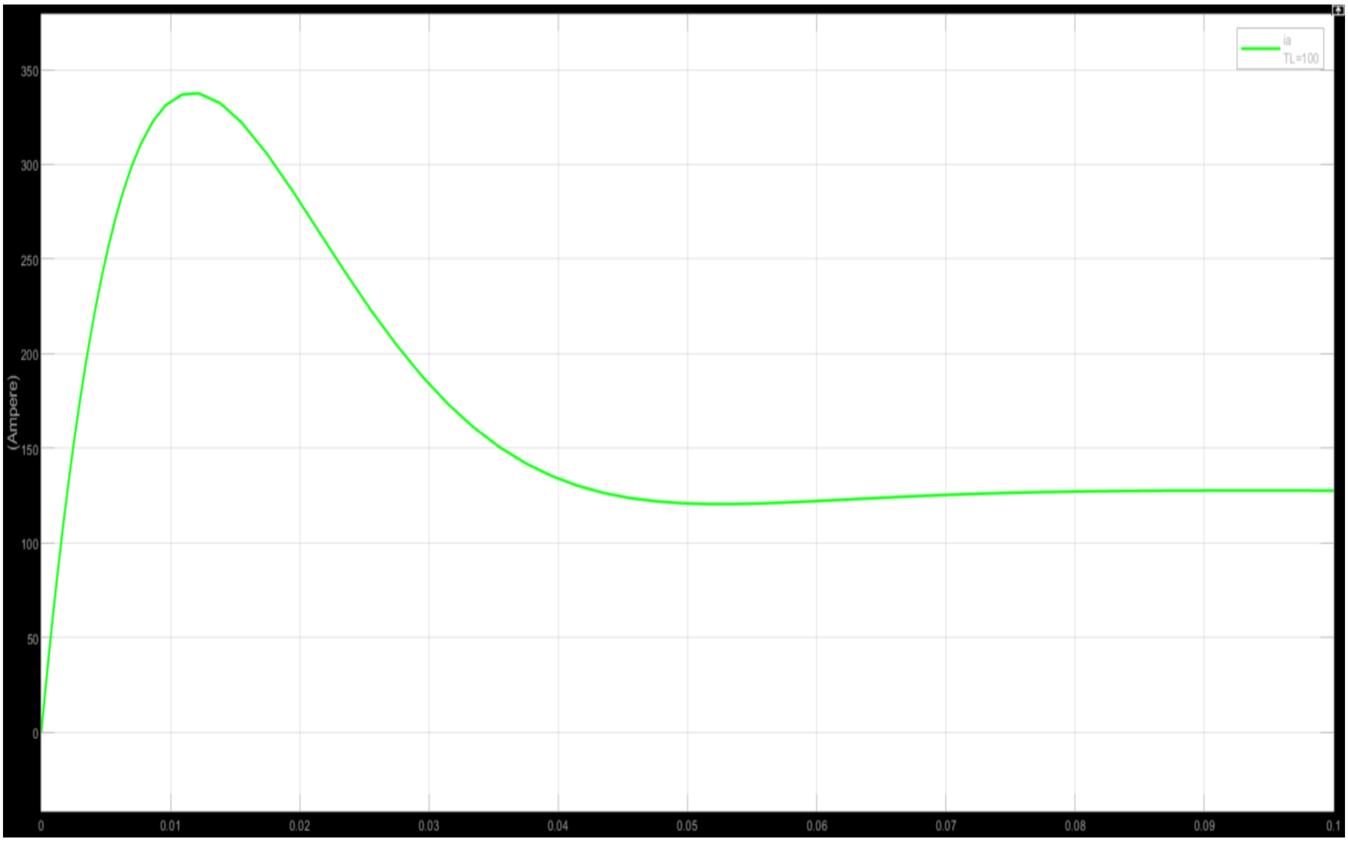

Fig. 5: Armature current when the starting Torque is 100N.m

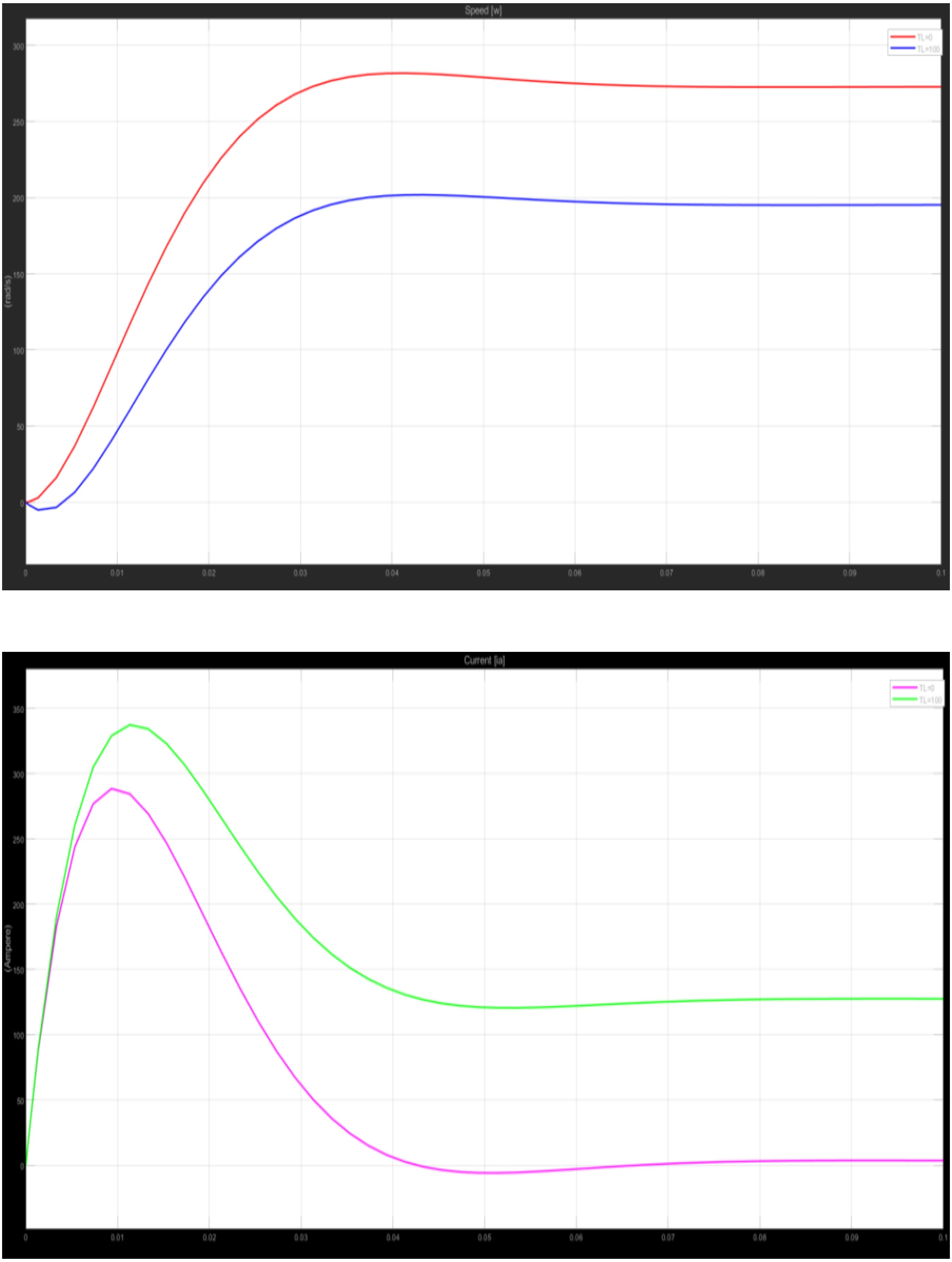

Fig. 6: Combined Simulation Results