1 DC Motor Modeling and Verification

Before designing the power electronics converter, the DC motor parameters were calculated and verified in the Simulink environment to ensure the simulation model accurately represents the physical plant.

1.1 Parameter Extraction

The available motor is a 5.5 HP, 220 V, 1500 RPM Separately Excited DC Machine. While the electrical resistances (R_a, R_f) and inductances (L_a, L_f) were measured directly, the mechanical and electromagnetic parameters required for the Simulink "DC Machine" block were derived analytically.

1.1.1 Field-Armature Mutual Inductance (L_{af})

The mutual inductance determines the back-EMF generated for a given field current. Using the rated values ($V_t = 220$ V, $I_a = 23.4$ A, $\omega = 157$ rad/s) and the measured total armature resistance ($R_{total} = 0.8 + 0.27 = 1.07\,\Omega$):

$$E_a = V_t - I_a R_{total} = 220 - (23.4 \times 1.07) \approx 195 \text{ V} \tag{1}$$

With a field current $I_f \approx 1.05$ A (at 220 V excitation), L_{af} was calculated as:

$$L_{af} = \frac{E_a}{I_f \cdot \omega} = \frac{195}{1.05 \cdot 157} \approx 1.18 \text{ H} \tag{2}$$

1.1.2 Mechanical Parameters

To account for the coupled generator setup, the total inertia (J) was estimated to be double that of a standard motor ($0.06 \text{ kg} \cdot \text{m}^2$). The viscous friction coefficient (B_m) was derived assuming friction losses are approximately 2% of the rated power.

The final parameters used in the simulation are summarized in Table 1.

Table 1: Derived Simulation Parameters for DC Machine

Parameter	Symbol	Value
Armature Resistance	R_a	$1.07\,\Omega$
Armature Inductance	L_a	24.5 mH
Field Resistance	R_f	$210\,\Omega$
Mutual Inductance	L_{af}	1.18 H
Total Inertia	J	$0.06 \text{ kg} \cdot \text{m}^2$
Viscous Friction	B_m	$0.0032 \text{ N} \cdot \text{m} \cdot \text{s}$

1.2 Model Verification Results

A test simulation was conducted to verify these parameters. The motor was supplied with rated voltage (220 V DC) and subjected to a step load torque of 26.1 Nm (Rated Torque) at $t = 2.0$ s. The resulting transient response is visualized in Figure 1.

- **No-Load Condition ($t < 2$ s):** The motor speed settles at approximately 177 rad/s (1690 RPM).
- **Full-Load Condition ($t > 2$ s):** Upon application of rated torque, the speed drops to 159 rad/s (1518 RPM) and the current settles at 21 A.

These results deviate by less than 1.5% from the nameplate speed of 1500 RPM, confirming that the dynamic model is accurate enough for drive design.

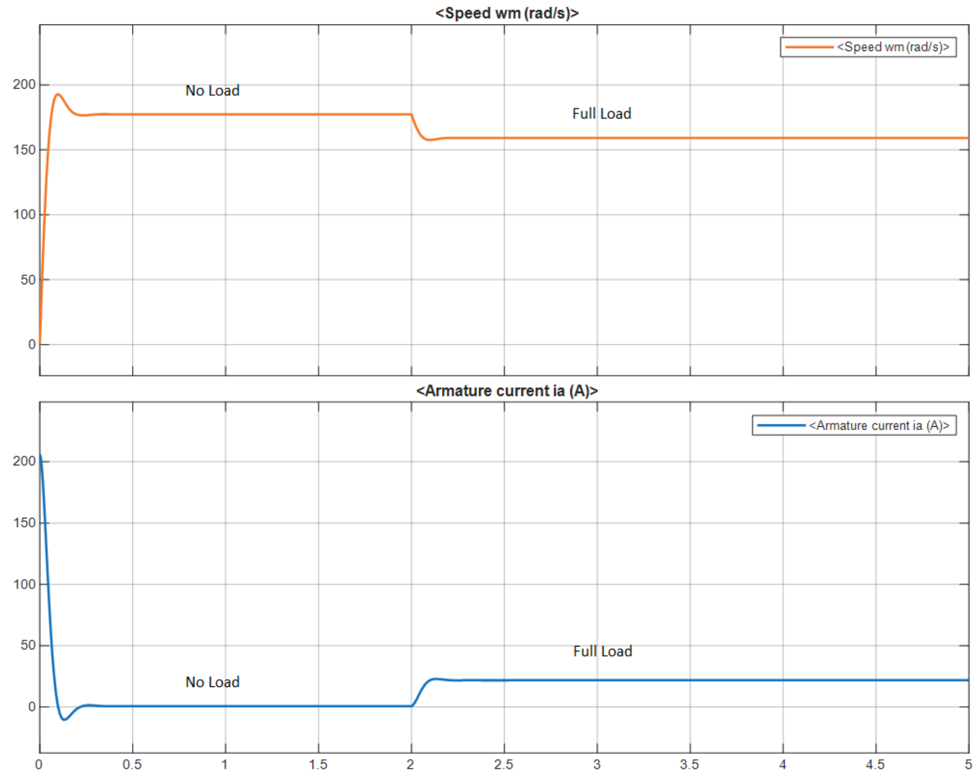

Figure 1: Motor Step Response: Speed (top) and Armature Current (bottom). A rated load torque of 26.1 Nm is applied at t=2s, causing the speed to settle near the rated 1500 RPM.