Problem Set 5 Transient and Dynamics

1. A separately excited DC motor consists of the following parameters

   $R_a = 0.5\ \Omega$ $L_{aq} = 0$ $B = 0$ $J = 0.1\ \text{kgm}^2$

   The rotational loss is negligible. The motor is used to drive an inertia load of 1.0 kgm^2. With the rated field current and an armature terminal voltage of 100 V, the motor and the load consist of a steady-state speed of 1500 rpm. At a certain time, the armature terminal voltage is suddenly increased to 120 V.

   a. Obtain an expression for the speed as a function of time.

   b. Find the speed 1 second after the step increase in the terminal voltage.

   c. Find the final steady-state speed of the motor.

2. A separately excited DC motor consists of the following parameters

   $R_a = 0.4\ \Omega$ $L_{aq} = 0$ $K_f = 1$ $B = 0$ $J = 4.5\ \text{kgm}^2$

   The motor operates at no-load with terminal voltage of 220 V and field current of 2 A. Rotational losses are negligible. The motor is intended to be stopped by plugging, i.e., by reversal of its armature terminal voltage ($V_t = -220$ V)

   a. Find the no-load speed of the motor.

   b. Obtain an expression for the motor speed after plugging.

   c. Find the time taken for the motor to reach zero speed.

3. A separately excited DC motor consists of the following parameters

   $R_a = 0.4\ \Omega$ $K_f = 1$ $B = 0.1\ \text{kgm}^2/\text{s}$ $J = 2.0\ \text{kgm}^2$

   The motor drives a constant load torque. With field current of 2 A and armature terminals connected to a 100 V DC source, the motor rotates at 450 rpm.

   a. Find the motor current.

   b. Find the friction torque ($B\omega_m$) and load torque.

   c. The motor is now disconnected from the DC supply. Obtain an expression for speed as a function of time.

   d. Following (c), the load torque remains on the motor shaft after the motor is disconnected from the supply. Find the new steady-state speed.

4. A separately excited DC motor consists of the following parameters

$R_a = 0.5\ \Omega$ $K_f = 1$ $B = 0.1\ \text{kgm}^2/\text{s}$ $J = 2.0\ \text{kgm}^2$

With field current of 2 A and the motor terminals connected to a 100 V DC supply, the motor rotates at no-load and draws an armature current of 2.469 A.

   a. Find the motor speed and developed torque.

   b. A load of constant torque of 10 Nm is now applied. Obtain an expression for speed as a function of time.

   c. Following (b), find the new steady-state speed, motor current and developed torque.

5. Consider a separately excited DC generator with following parameters

$R_f = 100\ \Omega$ $L_f = 40\ \text{H}$ $R_a = 0.2\ \Omega$ $L_{aq} = 10\ \text{mH}$

$K_g = 100$ V per field ampere at 1000 rpm

The generator is operated at rated speed of 1200 rpm with field current as 2 A. The armature is suddenly connected to a load with 1.8 Ω and 10 m H in series. Find

   a. Load terminal voltage as a function of time.

   b. Steady-stage value of the load terminal voltage.

   c. Torque as a function of time.

6. Consider a separately excited DC generator with following parameters

$R_a = 0.5\ \Omega$ $K_f = 1$ $B = 0.1\ \text{kgm}^2/\text{s}$ $J = 2.0\ \text{kgm}^2$

With field current of 2 A, the motor is connected to a 100 V DC supply. It rotates at no-load with speed of 471.569 rpm.

   a. Find the motor current and developed torque.

   b. If the field current is reduced to 1 A, derive an expression for speed as a function of time.

   c. Find the new steady-state speed, motor current and developed torque.

Answer

1. (a) $\omega_m(t) = 187 - 29.9\, e^{-0.744t}$ (b) 173 rad/s (c) 187 rad/s

2. (a) 110 rad/s (b) $\omega_m(t) = -110 + 220\, e^{-2.22t}$ (c) 0.315 s

3. (a) 11.5 A (b) 18.3 Nm (c) $\omega_m(t) = -182.9 + 230\, e^{-0.05t}$ (d) – 182.9 rad/s

4. (a) 471.5 rpm; 4.94 Nm (b) $\omega_m(t) = 48.2 + 1.23\, e^{-4.05t}$ (c) 459.8 rpm; 7.4 A; 14.8 Nm

5. (a) $V_t(t) = 216 - 96e^{-100t}$ (b) 216 V (c) $T = 229.2(1 - e^{-100t})$

6. (a) 2.48 A; 4.96 Nm (b) $\omega_m(t) = 95.24 - 45.86e^{-1.05t}$ (c) 909.5 rpm; 9.52 A; 9.52 Nm