Example 4.9: DC Series Motor

Controlling speed of DC series motor by Resistance

Dummy unit: $\Omega \equiv 1$ $rpm \equiv 1$ $V \equiv 1$ $A \equiv 1$ $Hz \equiv 1$ $kW \equiv 10^3$ $Nm \equiv 1$ $W \equiv 1$ $k \equiv 10^3$

$V_t := 220 \cdot V$ $R_a := 0.6\Omega$ $R_{sr} := 0.4\Omega$

(a)

At the point 1: $V_{t1} := 220 \cdot V$ $I_{a1} := 25 \cdot A$ $R_{ae1} := 0$ $N_{m1} := 300rpm$

$$E_{a1} := V_{t1} - I_{a1} \cdot (R_a + R_{sr} + R_{ae1}) \qquad E_{a1} = 195\,V$$

$$P_1 := E_{a1} \cdot I_{a1} \qquad P_1 = 4.875\,kW$$

$$\omega_{m1} := \frac{N_{m1}}{60} \cdot 2\pi \qquad T_1 := \frac{E_{a1} \cdot I_{a1}}{\omega_{m1}} \qquad T_1 = 155.176\,Nm$$

(b)

At the point 2: $V_{t2} := V_{t1}$ $N_{m2} := 200rpm$

Relationship between T and ω that is given by load torque characteristics.

Load torque characteristic is given as: $T = k \cdot \omega_m^2$

It can also be stated as: $\frac{T_2}{T_1} = \left(\frac{\omega_{m2}}{\omega_{m1}}\right)^2$ or $\frac{T_2}{T_1} = \left(\frac{N_{m2}}{N_{m1}}\right)^2$

$$T_2 := \left(\frac{N_{m2}}{N_{m1}}\right)^2 \cdot T_1 \qquad T_2 = 68.967\,Nm$$

Relationship between T and I_a is given by motor torque equation.

$$T = K_{sr} \cdot I_a^2$$

At the point 1: $T_1 = 155.176\,Nm$ $I_{a1} = 25\,A$

$$K_{sr} := \frac{T_1}{I_{a1}^2} \qquad K_{sr} = 0.248$$

Relationship between T and ω that is given by motor torque characteristics.

$$\omega_m = \frac{V_t}{\sqrt{K_{sr}} \cdot \sqrt{T}} - \frac{R_a + R_{sr} + R_{ae}}{K_{sr}}$$

At the point 2: $\omega_{m2} := \frac{N_{m2}}{60} \cdot 2\pi$ $\qquad T_2 = 68.967\,\text{Nm}$

$$R_{ae2} := \left(\frac{V_t}{\sqrt{K_{sr}} \cdot \sqrt{T_2}} - \omega_{m2}\right) \cdot K_{sr} - \left(R_a + R_{sr}\right) \qquad R_{ae2} = 7\,\Omega$$

$P_2 := T_2 \cdot \omega_{m2}$ $\qquad P_2 = 1.444\,\text{kW}$