

**Problem 1: Steady-state characteristics of a DC motor**

A DC motor with a separately excited field winding is considered. The rated armature voltage is  $u_N = 600$  V, rated torque  $\tau_N = 420$  Nm, rated speed  $n_N = 1\,600$  r/min, and maximum speed  $n_{\max} = 3\,200$  r/min. The losses are omitted.

- The flux factor  $k_f$  is kept constant at its rated value. When the armature voltage is varied from 0 to  $u_N$ , the speed varies from 0 to  $n_N$ . Determine the rated armature current  $i_N$ .
- A load is to be driven in the speed range from  $n_N$  to  $n_{\max}$  by weakening the flux factor while the armature voltage is kept constant at  $u_N$ . Determine the torque available at maximum speed, if the rated current  $i_N$  is not exceeded.
- Sketch the armature voltage  $u$ , flux factor  $k_f$ , torque  $\tau_M$ , and mechanical power  $p_M$  as a function of the speed, when the armature current is kept at  $i_N$ .

**Problem 2: Transfer functions**

- A DC motor is considered. Derive the transfer function from the terminal voltage  $u(s)$  to the terminal current  $i(s)$ .
- A lumped thermal capacity model is considered:

$$p_d(t) = \frac{1}{R_{\text{th}}}\theta(t) + C_{\text{th}}\frac{d\theta(t)}{dt}$$

Derive the transfer function from the power loss  $p_d(s)$  to the temperature rise  $\theta(s)$ .

**Problem 3: Properties of first-order systems**

Consider a first-order system

$$G(s) = \frac{K}{1 + sT}$$

- What is the steady-state gain of the system?
- Derive the rise time from 10% to 90% for a step input.
- What is the 3-dB bandwidth  $\alpha$  of the system?