Problem 1: Torque expressions of an induction machine

The electromagnetic torque of an induction machine can be expressed in terms of the stator flux linkage and the stator current as

$$\tau_\mathrm{M} = \frac{3n_\mathrm{p}}{2}\,\mathrm{Im}\,\{\boldsymbol{i}_\mathrm{s}\boldsymbol{\psi}_\mathrm{s}^*\}$$

(a) Formulate the given torque expression in the dq component form.

(b) Using the given torque expression as the starting point, derive the corresponding torque expression in terms of the stator current and the rotor flux linkage.

(c) Derive the torque expression in terms of the stator flux linkage and the rotor flux linkage.

Problem 2: Steady-state torque expressions

Express the torque τ_M of an induction motor in the steady state as a function of:

(a) the slip angular frequency ω_r and the rotor-flux magnitude ψ_R;

(b) the slip angular frequency ω_r and the stator-flux magnitude ψ_s.

Problem 3: Determination of induction motor parameters

The parameters of an inverter-fed induction motor are estimated using three tests:

(a) A direct current is commanded into the α-axis at standstill, resulting in the space vectors $\boldsymbol{i}_\mathrm{s}^\mathrm{s} = 4.0$ A and $\boldsymbol{u}_\mathrm{s}^\mathrm{s} = 14.8$ V. Determine the stator resistance. What are the phase currents?

(b) A pulsating sinusoidal current is commanded into the α-axis at standstill, resulting in the space vectors

$$\boldsymbol{i}_\mathrm{s}^\mathrm{s}(t) = i_\mathrm{s}\sin(\omega_\mathrm{s}t + \varphi_\mathrm{i}) \qquad \boldsymbol{u}_\mathrm{s}^\mathrm{s}(t) = u_\mathrm{s}\sin(\omega_\mathrm{s}t + \varphi_\mathrm{u})$$

where $\omega_\mathrm{s} = 2\pi \cdot 80$ rad/s, $i_\mathrm{s} = 4.0$ A, $\varphi_\mathrm{i} = 0$, $u_\mathrm{s} = 48.2$ V, and $\varphi_\mathrm{u} = 61.2°$. Determine the leakage inductance and the rotor resistance. Assume the magnetizing current to be zero, since the excitation frequency ω_s is comparatively high.

(c) The motor is driven at no load in the steady state. The rotating space vectors are

$$\boldsymbol{i}_\mathrm{s}^\mathrm{s}(t) = i_\mathrm{s}\mathrm{e}^{\mathrm{j}(\omega_\mathrm{s}t+\varphi_\mathrm{i})} \qquad \boldsymbol{u}_\mathrm{s}^\mathrm{s}(t) = u_\mathrm{s}\mathrm{e}^{\mathrm{j}(\omega_\mathrm{s}t+\varphi_\mathrm{u})}$$

where $\omega_\mathrm{s} = 2\pi \cdot 30$ rad/s, $i_\mathrm{s} = 4.0$ A, $\varphi_\mathrm{i} = 0$, $u_\mathrm{s} = 185$ V, and $\varphi_\mathrm{u} = 85.5°$. Determine the magnetizing inductance. Assume that the stator resistance is unknown.