

**Problem 1: Flux estimation based on the current model**

The rotor flux of the induction motor can be estimated in many ways. If the drive is equipped with a speed sensor, a current-model based flux estimator in synchronous coordinates can be used:

$$\frac{d\hat{\psi}_R}{dt} = R_R \left( i_d - \frac{\hat{\psi}_R}{L_M} \right) \quad \text{and} \quad \frac{d\hat{\vartheta}_s}{dt} = \omega_m + \frac{R_R i_q}{\hat{\psi}_R}$$

where  $\hat{\psi}_R$  is the estimate of the flux magnitude and  $\hat{\vartheta}_s$  is the estimate of the flux angle. Derive these equations starting from the voltage and flux equations in stator coordinates. Draw also the block diagram of the rotor-flux-oriented control system.

**Problem 2: Calculation of operating points**

The rated values of a three-phase induction motor are:  $U_N = 400$  V;  $f_N = 50$  Hz;  $n_N = 1460$  r/min. The motor parameters are:

$$R_s = 0.45 \, \Omega \quad R_R = 0.28 \, \Omega \quad L_M = 0.075 \, \text{H} \quad L_\sigma = 7.1 \, \text{mH}$$

- Rotor-flux-oriented vector control is used. Calculate the stator current components  $i_d$  and  $i_q$  as well as the mechanical power in the rated operating point.
- The motor is driven in the field-weakening region. Evaluate the slip angular frequency and the torque in the steady state when  $i_d$  is reduced to 50% but  $i_q$  is kept constant. Calculate also the stator frequency and the stator voltage assuming that the rotor speed is two times the rated speed.

**Problem 3: Flux dynamics**

The rotor flux of an induction motor is controlled by the stator current component  $i_d$  in rotor-flux coordinates. At  $t = 0$ , a stepwise change  $\Delta i_d$  is assumed in the d-component of the stator current. Derive expressions for the change  $\Delta \psi_R(t)$  in the rotor flux and for the change  $\Delta i_{Rd}(t)$  in the d-component of the rotor current (that is parallel to the rotor flux).