CLEMSON UNIVERSITY

ECE 802, Electric Motor Control

Multiple Reference Frame Estimator / Regulator

P.L. Chapman and S.D. Sudhoff, “A Multiple Reference Frame Synchronous Estimator/Regulator,” *IEEE Transactions on Energy Conversion*, volume 15, number 2, pages 197-202, June 2000.

MRF Control

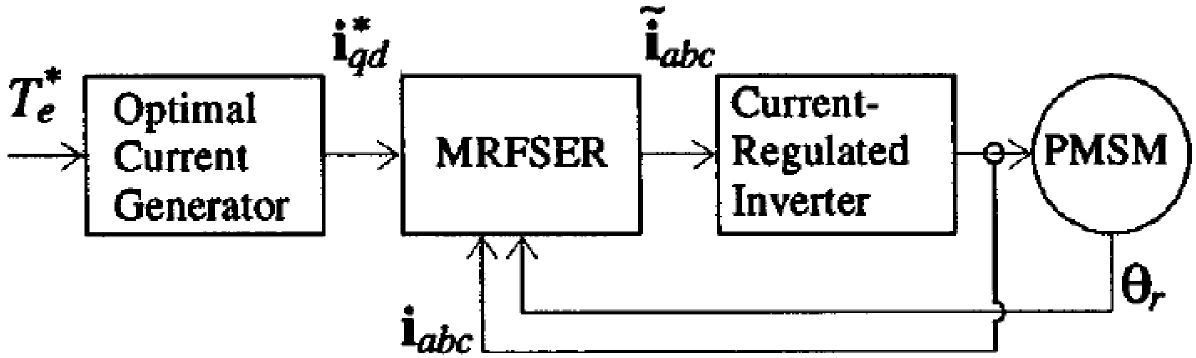

Fig. 1. System diagram.

$$\mathbf{i}_{abc} = \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} \qquad \mathbf{i}_{qd}^* = \begin{bmatrix} i_q^\alpha \\ i_d^\alpha \\ i_q^\beta \\ i_d^\beta \\ \vdots \\ i_q^\Omega \\ i_d^\Omega \end{bmatrix}$$

Transformations

Transformation

$$\mathbf{i}_{qd}^{x} = \begin{bmatrix} i_q^x \\ i_d^x \end{bmatrix} = \mathbf{K}^x \mathbf{i}_{abc} \qquad \mathbf{K}^x = \frac{2}{3}\begin{bmatrix} \cos\left(x\theta_r\right) & \cos\left(x\left(\theta_r - \tfrac{2\pi}{3}\right)\right) & \cos\left(x\left(\theta_r + \tfrac{2\pi}{3}\right)\right) \\ \sin\left(x\theta_r\right) & \sin\left(x\left(\theta_r - \tfrac{2\pi}{3}\right)\right) & \sin\left(x\left(\theta_r + \tfrac{2\pi}{3}\right)\right) \end{bmatrix}$$

$$x = \alpha, \beta, \ldots \Omega$$

Inverse transformation

$$\mathbf{i}_{abc} = \sum_{x \in N}^{N} \left(\mathbf{K}^x\right)^{-1} \mathbf{i}_{qd}^{x} \qquad \left(\mathbf{K}^x\right)^{-1} \triangleq \frac{3}{2}\left(\mathbf{K}^x\right)^T$$

N - set of all harmonics considered

Estimator

as $e_\alpha \rightarrow 0$
$e_\beta \rightarrow 0$
$e_\Omega \rightarrow 0$

$$\hat{\mathbf{i}}_{qd}^{\alpha} \rightarrow \mathbf{i}_{qd}^{\alpha}$$

$$\hat{\mathbf{i}}_{qd}^{\beta} \rightarrow \mathbf{i}_{qd}^{\beta}$$

$$\hat{\mathbf{i}}_{qd}^{\Omega} \rightarrow \mathbf{i}_{qd}^{\Omega}$$

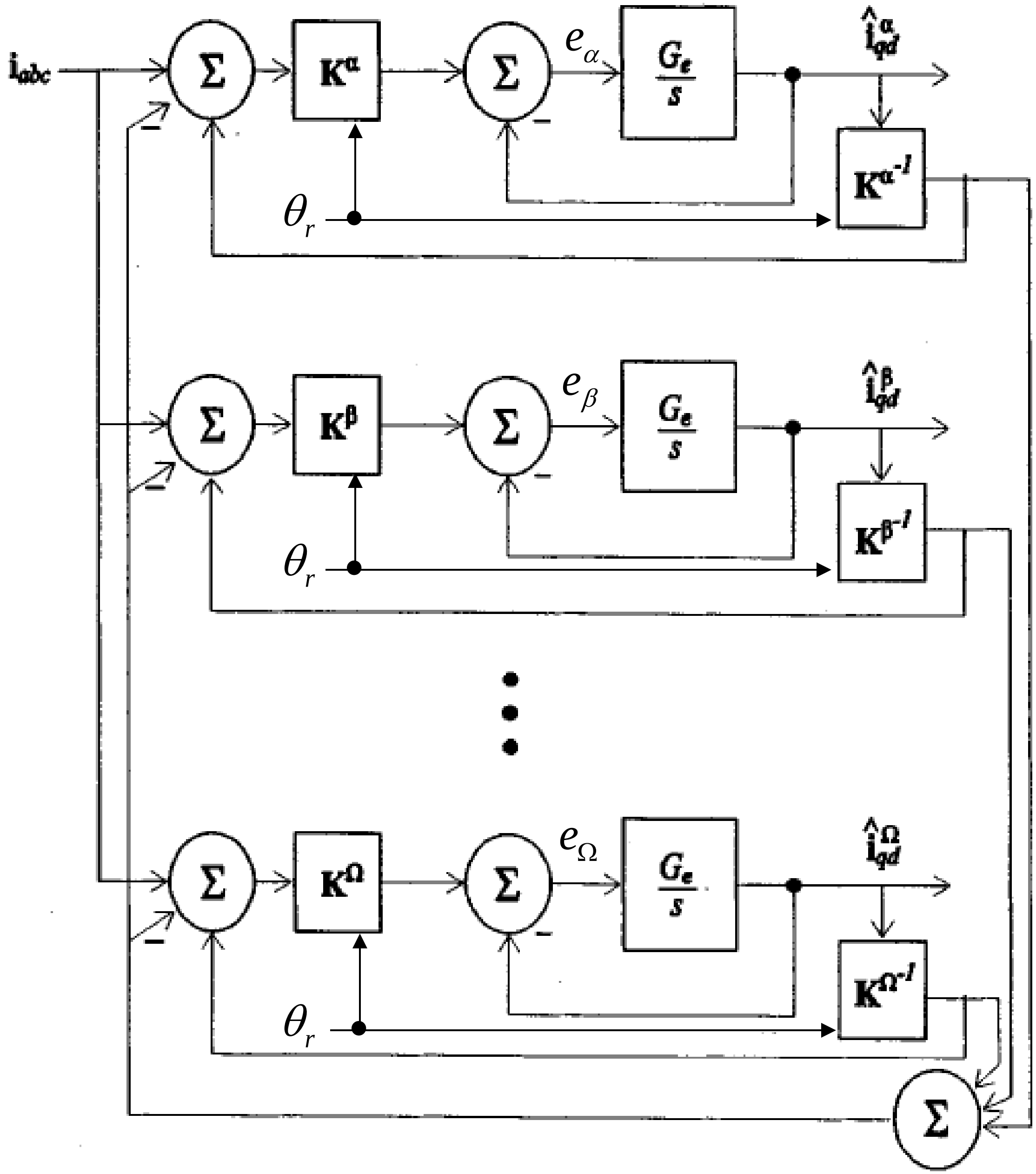

Fig. 3. MRFSER estimator applied to current-controlled PMSM drive.

Estimator Example: *N* is { 1, 3, -5 }

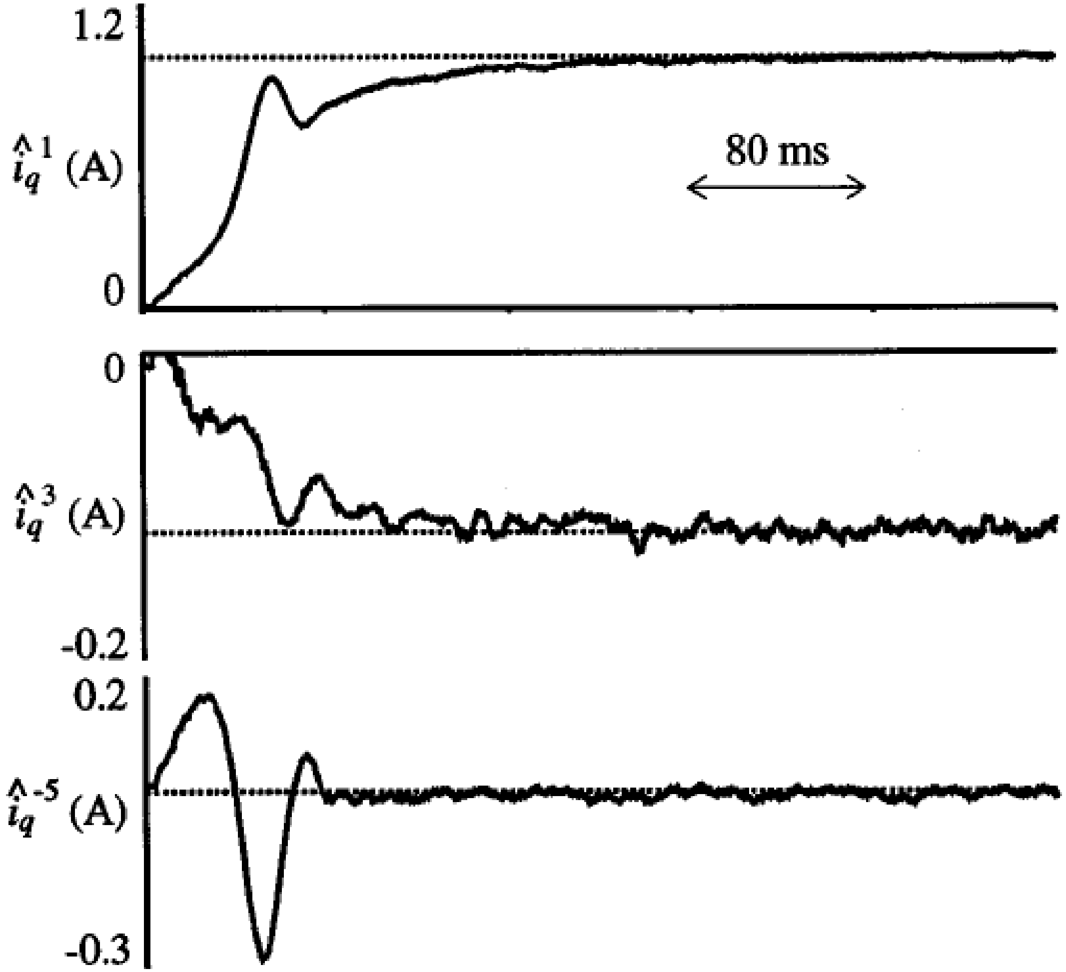

Fig. 4. Simulated estimated q-axis currents on start-up (dashed lines depict the commanded values).

Regulator

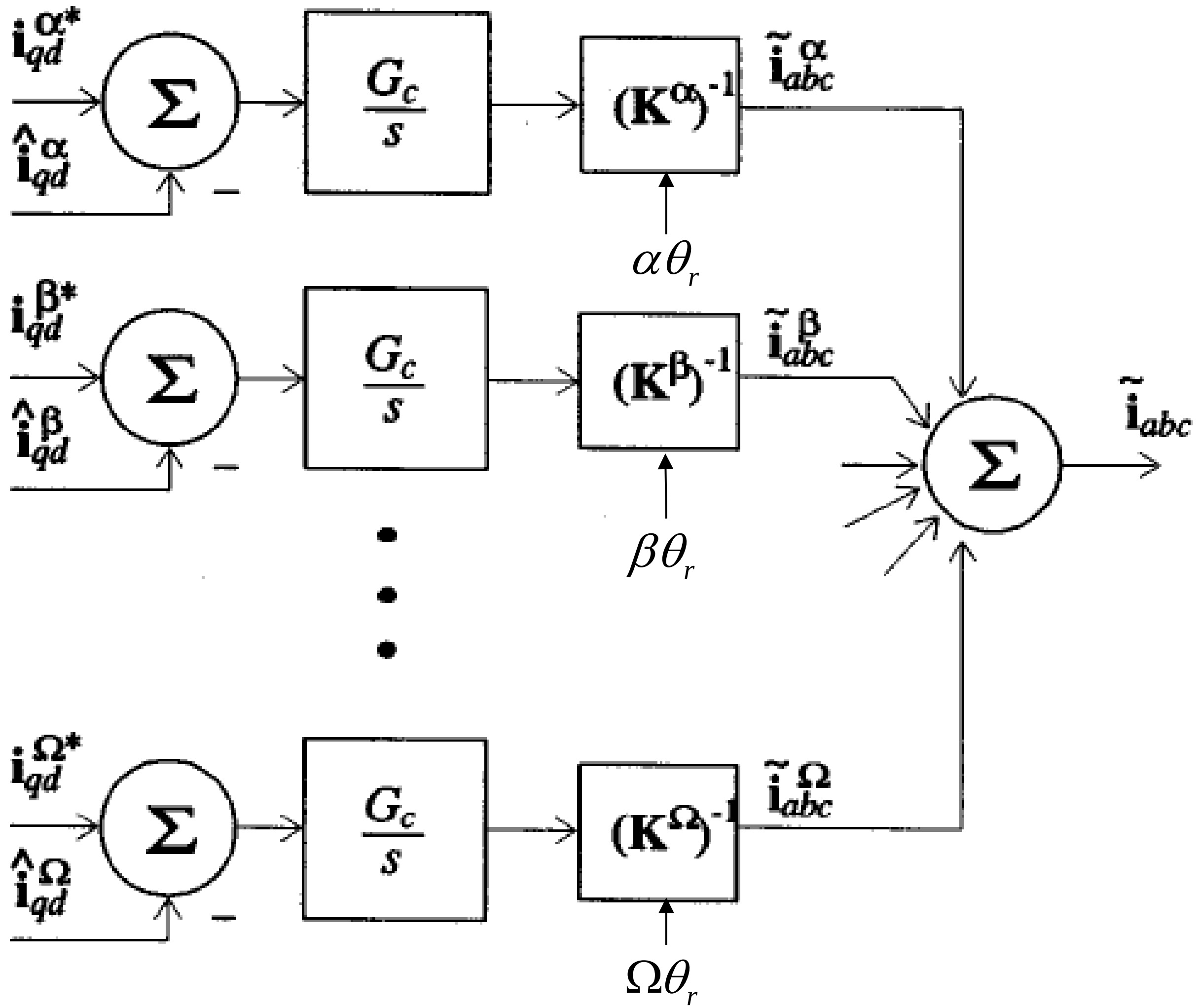

Fig. 2. MRFSER regulator applied to current-controlled PMSM drive.