August 2012 QE

Problem 1. 50 pts. Starting with the expressions for electrical and mechanical energy transferred to a coupling field, derive the relationship between force and field energy for a system with several electrical inputs and one mechanical degree of freedom, i.e. that

$$f_e = -\frac{\partial W_f(\lambda, x)}{\partial x}$$

where λ is the vector of electrical input flux linkages, x is the position of the mechanical degree of freedom, and f_e is electromagnetic force defined positive in the same direction as x is defined.

Problem 2. 25 pts. Clark's transformation may be written as

$$\mathbf{f}_{\alpha\beta 0} = \mathbf{C}\mathbf{f}_{abcs}$$

where

$$\mathbf{f}_{\alpha\beta 0} = \begin{bmatrix} f_\alpha & f_\beta & f_0 \end{bmatrix}^T$$

$$C = \frac{2}{3}\begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & -\frac{\sqrt{3}}{2} & \frac{\sqrt{3}}{2} \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix}$$

Relate f_{qs}^s, f_{ds}^s, and f_{0s} to f_α, f_β, and f_0.

Problem 3. 25 pts. The inductance matrix of a 2-phase reluctance machine may be expressed in machine variables as

$$L_S = \begin{bmatrix} L_A - L_B\cos 2\theta_r & -L_B\sin 2\theta_r \\ -L_B\sin 2\theta_r & L_A + L_B\cos 2\theta_r \end{bmatrix}$$

Express the inductance matrix of the *qd* model in the rotor reference frame where

$$K_s^r = \begin{bmatrix} \cos\theta_r & \sin\theta_r \\ \sin\theta_r & -\cos\theta_r \end{bmatrix}$$

Recall

$$\cos A\cos B = 0.5(\cos(A+B) + \cos(A-B))$$
$$\sin A\sin B = 0.5(\cos(A-B) - \cos(A+B))$$
$$\sin A\cos B = 0.5(\sin(A+B) + \sin(A-B))$$
$$\cos(A\pm B) = \cos A\cos B \mp \sin A\sin B$$
$$\sin(A\pm B) = \sin A\cos B \pm \cos A\sin B$$

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