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Lec NO. 14
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d - q - o transformation

$$\begin{bmatrix} f_a \\ f_b \\ f_c \end{bmatrix} = C_p \begin{bmatrix} f_d \\ f_q \\ f_o \end{bmatrix}$$

C_p is a function of "θ"

$$\begin{bmatrix} f_d \\ f_q \\ f_o \end{bmatrix} = C_p^{-1} \begin{bmatrix} f_a \\ f_b \\ f_c \end{bmatrix}$$

$$C_p = \begin{bmatrix} K_d \cos\theta & K_q \sin\theta & K_0 \\ K_d \cos(\theta - 2\pi/3) & K_q \sin(\theta - 2\pi/3) & K_0 \\ K_d \cos(\theta + 2\pi/3) & K_q \sin(\theta + 2\pi/3) & K_0 \end{bmatrix}$$

$$C_p^{-1} = \begin{bmatrix} K_1 \cos\theta & K_1 \cos(\theta - 2\pi/3) & K_1 \cos(\theta + \frac{2\pi}{3}) \\ K_2 \sin\theta & K_2 \sin(\theta - 2\pi/3) & K_2 \sin(\theta + \frac{2\pi}{3}) \\ K_3 & K_3 & K_3 \end{bmatrix}$$

$$K_1 = \frac{2}{3K_d} \qquad K_2 = \frac{2}{3K_q} \qquad K_3 = \frac{1}{3K_0}.$$

$$\begin{bmatrix} \psi_s \\ \\ \psi_r \end{bmatrix} = \begin{bmatrix} C_p & 0_{3\times 4} \\ \\ 0_{4\times 3} & I_{4\times 4} \end{bmatrix} \begin{bmatrix} \psi_{dq0} \\ \\ \psi_r \end{bmatrix}$$

$$\begin{bmatrix} \psi_s \\ \psi_r \end{bmatrix} = \underbrace{\begin{bmatrix} L_{ss}(\theta) & L_{sr}(\theta) \\ L_{rs}(\theta) & L_{rr} \end{bmatrix}}_{\mathbf{L}} \begin{bmatrix} i_s \\ i_r \end{bmatrix}$$

$$\begin{bmatrix} \psi_{dq0} \\ \psi_r \end{bmatrix} = \begin{bmatrix} C_p^{-1} & 0 \\ 0 & I \end{bmatrix} \begin{bmatrix} \\ L \\ \\ \end{bmatrix} \begin{bmatrix} C_p & 0 \\ 0 & I \end{bmatrix} \begin{bmatrix} i_{dq0} \\ i_r \end{bmatrix}$$

$$\begin{bmatrix} \psi_{dq0} \\ \psi_r \end{bmatrix} = \begin{bmatrix} L_{ss}' & L_{sr}' \\ L_{rs}' & L_{rr} \end{bmatrix} \begin{bmatrix} i_{dq0} \\ i_r \end{bmatrix}$$

$$L_{ss}' = \begin{bmatrix} L_d & 0 & 0 \\ 0 & L_q & 0 \\ 0 & 0 & L_0 \end{bmatrix}$$

$$L_d = L_{aa0} - L_{ab0} + 3/2\, L_{aa2}$$

$$L_q = L_{aa0} - L_{ab0} - 3/2\, L_{aa2}$$

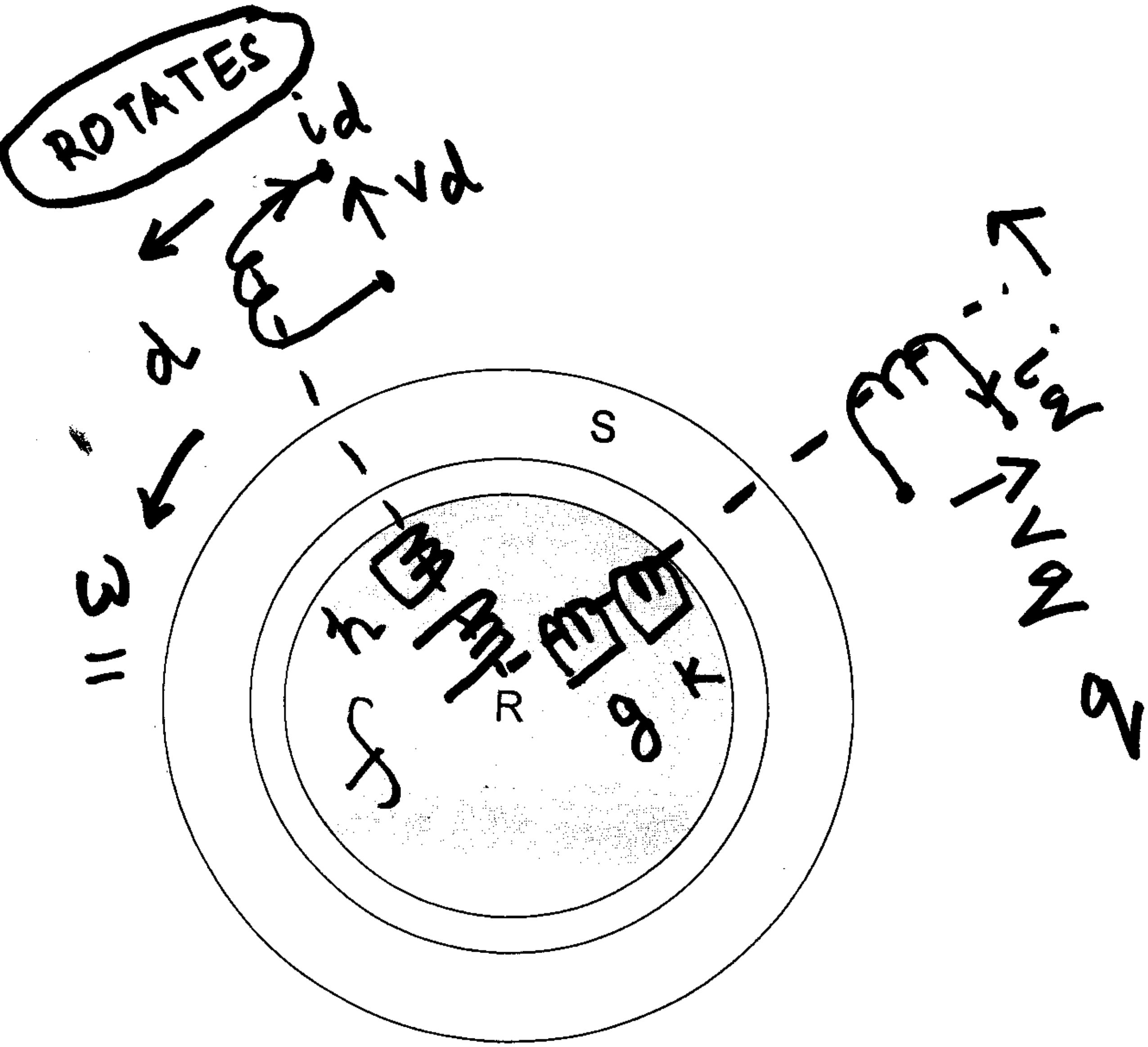
$$L_0 = L_{aa0} + 2\, L_{ab0} .$$

$$L'_{sr} = \begin{bmatrix} \frac{M_{af}}{K_d} & \frac{M_{ah}}{K_d} & 0 & 0 \\ 0 & 0 & \frac{M_{ag}}{K_q} & \frac{M_{ak}}{K_q} \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\underline{L'_{sr}} = \underline{(L'_{rs})^T} \quad \text{if} \quad K_d^2 = \frac{2}{3}$$

$$\underline{K_q^2 = 2/3.}$$

$$L_{sr} = L_{rs}^T$$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$$\frac{dC_p}{d\theta} = \begin{bmatrix} -K_d \sin\theta & K_q \cos\theta & 0 \\ -K_d \sin\left(\theta - \frac{2\pi}{3}\right) & K_q \cos\left(\theta - \frac{2\pi}{3}\right) & 0 \\ -K_d \sin\left(\theta + \frac{2\pi}{3}\right) & K_q \cos\left(\theta + \frac{2\pi}{3}\right) & 0 \end{bmatrix}$$

$$= C_p \cdot P_1$$

$$P_1 = \begin{bmatrix} 0 & K_a/K_d & 0 \\ -\frac{K_d}{K_a} & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

$$\frac{dC_p}{d\theta} = C_p \cdot P_1$$

$$-C_p \frac{d\psi_{dq0}}{dt} - \dot{\theta} C_p P_1 \psi_{dq0}$$

$$- R_s C_p i_{dq0} = C_p V_{dq0}$$

$$-\frac{d\psi_{dq0}}{dt} - \dot{\theta} P_1 \psi_{dq0} - R_a i_{dq0}$$

$$= V_{dq0}.$$

$$-\frac{d\psi_d}{dt} - \underbrace{\omega \frac{K_q}{K_d}}\psi_q - R_a i_d = V_d$$

$$-\frac{d\psi_q}{dt} + \underbrace{\omega \frac{K_d}{K_q}}\psi_d - R_a i_q = V_q$$

$$-\frac{d\psi_0}{dt} - R_a i_0 = V_0 .$$

$$\omega = d\theta/dt$$

$$\frac{d\psi_f}{dt} + R_f i_f = v_f$$

$$\frac{d\psi_h}{dt} + R_h i_h = 0$$

$$\frac{d\psi_g}{dt} + R_g i_g = 0$$

$$\frac{d\psi_k}{dt} + R_k i_k = 0$$

$$\begin{bmatrix} \psi_{dq0} \\ \psi_r \end{bmatrix} = \begin{bmatrix} L_{ss}' & L_{sr}' \\ L_{rs}' & L_{rr} \end{bmatrix} \begin{bmatrix} i_{dq} \\ i_r \end{bmatrix}$$

$$\dot{\psi} = \text{"}A\text{"}\,\psi + B\,\text{"}\dot{v}\text{"}$$

$$\psi = \begin{bmatrix} \psi_{dqo} \\ \psi_r \end{bmatrix}$$

ω

$$T_e' = -\frac{1}{2}\left\{ [i_{dq0}^T] \times C_p^T \times \frac{\partial L_{ss}}{\partial \theta} \times i_{dq0} \right.$$

$$\left. + 2\, i_{dq0}^T\, C_p^T \frac{\partial L_{sr}}{\partial \theta} i_r \right\}$$

$$\frac{\partial L_{ss}}{\partial \theta} = -2L_{aa2} \begin{bmatrix} \sin 2\theta & \sin(2\theta - \frac{2\pi}{3}) & \sin(2\theta + \frac{2\pi}{3}) \\ \sin(2\theta - \frac{2\pi}{3}) & \sin(2\theta + \frac{2\pi}{3}) & \\ \sin(2\theta + \frac{2\pi}{3}) & \sin 2\theta & \end{bmatrix}$$

$$\frac{\partial L_{sr}^{d}}{\partial \theta} = \begin{bmatrix} -M_{af}\sin\theta & -M_{ah}\sin\theta \\ -M_{af}\sin\left(\theta-\frac{2\pi}{3}\right) & -M_{ah}\sin\left(\theta-\frac{2\pi}{3}\right) \\ -M_{af}\sin\left(\theta+\frac{2\pi}{3}\right) & -M_{ah}\sin\left(\theta+\frac{2\pi}{3}\right) \end{bmatrix}$$

$$\frac{\partial L_{sr}^{q}}{\partial \theta} = \begin{bmatrix} M_{ag}\cos\theta & M_{ak}\cos\theta \\ M_{ag}\cos\left(\theta-\frac{2\pi}{3}\right) & M_{ak}\cos\left(\theta-\frac{2\pi}{3}\right) \\ M_{ag}\cos\left(\theta+\frac{2\pi}{3}\right) & M_{ak}\cos\left(\theta+\frac{2\pi}{3}\right) \end{bmatrix}$$

$$\frac{\partial L_{ss}}{\partial \theta} = -2L_{aa2}\begin{bmatrix} \sin 2\theta & \sin\left(2\theta - \frac{2\pi}{3}\right) & \sin\left(2\theta + \frac{2\pi}{3}\right) \\ \sin\left(2\theta - \frac{2\pi}{3}\right) & \sin\left(2\theta + \frac{2\pi}{3}\right) & \sin 2\theta \\ \sin\left(2\theta + \frac{2\pi}{3}\right) & \sin 2\theta & \sin\left(2\theta - \frac{2\pi}{3}\right) \end{bmatrix})$$

$$\frac{\partial L_{sr}}{\partial \theta} = \left[\frac{\partial L_{sr}^{d}}{\partial \theta} \;\vdots\; \frac{\partial L_{sr}^{q}}{\partial \theta} \right]$$

$$\frac{\partial L_{ss}}{\partial \theta} \cdot C_p = -3 L_{aa2} \, C_p \, P_2 .$$

$$P_2 = \begin{bmatrix} 0 & \frac{K_q}{K_d} & 0 \\ K_d/K_q & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

$$C_p^T \frac{\partial L_{sr}}{\partial \theta} = \begin{bmatrix} 0 & 0 & \frac{3}{2} K_d M_{ag} & \frac{3}{2} K_d M_{ak} \\ -\frac{3}{2} K_q M_{af} & -\frac{3}{2} K_q M_{ah} & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} .$$

$$T_e' = \frac{3}{2} K_d K_q \left\{ i_q \left(\frac{M_{af}}{K_d} i_f + \frac{M_{ah}}{K_d} i_h + \frac{3}{2} L_{aa2} i_d \right) - i_d \left(\frac{M_{ag}}{K_q} i_g + \frac{M_{ak}}{K_q} i_k - \frac{3}{2} L_{aa2} i_q \right) \right\}.$$

$$\psi_d = L_d + \frac{M_{af}}{K_d} i_f + \frac{M_{ah}}{K_d} i_h$$

$$\psi_q = L_q i_q + \frac{M_{ag}}{K_q} i_g + M_{ak}/K_q \, i_k.$$

$$T_e' = 3\, K_d K_q \left\{ i_q \left[\psi_d - \left(L_d - \frac{3}{2} L_{aa2} \right) \times i_d \right] - i_d \left[\psi_q - \left(L_q + \frac{3}{2} L_{aa2} \right) \times i_q \right] \right\}$$

$$T_e' = \frac{3}{2} K_d K_q \left[\psi_d i_q - \psi_q i_d \right]$$

$$K_d^2 = \frac{2}{3} \qquad K_q^2 = \frac{2}{3}.$$

$$L'_{sr} = \left(L'_{rs}\right)^T \qquad K_3 = \frac{1}{3K_0}$$

$$C_p^{-1} \longrightarrow K_1 = \frac{2}{3K_d} \quad K_2 = \frac{2}{3K_q}$$

$$K_d = K_q = \sqrt{\frac{2}{3}}$$

$$L_{sr}' = \left(L_{rs}'\right)^T \qquad K_0 = \sqrt{\frac{1}{3}}$$

$$C_p^{-1} = C_p^T \; !$$

$$\left.\begin{aligned} K_d &= 1 \\ K_q &= -1 \end{aligned}\right\}$$

$$C_{p1} = T_k \, C_p$$