ELEC 343, Assignment 5, Synchronous Motors:

Do Study Problem: SP7.3-2, SP7.4-1, SP7.4-3, do the examples 7B and 7C (absolutely vital), SP7.7-4

Textbook Chapter 7 Problem(s) - 3, 9, 10, and 11.

SP7.3-2. $v_{as} = r_s i_{as} + L_{asas}\frac{di_{as}}{dt} + \frac{d(L_{asfd}\, i_{fd})}{dt}$

With $i_{as} = 0$,

$$v_{as} = L_{asfd}\frac{di_{fd}}{dt} + i_{fd}\frac{dL_{asfd}}{dt}$$

With i_{fd} a constant, $v_{as} = i_{fd}\frac{\partial L_{asfd}}{\partial \theta_r}\frac{d\theta_r}{dt} = i_{fd}\,\omega_r L_{sfd}\cos\theta_r$

Since $\omega_r = \frac{d\theta_r}{dt}$, we have $V_{as} = (1)(10)(0.1)\cos 10t = \cos 10t$ V

$$v_{bs} = i_{fd}\frac{\partial L_{bsfd}}{\partial \theta_r}\frac{d\theta_r}{dt} = i_{fd}\,\omega_r L_{sfd}\sin\theta_r$$

Thus, $V_{bs} = (1)(10)(0.1)\sin 10t = \sin 10t$ V

SP7.4-1. Note that when $L_{md} = L_{mq}$ the term with $(L_{md} - L_{mq})$ disappears. Also note that the currents within the [ ] are stator currents. This is the reluctance torque.

SP7.4-3. The terms containing i'_{fd}, which also multiplies only the stator currents.

SP7.7-4. From (7.7-30) with E'^r_{xfd} terms eliminated,

$$T_e = -\left(\frac{P}{2}\right)\left(\frac{1}{\omega_e}\right)\left[\frac{1}{2}\left(\frac{1}{X_q} - \frac{1}{X_d}\right)(\sqrt{2}\,V_s)^2 \sin 2\delta\right]$$

From Example 7C,

$X_q = (377)(0.025) = 9.43\ \Omega$ $\qquad$ $X_d = (377)(0.105) = 39.59\ \Omega$

$$\left(\frac{1}{X_q} - \frac{1}{X_d}\right) = \left(\frac{1}{9.43} - \frac{1}{39.59}\right) = 0.0808$$

$$(\sqrt{2}\,V_s)^2 = [\sqrt{2}\,(110)]^2 = 24{,}200$$

$$T_e = -\left(\frac{2}{2}\right)\left(\frac{1}{377}\right)\left[\left(\frac{1}{2}\right)(0.0808)(24{,}200)\sin(-60^o)\right] = -2.25\ \text{N·m}$$

3. From Fig. 7.5-1,

$$\begin{bmatrix} f^r_{qs} \\ f^r_{ds}\end{bmatrix} = \begin{bmatrix} -\sin\theta_r & \cos\theta_r \\ \cos\theta_r & \sin\theta_r \end{bmatrix}\begin{bmatrix} f_{as} \\ f_{bs}\end{bmatrix} \quad \text{Thus,} \quad K^r_s = \begin{bmatrix} -\sin\theta_r & \cos\theta_r \\ \cos\theta_r & \sin\theta_r \end{bmatrix}$$

9. $\sqrt{2}\,\tilde{I}_{as}\,e^{-j\delta} = I^r_{qs} - j I^r_{ds}$. From Example 7B(a),

$$\sqrt{2}\,\tilde{I}_{as}\,e^{-j\delta} = \sqrt{2}\,(52.5)\,\underline{/-30^\circ}\,e^{-j(-23.4^\circ)}$$

$$= 74.2\,\underline{/-6.6^\circ} = 73.8 - j\,8.53\text{ A}$$

$$I^r_{qs} = 73.8\text{ A}; \quad I^r_{ds} = 8.53\text{ A}$$

$P_{in} = 40 \times 10^3$ W

$$2\,|\tilde{I}_{as}|^2\,r_s = (2)(52.5)^2(0.3) = 1.654\text{ kW}$$

$$T_e = \frac{P_{out}}{\omega_{rm}} = \frac{40{,}000 - 1654}{(377)(\frac{2}{6})} = 305\text{ N·m}$$

This is essentially the torque for all parts since only the $|(\tilde{I}_{as})|^2\,r_s$ terms change in (b) and its magnitude is insignificant compared to the total power input.

From Example 7B(b),

$$\sqrt{2}\,\tilde{I}_{as}\,e^{-j\delta} = \sqrt{2}\,(45.4\,\underline{/0^\circ})\,e^{-j(-19.9^\circ)}$$

$$= 64.2\,\underline{/19.9^\circ} = 60.4 + j\,21.9\text{ A}$$

$$I^s_{qr} = 60.4\text{ A}; \quad I^s_{dr} = -21.9\text{ A}$$

From example 7B(c),

$$\sqrt{2}\,\tilde{I}_{as}\,e^{-j\delta} = \sqrt{2}\,(52.5\,\underline{/30^\circ})\,e^{-j(-17.4^\circ)}$$

$$= 74.2\,\underline{/47.4^\circ} = 50.3 + j\,54.7\text{ A}$$

$$I^s_{qr} = 50.3\text{ A}; \quad I^s_{dr} = -54.7\text{ A}$$

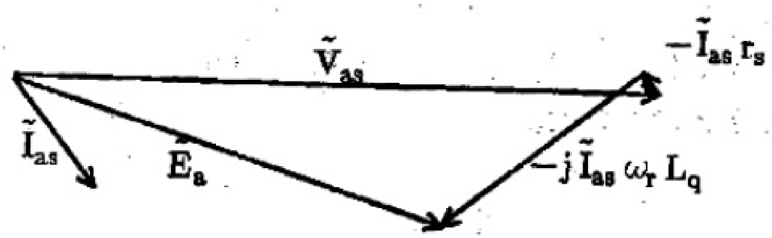
10. From Example 6C, $\tilde{V}_{as} = 110 \angle 0^\circ$ and $\tilde{I}_{as} = 4.55 \angle -51.6^\circ$

$$\tilde{E}_a = \tilde{V}_{as} - (r_s + jX_q)\tilde{I}_{as}$$

$$= 110 \angle 0^\circ - [1 + j(377)(0.005 + 0.02)]\,(4.55 \angle -51.6^\circ)$$

$$= 110 \angle 0^\circ - 43.1 \angle 32.3^\circ = 77.1 \angle -17.4^\circ \text{ V}$$

Note that, in Example 6C, δ was found to be -17.4° which checks with the above calculation. The phasor diagram is



11. $\tilde{V}_{as} = (r_s + jX_q)\tilde{I}_{as} + \tilde{E}_a$

For open circuit conditions, $\tilde{V}_{as} = \tilde{E}_a$; also,

$$\tilde{E}_a = \frac{1}{\sqrt{2}}\left[(X_d - X_q)I_{ds} + X_{md} I'^r_{fd}\right]e^{j\delta}$$

With $\tilde{I}_{as} = 0$ and $\tilde{V}_{as} = 440 \angle 0^\circ$,

$$\tilde{E}_a = \frac{1}{\sqrt{2}} X_{md} I'^r_{fd} \angle 0^\circ = 440 \angle 0^\circ$$

$$I'^r_{fd} = \frac{440\sqrt{2}}{(377)(13.7 \times 10^{-3})} = 120.5 \text{ A}$$

$$V'^r_{fd} = r'_{fd} I'^r_{fd} = (0.13)(120.5) = 15.7 \text{ V}$$

The value of I'^r_{fd} in Fig. 6.8-1 appears to be slightly less than 125 A; however, the scale of the graph does not allow us to check this value exactly.