Problem 6

$$\omega_f = \frac{\omega_e}{P} = \frac{2\pi \times 60}{3} = 125.7 \text{ r/sec}$$

$$T_{e,r} = \frac{1100 \times 10^3}{125.7} = 8751 \text{ N.m}$$

$$V = \frac{6600}{\sqrt{3}} = 3810.5 \text{ V}$$

$$\vec{I}_m = \frac{V}{jX_s} = \frac{3810.5}{j36} = 105.8 \angle -90^\circ \text{ A}$$

1) $P_{in} = P_{out} + 3I_s^2 R_s$

$$\sqrt{3} V I_s \cos\theta = 1100 \times 10^3 + 3 I_s^2 \times 1.2$$

($\cos\theta = 1$)

$$\sqrt{3}(6600) I_s = 1100 \times 10^3 + 3.6 I_s^2$$

which gives $I_s = 99 \angle 0^\circ$ A.

$$\vec{I}_f' = \vec{I}_m' - \vec{I}_s = (105.8 \angle -90^\circ) - (99 \angle 0^\circ)$$

$$I_f' = 144.9 \angle -133^\circ \text{ A}$$

$$I_f = \frac{X_s}{X_m} I_f', \quad I_F = \frac{I_f}{n}$$

$$\Rightarrow I_F = \frac{X_s}{n X_m} I_f' = \frac{36}{2(30)} (144.9) = \boxed{86.94 \text{ A DC}}$$

$$P_{out} = 3 V I_f' \sin\delta \Rightarrow \sin\delta = \frac{1100 \times 10^3}{3\left(\frac{6600}{\sqrt{3}}\right) \times 144.9} = 0.66$$

$$\Rightarrow \boxed{\delta = 13.9^\circ}$$

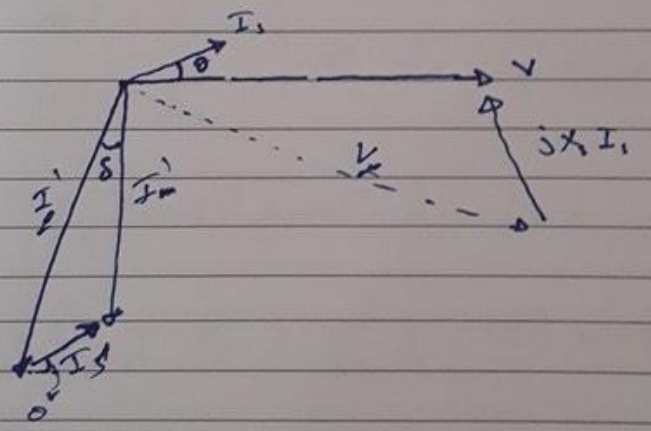
2) $T_{el,max} = \frac{3VI_f'}{\omega_1} = \frac{3}{125.7}\left(\frac{6600}{\sqrt{3}}\right)(144.9)$

$$\boxed{T_{el,max} = 13178\ N.m}$$

3) $T_{el} = \frac{T_{el,r}}{2} = 4375.5\ N.m$

$$T_{el} = \frac{3VI_f'}{\omega_1}\sin\delta \Rightarrow 4375.5 = \frac{3}{125.7}\left(\frac{6600}{\sqrt{3}}\right)(144.9)\sin\delta$$

$\sin\delta = 0.33$ or $\cos\delta = 0.94$



$$\left.\begin{aligned} I_1\cos\theta &= I_f'\sin\delta \\ I_1\sin\theta &= I_f'\cos\delta - I_m' \end{aligned}\right) \Rightarrow I_1 = \sqrt{I_f'^2 + I_m'^2 - 2I_f'I_m'\cos\delta}$$

$$I_1 = \sqrt{(144.9)^2 + (105.8)^2 - 2(144.9)(105.8)(0.94)}$$

$$\boxed{I_1 = 56.6\ A}.$$

$$\cos\theta = \frac{I_f'}{I_1}\sin\delta = \frac{144.9}{105.8}(0.33) = \boxed{0.84\ (leading)}$$

$P_m = T_{ed}\,\omega_s$

$P_m = 4775.5 \times 125.7 = 550\ kW$

$losses = 3(56.6)^2 \times 1.2 + (86.94)^2(5) = 49.32\ kW$

$\eta = \dfrac{550}{550 + 49.32} = \boxed{92\%}$

4) $P_{in} = \sqrt{3}\,V I_1 = 550 \times 10^3 + 3 I_1^2 \times 1.2$

which gives $I_1 = 48.5\ A$

$$\left.\begin{aligned} I_y' \cos\delta &= I_m' \\ I_y' \sin\delta &= I_1 \end{aligned}\right\} \Rightarrow I_y' = \sqrt{I_m'^2 + I_1^2}$$

$I_y' = \sqrt{(105.8)^2 + (48.5)^2} = 116\ A$

$I_F = \dfrac{X_s}{X_m}\,\dfrac{1}{n}\,I_y' = \dfrac{36}{30}\,\dfrac{1}{2}\,(116) = \boxed{69.6\ A}$

Problem 7

From problem 6,

$I_m' = 105.8\ A$

$PF = 1.0$

$T_{ae,r} = 8751\ N.m$

$\delta = 41.6°$

$I_s = 99\ A$

$I_y' = 144.9\ A$

$\omega_s = 125.7\ r/sec.$

1) $I_s = 99\ A$
$\delta = 41.6°$
$PF = 1.0$

2) $T_{ind} = \frac{T_{ae,r}}{2} = 3 P L_s I_y' I_m' \sin\delta$

$4375.5 = 3(3)\left(\frac{36}{2\pi \times 60}\right)(105.8)(144.9)\sin\delta$

$\sin\delta = 0.33 \quad \text{or} \quad \cos\delta = 0.94$

$I_s \cos\theta = I_y' \sin\delta$
$I_s \sin\theta = I_y' \cos\delta - I_m'$ $\Rightarrow I_s = \sqrt{I_y'^2 + I_m'^2 - 2 I_y' I_m' \cos\delta}$

$I_s = \sqrt{(144.9)^2 + (105.8)^2 - 2(144.9)(105.8)(0.94)}$

$I_s = 56.6\ A$

$\cos\theta = \frac{I_y'}{I_s}\sin\delta = \frac{144.9}{56.6}(0.33) = 0.84$ leading

3) $T_{ee} = T_{ee,r}\left(\frac{\omega_{m,r}}{\omega_m}\right)$

$T_{ee} = 8751\left(\frac{1200}{1500}\right)$

$\boxed{T_{ee} = 7003 \text{ N.m}}$

$I_m' = I_{m,r}'\left(\frac{\omega_{m,r}}{\omega_m}\right)$

$I_m' = 105.8\left(\frac{1200}{1500}\right)$

$\boxed{I_m' = 84.68 \text{ A}}$

$\left.\begin{aligned} I_y' \cos\delta &= I_m' \\ I_y' \sin\delta &= I_s \end{aligned}\right\} \Rightarrow I_y' = \sqrt{I_m'^2 + I_s^2}$

$I_y' = \sqrt{(84.68)^2 + (99)^2}$

$\boxed{I_y' = 130 \text{ A}}$