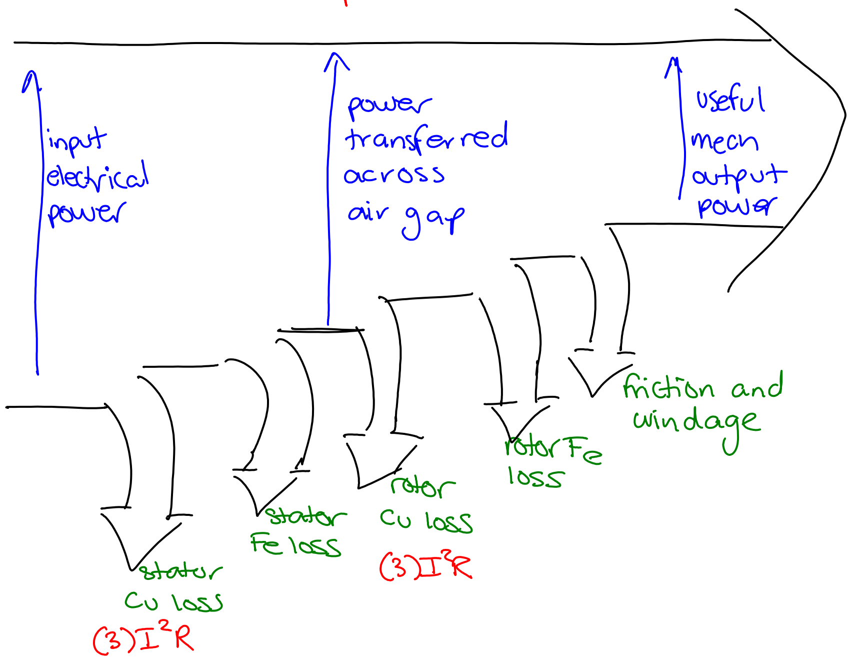
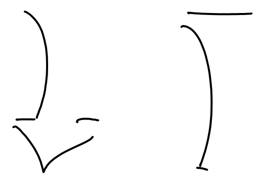
Lecture 12

Tuesday, 15 September 2009
4:36 PM

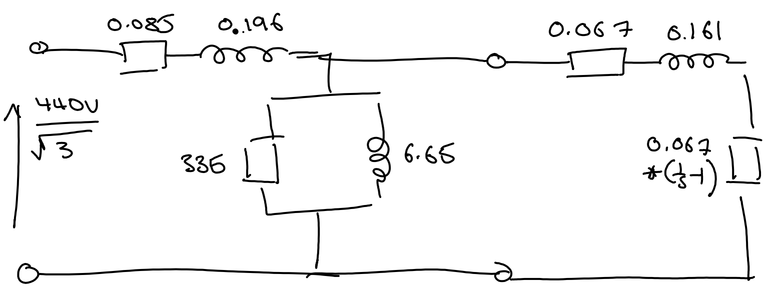
Power Balance

$$\frac{\text{output}}{\text{input}} = \frac{\text{input} - \text{losses}}{\text{input}} = \frac{\text{output}}{\text{output} + \text{losses}}$$





Eg: A 100hp 3ϕ, $\curlywedge$ connected, 440V, 50 Hz, 8-pole induction motor has the following equivalent cct parameters referred to the stator.



The total rotational & stray load losses are 2.7kW and 0.5kW respectively and may be considered constant.

Calculate for a slip of 3%

i) P_m

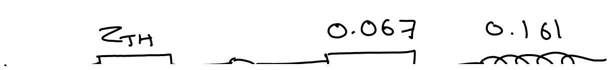
ii) I_a

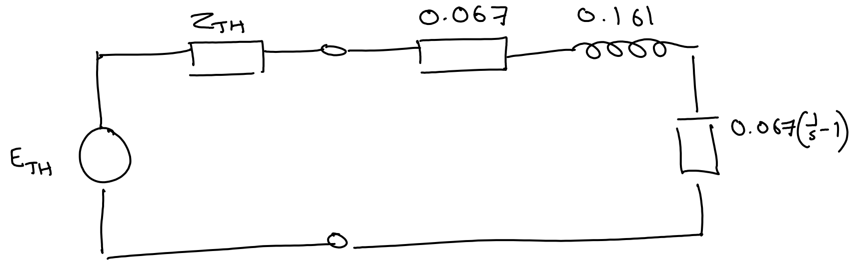
iii) pf

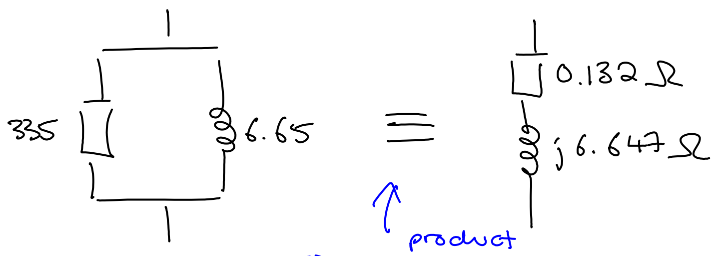
iv) stator active power loss

v) N_m

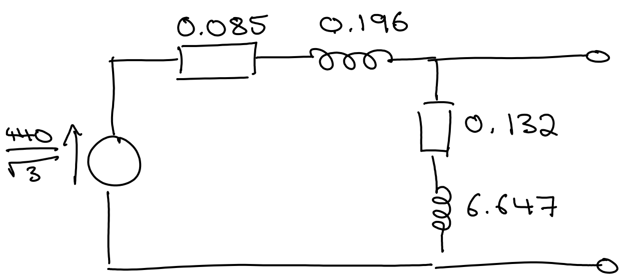
vi) η







using $\frac{\text{product}}{\text{sum}}$



parallel

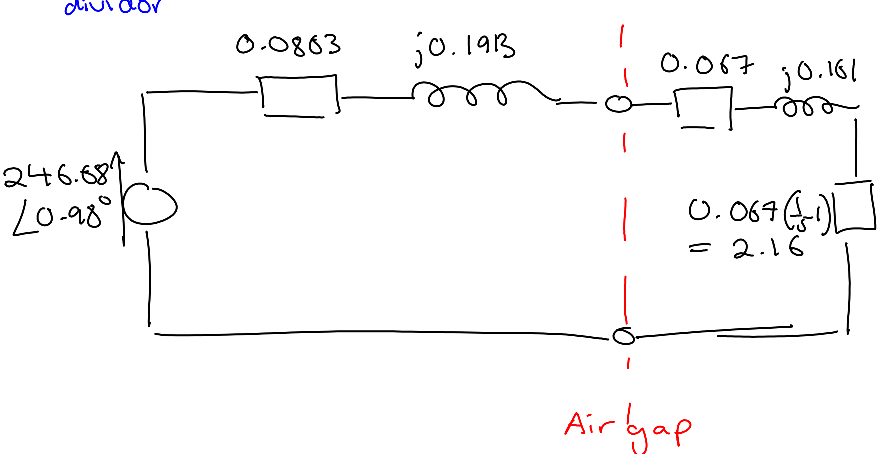
$$Z_{TH} = \frac{(0.085 + j0.196)(0.132 + j6.647)}{(0.085 + j0.196) + (0.132 + j6.647)}$$

$$= 0.0803 + j0.1913 \ \Omega$$

$$E_{TH} = \frac{0.132 + j6.647}{(0.132 + j6.647) + (0.085 + j0.196)} \times \frac{440}{\sqrt{3}}$$

voltage divider

$$= 246.68 \angle 0.68^\circ$$



$$I_a' = \frac{E_{TH}}{(0.0803 + j0.1913) + (0.067 + j0.161) + 2.16}$$

$$= 105.4 \angle -8.0^\circ$$

$$P_{ma} = 3 I_a^2 \left(\frac{R_r'}{s}\right)$$

$$= 3 \times (105.4)^2 \, \frac{0.067}{0.03}$$

$$= 74442W$$

$$P_m = P_{ma}(1 - s)$$

$$= 0.97 \times 74442W$$

$$= 72208W$$

$$V = I_a' \left(\frac{0.067}{s} + j0.161 \right)$$

$$= (105.4 \angle -8)\left(\frac{0.067}{0.03} + j0.161\right)$$

$$I_{ma} = \frac{V}{0.132 + j6.647}$$

$$= 35.5 \angle -92.7^\circ$$

$$\therefore I_a = I_a' + I_{ma}$$

$$= 105.4 \angle -8 + 35.5 \angle -92.7^\circ$$

$$= 114.3 \angle -26^\circ$$

$$pf = \cos\phi$$

$$= \cos 26$$

$$= 0.89 \text{ lag}$$

iv) $3 I_a^2 \, 0.085$

$$= 3 \times 114.3^2 \times 0.085$$

$= 3330W$

Fe loss: $3\frac{V^2}{R_c}$

$$= 3 \times \frac{236^2}{335}$$

$$= 498W$$

$$N_{ms} = \frac{120f}{P}$$

$$= \frac{120 \times 50}{80}$$

$$= 750 \text{ rpm}$$

$$N_m = N_{ms}(1-s)$$

$$= 727.5 \text{ rpm}$$

$$\eta = \frac{P_{out}}{P_{in}}$$

$$P_m = 72208W$$

$$P_{m\text{-}out} = 72208 - 3200$$

$$= 69008$$

$$P_{in} = 3VI\cos\phi$$

$$= 3 \times \frac{440}{\sqrt{3}} \times 114.3 \cos 26$$

$$= 78292W$$

$$\eta = \frac{69008}{78292} = 88\%$$

From the equiv cct

$$I'_a = \frac{E_{TH}}{Z_{TH} + R'_r/s + j\omega_s L'_{er}}$$

$$|I'| = \frac{E_{TH}}{}$$

$$|I_a'| = \frac{\quad}{\sqrt{\left(R_{TH} + \frac{R_r'}{s}\right)^2 + \left(X_{TH} + X'_{er}\right)^2}}$$

$$(I_a')^2 = \frac{E_{TH}^2}{\left(R_{TH} + \frac{R_r'}{s}\right)^2 + \left(X_{TH} + X'_{er}\right)^2}$$

$$\tau = \frac{P_{ma}}{\omega_{ms}}$$

$$P_{ma} = 3 I_a'^2 \frac{R_r'}{s}$$

$$\therefore \tau = \frac{3}{\omega_{ms}} (I_a')^2 \frac{R_r'}{s}$$

$$= \frac{3}{\omega_{ms}} \left[\frac{E_{TH}^2}{(R_{TH} + R_r'/s)^2 + (X_{TH} + X'_{er})^2}\right] \frac{R_r'}{s}$$

for small slip $s \to 0$

$$\left(R_{TH} + \frac{R_r'}{s}\right) >> \left(X_{TH} + X'_{er}\right) \Rightarrow \left(R_{TH} + \frac{R_r'}{s}\right)^2 >>>> \left(X_{TH} + X'_{er}\right)^2$$

and $\frac{R_r'}{s} >> R_{TH}$

$\therefore$

$$\tau \simeq \frac{3E_{TH}^2}{\omega_{ms}} \left(\frac{1}{(R_r'/s)^2}\right) \frac{R_r'}{s}$$

$$= \frac{3E_{TH}^2}{\omega_{ms}} \frac{s}{R_r'}$$

ie $\tau \propto s$ for a small slip.

For a large slip $(s \to 1)$

$$\left(R_{TH} + \frac{R_r'}{s}\right) << \left(X_{TH} + X'_{er}\right)$$

so

$$\left(R_{TH} + \frac{R_r'}{s}\right)^2 <<<< \left(X_{TH} + X'_{er}\right)^2$$

$$\therefore \tau = \frac{3E_{TH}^2}{\omega_{ms}} \left[\frac{1}{(X_{TH} + X'_{er})^2}\right] \frac{R_r'}{s}$$

ie $\tau \propto \frac{1}{s}$ for a large slip.