Goh Kheng Xi Jevan A0199806L

Induction Motors

Date No.

1. $n_r = (1-s)\, n_s$ $\quad s = \frac{n_s - n_r}{n_s}$

At rest: $n_r = 0$ $\quad s = 1$ if $n_r = 0$

$\Rightarrow 0 = (1-s)\, n_s$

$s = 1$ or 100%

2. 3ϕ, 2 poles, 60Hz, $n_r = 3502$ rpm

$P_{in} = 15.7\,kW$, $I_1 = 22.6A$

$r_1 = 0.2\Omega$ / phase

$P_{RCL} = ?$

$P_{core} = 0W$

$P_{SCL} = 3I_1^2 r_1$

$= 3(22.6)^2(0.2)$

$= 306.46W$

$= 15393.54W$

$P_{AG} = P_{in} - P_{core} - P_{SCL}$

$= 15.7kW - 0 - 306.46$

$= 15393.54W$

$P_{AG} = 3I_2'^2 \frac{R_2'}{s}$

$\downarrow$

$s.P_{AG} = 3I_2'^2 \cdot R_2'$

$P_{in} = 3V_1 I_1 \cos\theta$

$\rightarrow P_{SCL} = 3I_1^2 R_1$ $\quad P_{SCL}$ = Stator copper loss

$\rightarrow P_{core} = \frac{3E_1^2}{R_C}$

$P_{AG} \rightarrow P_{AIRGAP} = P_{in} - P_{SCL} - P_{core}$ $\quad \rightarrow 3I_2'^2 \cdot R_2$

$P_{AG} = 3I_2'^2 \cdot \frac{R_2'}{s}$

$\rightarrow P_{RCL} = 3I_2'^2 \cdot R_2'$

$P_{elec} = P_{AG} - P_{RCL} = 3I_2'^2 \frac{R_2'}{s} - 3I_2'^2 \cdot R_2'$

$= 3I_2'^2 R_2' \left(\frac{1}{s} - 1\right)$

$= 3I_2'^2 R_2' \left(\frac{1-s}{s}\right)$

$\rightarrow P_{mech\ loss} = P_{friction} + P_{windage}$

$P_{out} = P_{elec} - P_{mech.\ loss}$

$P_{out} = \tau_m \cdot \omega_m = P_{shaft}$

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

$n_s = \frac{120 \times 60}{2} = 3600$ rpm

$s = \frac{n_s - n_r}{n_s} = \frac{3600 - 3502}{3600}$

$= 0.027$ or 2.7%

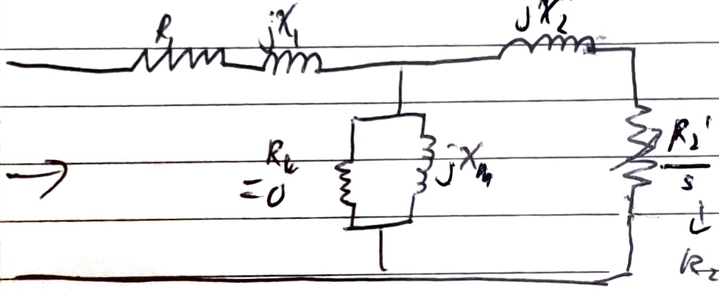
$s.P_{AG} = 3I_2'^2 \cdot R_2' = P_{RCL}$

$P_{RCL} = 0.027 \times 15393.54 = 419W$

3. 3ϕ, Y, 220V, 7.5kW, 60Hz, 6 pole

$R_1 = 0.1\Omega$, $R_2' = 0.1\Omega$, $X_1 = 0.2\Omega$, $X_2' = 0.2\Omega$

$X_m = 10\Omega$, $s = 0.01$



$n_s = \frac{120f}{P} = \frac{120 \times 60}{6} = 1200$ rpm

$n_r = (1-s)n_s = (1-0.01)1200$
$= 1188$ rpm

$\omega_r = 1188 \times \frac{2\pi}{60} = 124.4$ rad/s

$\frac{R_2'}{s} + jX_2'$

$Z_2' = \frac{0.1}{0.01} + j0.2 = 10 + j0.2\ \Omega$

$Z_2' \| jX_m = (10+j0.2) \| (j10) = 4.9 + j5\ \Omega$

$Z_{eq} = Z_1 + (Z_2' \| jX_m) = (0.1+0.2j) + (4.9+j5)\ \Omega$
$= 5 + j5.2\ \Omega$

$Z_{eq} = |Z_{eq}| \angle Z_{eq} \rightarrow \cos(\angle Z_{eq}) \rightarrow$ p.f. of the line

If load changes → s changes → Z_2' change

Power factor changing ← $\angle Z_{eq}$ changing ← Z_{eq} change

$s = \frac{n_s - n_r}{n_s}$

$1(n_s) = n_s - n_r$

$n_r = 0$

4.

$Z_2' = 5.41 + j3.1\,\Omega$, 7.5kW

$I_1 = 18.8A$, $s = 2\%$, $W_r = 123.2$ rad/s

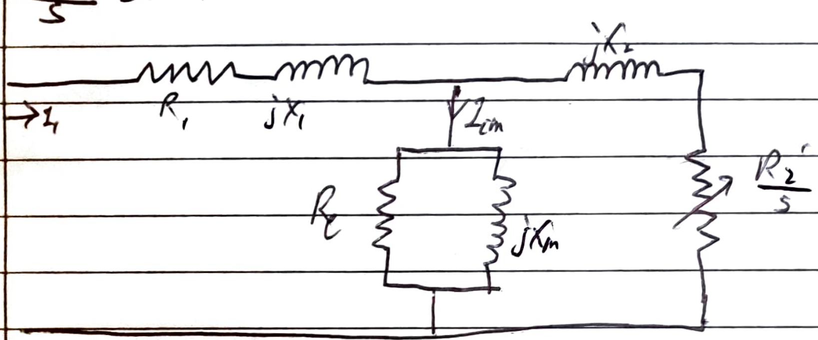
$P_{loss} = 403W$

$P_{shaft} = ?$

$\tau_{output} = ?$

$Z_2' = 5.41 + j3.1$

$\frac{R_2'}{s} = 5.41$



$I_1 = I_2' + I_{cm}$

I_{cm} = very small

$I_2' \approx I_1 = 18.8A$

$P_{AG} = 3I_2'^2 \cdot \frac{R_2'}{s}$

$= 3 \times 18.8^2 \times 5.41$

$= 5736.3W$

$P_{elec} = P_{AG} - P_{RCL}$

$= P_{AG} - s \cdot P_{AG}$

$= 5736.3(1 - 0.02)$

$= 5621.6W$

$P_{shaft} = P_{out} = P_{elec} - P_{motor\ loss}$

$= 5621.6 - 403 = 5218.6W$

$P_{in} = 3V_1 I_1 \cos\theta$ $\quad$ $P_{SCL} \to$ stator copper loss

$\to P_{SCL} = 3I_1^2 R_1$

$\to P_{core} = \frac{3E_1^2}{R_C}$

$P_{AG} = P_{airgap} = P_{in} - P_{SCL} - P_{core}$

$P_{AG} = 3I_2'^2 \cdot \frac{R_2'}{s}$

$\to P_{RCL} = 3I_2'^2 \cdot R_2'$

$= s P_{AG}$

$P_{elec} = P_{AG} - P_{RCL} = 3I_2'^2 \frac{R_2'}{s} - 3I_2'^2 \cdot R_2'$

$= 3I_2'^2 R_2' (\frac{1}{s} - 1)$

$= 3I_2'^2 R_2' (\frac{1-s}{s})$

$\to P_{motor\ loss} = P_{friction} + P_{windage}$

$P_{out} = P_{elec} - P_{motor\ loss}$

$P_{out} = \tau_m \cdot \omega_m = P_{shaft}$

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

$\tau_m = \frac{P_{shaft}}{\omega} = \frac{5218.6}{132.2} = 42.4Nm$

5. $\rightarrow 480V, 60Hz, 50Hp, 3\phi, I_1 = 60A$

$\cos\theta_1 = 0.85$ lag

$P_{SCL} = 2000W$, $P_{RCL} = 700W$

$P_{mech\ loss} = 600W$, $P_{core} = 1800W$

$P_{in} = 3V_{ph} I_{ph} \cos\theta$ $\rightarrow P_{in} = 3V_1 I_1 \cos\theta_1$

$P_{in} = 3V_1 I_1 \cos\theta_1$

$= 3 \times \frac{480}{\sqrt{3}} \times 60 \times 0.85$

$= 42400.6W$

$\rightarrow P_{SCL} = 3I_1^2 R_1$

$\rightarrow P_{core} = \frac{3E_1^2}{R_C}$

$P_{AG} \rightarrow P_{AirGap} = P_{in} - P_{SCL} - P_{core}$

$P_{AG} = 3I_2'^2 \cdot \frac{R_2'}{S}$ $R_{CL} \rightarrow$ Rotor copper Loss

a. $P_{AG} = P_{in} - P_{SCL} - P_{core}$

$= 42400.6 - 2000 - 1800$

$= 38600.6W$

$\rightarrow P_{RCL} = 3I_2'^2 \cdot R_2'$

$P_{elec} = P_{AG} - P_{RCL} = 3I_2'^2 \frac{R_2'}{S} - 3I_2'^2 \cdot R_2'$

$= 3I_2'^2 R_2' \left(\frac{1}{S} - 1\right)$

$= 3I_2'^2 R_S' \left(\frac{1-S}{S}\right)$

b. $P_{elec} = P_{conv} = P_{converted}$

$= P_{AG} - P_{RCL}$

$= 38600.6 - 700$

$= 37900.6W$

$\rightarrow P_{rotor\ loss} = P_{friction} + P_{windage}$

$P_{out} = P_{elec} - P_{rotor\ loss}$

c. $P_{out} = P_{elec} - P_{mech\_loss}$

$= 37900.6 - 600$

$= 37300.6W$

$P_{out} = \tau_m \cdot \omega_m = P_{shaft}$

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

d. $\eta = \frac{P_{out}}{P_{in}} \times 100\% = \frac{37300.6}{42400.6} \times 100\%$

$= 87.97\%$