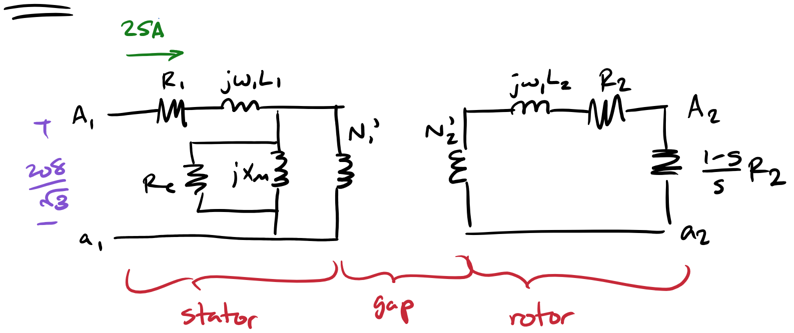
Induction Motors

Thursday, April 21, 2016 4:52 PM

A 208V, 50Hz, 40hp, three phase induction motor is drawing 25A at a pf of 0.8 inductive. The stator copper losses are 2kW, and the rotor copper losses are 700W. The friction and windage losses are 600W, and the core losses are 1kW (neglect stray losses).

- What is the air gap power.
- What is the converted power.
- What is the output power.
- What is the overall efficiency of the motor.



$$P_{3\phi} = \sqrt{3}\,\underbrace{V_L}_{208V}\,\overbrace{I_L}^{25A}\,\underbrace{\cos\theta}_{0.8}$$

$$P_{gap} = P_{in} - P_{\substack{stator\\copper}} - P_{core} = \sqrt{3}(208)25(0.8) - 2kW - 1kW = \boxed{4205W}$$

$P_{converted}$ is Power dissipated in $\frac{1-s}{s}R_2$

$$P_{conv} = P_{gap} - P_{\substack{rotor\\copper}} = \boxed{3505W}$$

$$P_{out} = P_{conv} - P_{\substack{friction\\windage}} = 3505 - 600 = \boxed{2905}$$

$$\eta = \frac{P_{out}}{P_{in}}100\% = \frac{2905}{7205}100 = \boxed{40.3\%}$$

A 460V, 60Hz, 25hp, four pole, Y connected induction motor, in ohms, per phase, referred to the stator circuit: R_1=0.641Ω; X_1=1.106Ω; R'_2=0.332Ω; X'_2=0.464Ω; X_m=26.3Ω. Rotational losses are assumed constant for any speed at 1100W. If the rotor slip is 3.3%.

- What is the speed of the motor, in rps, rpm and rad/s.
- What is the stator current.
- What is the power factor.

- What is the converted power, and the output power.
- What is the efficiency of the motor at this load.

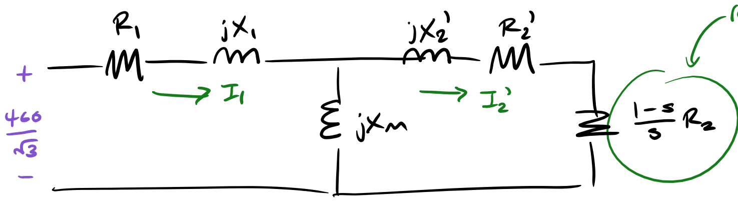
b/c connected in Y don't need to divide R_s & X_s by 3

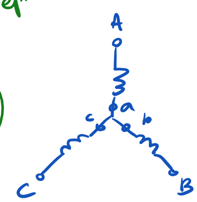
$V_L = 460$ $\qquad$ $s = 3.3\%$ at same load

$P_{\text{friction windage}} = 1100W$ $\qquad$ $n_o = 60\frac{f}{p} = 60\frac{60}{2} = 1800RPM$

$n_2 = (1-s)n_o \rightarrow n_2 = (1-0.033)1800 = \boxed{1741RPM}$

represents mechanical load





phase A of equivalent circuit in wye

$$I_1 = \frac{460/\sqrt{3}}{jX_m // (jX_2 + R_2 + \frac{1-s}{s}R_2) + R_1 + jX_1} = \boxed{25.7\angle -27A}$$

$$PF = \cos(\angle V - \angle I) = \cos(0 - -27°) = \boxed{0.887}$$

$$P_{conv} = 3\left(\frac{1-s}{s}R_2'\right)(I_2')^2 = 16362W \quad \text{(skipped MVA)}$$

note, converted power is 3 times this b/c only one line of Y

$$P_{out} = P_{conv} - P_{rot} = 16362 - 1100 = \boxed{15262W}$$

$$\eta = \frac{P_{out}}{P_{in}}100 = \frac{15262}{\sqrt{3}V_L I_L PF} = \boxed{83.6\%}$$

- A two pole, 50Hz, induction motor supplies 15kW at a speed 2900 rpm.
  - What is rotor slip.
  - What is the induced torque.
  - What is the new speed if the torque of the load doubles.
  - What is the output power with the doubled torque of the load

$$n_o = 60\frac{f}{p} = 60\frac{50}{1} = 3000RPM$$

$$s = \frac{n_o - n_s}{n_o} = \frac{3000-2900}{3000} = \boxed{3.33\%}$$

$P_{conv} = \tau_{ind}\,\omega_{rotor}$

$\tau_{ind} = \cancel{\tau_{\substack{friction\\ windage}}}^{\text{neglect}} + \tau_{out}$

$P_{conv} = P_{out} = 15kW$

$P_{out} = \tau_o\, n_2 \frac{2\pi}{60} = \tau_o \left(2900 \frac{2\pi}{60}\right) = 15kW$

$\hookrightarrow \tau_{ind} \approx \tau_{out} = \boxed{49.39\,Nm}$

$\times 2\ \tau$ means $\times 2$ slip in operating region

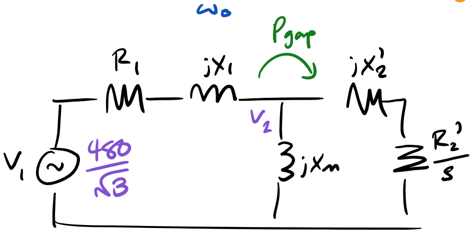
$n = (1-2s)n_o = \boxed{2800}$

$P_{new} = \frac{2\pi}{60}\, 2800\, (2(49.39Nm)) = \boxed{28.96\,kW}$

A 480V, 60Hz, 50hp, six pole, Y connected induction motor, in ohms, per phase, referred to the stator circuit: R_1=0.641Ω; X_1=1.106Ω; R'_2=0.332Ω; X'_2=0.464Ω; X_m=26.3Ω. Neglect windage and friction.

– At what speed the motor delivers maximum torque.

$\tau_{ind} = \frac{P_{gap}}{\omega_o}$ maximize P_{gap}, maximize τ



$P_{gap} = \frac{R_2'}{s} \cdot (I_2')^2 \cdot 3$

find thevenin equivalent, for max transfer $\frac{R_2'}{s} == Z_{th}$

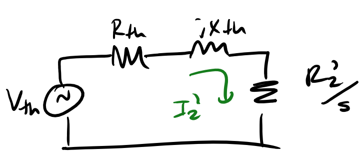
KILL SOURCES $\longrightarrow Z_{th} = (jX_m \,\|\, (R_1 + jX_1)) + jX_2' = (0.59,\ 1.539)$

$abs(Z_{th}) = 1.648$

$1.648 = \frac{R_2'}{s} \longrightarrow s_{max} = 0.201$

to find P_{gap}, find V_{th}

$\hookrightarrow$ voltage divider to get $V_{th} = 265.87 \angle 1.34°$



$I_2' = 97.89 \angle -33.18A$

$P_{gap}^{max} = 3 \frac{R_2'}{s} (I_2')^2 = 47.3kW$

$$\tau_{max} = \frac{P_{gen}^{max}}{\omega_0} = \boxed{377\,\mathrm{Nm}}$$