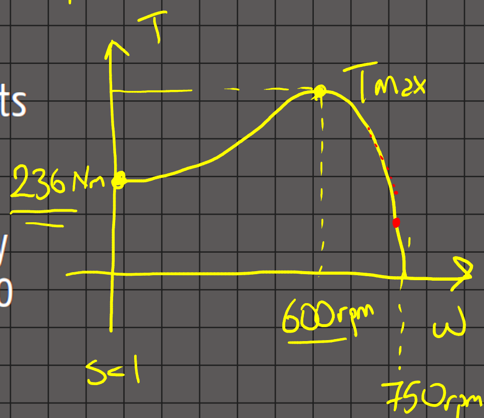
The following observations are made on a 3-phase, 50-Hz, Y-connected, 380 V rms line-to-line induction motor with negligible stator winding resistance and core loss.

i) At no-load the motor is rotating at 745 rpm. $\Rightarrow N_{syn} = 750$ rpm



ii) The stator can not be started with a heavy load, but it only starts when the load torque is reduced to 236 Nm

iii) When the motor is running at rated speed, the load is gradually increased and it is found that the rotor speed reduced down to 600 rpm, but after it decelerates and stops.

b-c) Calculate the referred rotor resistance and total leakage reactance (stator+rotor)?

a) Number of poles = ?

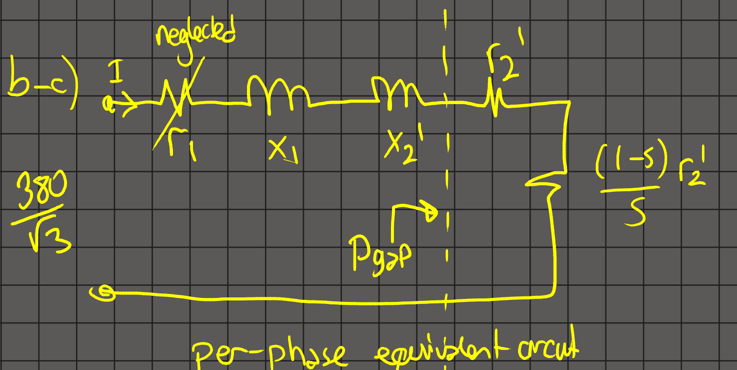
$S \cong 0 \quad N_r = 745$ rpm

$50\,Hz \rightarrow 2\text{ pole} \Rightarrow \frac{120 \cdot f}{P} \Rightarrow 3000$ rpm

4 pole $\Rightarrow$ 1500 rpm

8 pole $\Rightarrow$ 750 rpm

b-c)



per-phase equivalent circuit

At max torque

$\hookrightarrow$ Pgap should be max.

$$S_{max-T} = \frac{750-600}{750} = 0{,}2$$

Torque is max, when Pgap is max

$\hookrightarrow$ Pgap is max when max. power transfer is satisfied.

Pgap is max $\Rightarrow$

$$\hookrightarrow (X_1 + X_2') = \left(r_2' + \frac{(1-s)}{s} r_2'\right) = \frac{r_2'}{s}$$

$$(X_1 + X_2') = \frac{r_2'}{0{,}2} \Rightarrow \boxed{5 r_2' = (X_1 + X_2')}$$

$T_{start} = 236$ Nm $\quad (N_r = 0 \Rightarrow S = 1)$

$$T = \frac{3 V_1^2}{\left(\cancel{r_1} + \frac{r_2'}{s}\right)^2 + (X_1 + X_2')^2} \cdot \frac{r_2'}{s} \cdot \frac{1}{w_s}$$

$\leftarrow S = 1$

($r_1 = 0$; w_s: mech. synchronous speed)

$$T = \frac{3V_1^2}{r_2'^2 + 25r_2'^2} \cdot \frac{r_2'}{1} \cdot \frac{1}{\omega_s}$$

mech. synch. speed

$$\omega_s = \frac{2\pi f_e}{(P/2)} = \frac{2\pi . 50}{4}$$

$$V_1 = 380/\sqrt{3}$$

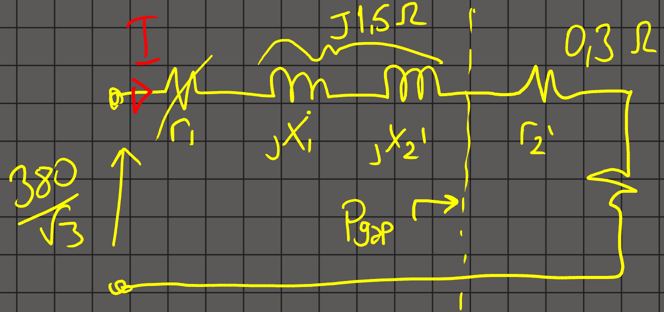
$$T = \frac{3\left(\frac{380}{\sqrt{3}}\right)^2}{26 r_2'^2} \cdot \frac{r_2'}{\frac{2\pi 50}{4}} \Rightarrow \boxed{r_2' = 0{,}3\,\Omega} \quad \boxed{(X_1 + X_2') = 1{,}5\,\Omega}$$

d) If the rotational power (friction) is 1518 W, find the air-gap power, rotor copper loss, internal mechanical power (gross) and the net output power when the rotor is rotating at 712.5 rpm

$N_r = 712.5$ rpm

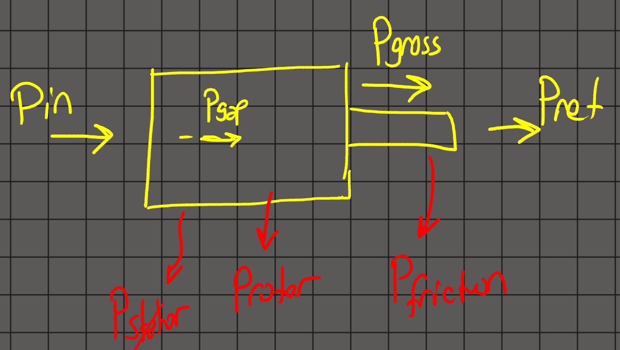
$N_s = 750$ rpm

$$s = \frac{750 - 712{,}5}{750} = 0{,}05$$



$$\frac{(1-s)}{s} \cdot r_2' = \frac{1-0{,}05}{0{,}05} \cdot 0{,}3 = 5{,}7\,\Omega$$

$$I = \frac{380/\sqrt{3}}{\sqrt{6^2 + 1{,}5^2}} = 35{,}47\,A$$



$P_{in} = P_{gap}$

$$P_{gap} = 3I^2 \cdot \frac{r_2'}{s}$$

$$= 3(35{,}47)^2 . 6 = 22{,}65\,kW$$

$$P_{cu(rotor)} = 3I^2 . r_2'$$

$$= 3(35{,}47)^2 . 0{,}3 = 1{,}13\,kW$$

$$P_{gross\ mech} = 22{,}65 - 1{,}13\,kW$$

$$= 21{,}52\,kW$$

$$P_{net} = P_{gross} - P_{friction}$$

$$= 21{,}52 - 1{,}52 = 20\,kW$$

Efficiency

$$\eta = \frac{P_{out}}{P_{in}} = \frac{20\,kW}{22.65\,kW} = \boxed{88{,}3\%}$$