Q1):

A 3ϕ, 10 hp, 460 V, 60 Hz, 4-pole induction motor runs at 1730 rpm at full-load. The stator copper loss is 200 W and the windage and friction loss is 320 W. Determine

(a) The mechanical power developed, P_{mech}.

(b) The air gap power, P_{ag}.

(c) The rotor copper loss, P_{cu2}.

(d) The input power, P_{in}.

(e) The efficiency of the motor.

Solution:

a) $P_{out} = 10^{hp} \times 746^{W} = 7460^{W}$

$$\boxed{P_{mech} = P_{out} + P_{rot} = 7460^{W} + 320^{W} = 7780^{W}}$$

b) $N_s = \dfrac{120 f_s}{P} = \dfrac{120 \times 60}{4} = 1800 \text{ rpm}$

$$s = \frac{N_s - N_m}{N_s} = \frac{1800 - 1730}{1800} = 0.0389$$

$$P_{mech} = (1-s) P_{ag} \Rightarrow \boxed{P_{ag} = \frac{P_{mech}}{1-s} = \frac{7780^{W}}{1-0.0389} = 8094.89^{W}}$$

c) $$\boxed{P_{cu,r} = s P_{ag} = 0.0389 \times 8094.89^{W} = 314.891^{W}}$$

d) $$\boxed{P_{in} = P_{cu,s} + P_{ag} = 200^{W} + 8094.89^{W} = 8294.89^{W}}$$

e) $$\boxed{\eta = \frac{P_{out}}{P_{in}} = \frac{7460^{W}}{8294.89^{W}} = 0.8993}$$

Q2):

A 3ϕ, 100 kVA, 460 V, 60 Hz, eight-pole induction machine has the following equivalent circuit parameters:

$$R_1 = 0.07\,\Omega, \qquad X_1 = 0.2\,\Omega$$
$$R_2' = 0.05\,\Omega, \qquad X_2' = 0.2\,\Omega$$
$$X_m = 6.5\,\Omega$$

(a) Derive the Thevenin equivalent circuit for the induction machine.

(b) If the machine is connected to a 3ϕ, 460 V, 60 Hz supply, determine the starting torque, the maximum torque the machine can develop, and the speed at which the maximum torque is developed.

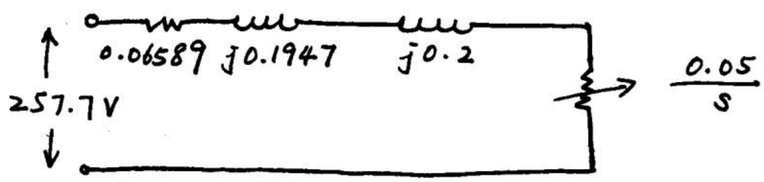
(c) If the maximum torque is to occur at start, determine the external resistance required in each rotor phase. Assume a turns ratio (stator to rotor) of 1.2.

Solution:

(a) Thevenin Eq. cct.

$$V_{th} = \frac{X_m}{X_1 + X_m} V_1 = \frac{6.5}{0.2 + 6.5} \times 265.6 = 257.7$$

$$R_{th} + jX_{th} = \frac{(j6.5)(j0.2 + 0.07)}{0.07 + j0.2 + j6.5} = 0.06589 + j0.1947$$



(b) $$T_{st} = \frac{3 \times 257.7^2 \times 0.05}{94.25\left[(0.06589 + 0.05)^2 + (0.19467 + 0.2)^2\right]}$$

$$= 624.7 \text{ N·m}$$

$$T_{max} = \frac{3 \times 257.7^2}{2 \times 94.25\left[0.06589 + \sqrt{0.06589^2 + (0.1947 + 0.2)^2}\right]}$$

$$= 2267.8 \text{ N·m}$$

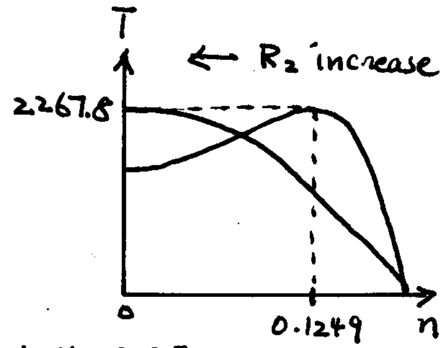
$$s_{Tmax} = \frac{0.05}{\sqrt{0.06589^2 + (0.1947 + 0.2)^2}} = 0.1249$$

speed in rpm for which max torque occurs

$$= (1 - s_{Tmax})\, n_s = (1 - 0.1249)\,900 = 787.5 \text{ rpm}$$

(c)

$$S_{Tmax} = \frac{r_2'}{\sqrt{r_1^2 + (x_1 + x_2)^2}} \propto r_2'$$



$$S_{Tmax} = K r_2'$$

$$\frac{S_{Tmax}}{r_2'} = \frac{S/start}{r_2' \text{ at start}}$$

$$\therefore\ r_2'|_{start} = \frac{S/start}{S_{Tmax}} \times r_2' = \frac{1 \times 0.05}{0.1249} = 0.4\,\Omega$$

$$\therefore\ r_2|_{ext} = (0.4 - 0.05)/1.2^2 = 0.243\,\Omega$$