KING FAHD UNIVERSITY OF PETROLEUM & MINERALS
ELECTRICAL ENGINEERING DEPARTMENT

EE 306 – Term 192

HW # 6: Induction Motors

Key Solutions

Problem # 1:

A 480-V three-phase two-pole 60-Hz induction motor is running at a slip of 2.5 percent. Find:

(a) The speed of the magnetic fields in revolutions per minute

(b) The speed of the rotor in revolutions per minute

(c) The slip speed of the rotor

(d) The rotor circuit (current) frequency in hertz

Solution:

(a) The speed of the magnetic fields is

$$n_{\text{sync}} = \frac{120 f_{se}}{P} = \frac{120(60\text{ Hz})}{2} = 3600\text{ r/min}$$

(b) The speed of the rotor is

$$n_m = (1-s)\, n_{\text{sync}} = (1-0.025)(3600\text{ r/min}) = 3510\text{ r/min}$$

(c) The slip speed of the rotor is

$$n_{\text{slip}} = s n_{\text{sync}} = (0.025)(3600\text{ r/min}) = 90\text{ r/min}$$

(d) The rotor frequency is

$$f_{re} = \frac{n_{\text{slip}} P}{120} = \frac{(90\text{ r/min})(2)}{120} = 1.5\text{ Hz}$$

Problem # 2:

A 50-kW, 460-V, 50-Hz, two-pole induction motor has a slip of 5 percent when operating a full-load conditions. At full-load conditions, the friction and windage losses are 700 W, and the core losses are 600 W. Find the following values for full-load conditions:

(a) The shaft speed n_m

(b) The output power in watts

(c) The load torque τ_{load} in newton-meters

(d) The induced torque τ_{ind} in newton-meters (considering the core loss with the rotational losses)

(e) The rotor circuit (current) frequency in hertz

Solution:

(a) The synchronous speed of this machine is

$$n_{\text{sync}} = \frac{120 f_{se}}{P} = \frac{120(50 \text{ Hz})}{2} = 3000 \text{ r/min}$$

Therefore, the shaft speed is

$$n_m = (1-s)\; n_{\text{sync}} = (1-0.05)(3000 \text{ r/min}) = 2850 \text{ r/min}$$

(b) The output power in watts is 50 kW (stated in the problem).

(c) The load torque is

$$\tau_{\text{load}} = \frac{P_{\text{OUT}}}{\omega_m} = \frac{50 \text{ kW}}{(2850 \text{ r/min})\left(\frac{2\pi \text{ rad}}{1 \text{ r}}\right)\left(\frac{1 \text{ min}}{60 \text{ s}}\right)} = 167.5 \text{ N}\cdot\text{m}$$

(d) The induced torque can be found as follows:

$$P_{\text{conv}} = P_{\text{OUT}} + P_{\text{F\&W}} + P_{\text{core}} + P_{\text{misc}} = 50 \text{ kW} + 700 \text{ W} + 600 \text{ W} + 0 \text{ W} = 51.3 \text{ kW}$$

$$\tau_{\text{ind}} = \frac{P_{\text{conv}}}{\omega_m} = \frac{51.3 \text{ kW}}{(2850 \text{ r/min})\left(\frac{2\pi \text{ rad}}{1 \text{ r}}\right)\left(\frac{1 \text{ min}}{60 \text{ s}}\right)} = 171.9 \text{ N}\cdot\text{m}$$

(e) The rotor frequency is

$$f_r = s f_e = (0.05)(50 \text{ Hz}) = 2.5 \text{ Hz}$$

Problem # 3:

A 3-phase, 460 V, 60 Hz, 20 kW induction machine draws 25 A at a power factor of 0.9 lagging when connected to a 3-phase, 460 V, 60 Hz power supply. The core loss is 900 W, stator copper loss is 1100 W, rotor copper loss is 550 W, and friction and winding loss is 300 W. Calculate

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

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

(c) The output horse power.

(d) The efficiency.

Solution:

(a) $P_{ag} = P_{in} - P_{core} - P_{cu,stator} = \sqrt{3} \times 460 \times 25 \times 0.9 - 900 - 1100$

$= 17926.2 - 900 - 1100 = 15926.2 \text{ W}$

(b) $P_{mech} = P_{ag} - P_{cu,rotor} = 15926.2 - 550 = 15376.2 \text{ W}$

(c) $P_{out} = 15376.2 - 300 = 15076.2 \text{ W}$

$HP = \frac{15076.2}{746} = 20.2$

(d) $Eff = \frac{15076.2}{17926.2} \times 100\% = 84.1\%$

Problem # 4:

A 3-phase, 2-pole, 60 Hz, induction motor operates at 3546 rpm while delivering 20 kW to a load. Neglect all losses. Determine

(a) The slip of the motor.

(b) The developed torque.

(c) The speed of the motor if the torque is doubled. Assume that in the low slip region, the torque speed curve is linear.

(d) The power supplied by the motor for the load condition of (c).

Solution:

(a) $$n_s = \frac{120 \times 60}{2} = 3600 \text{ rpm}$$

$$s = \frac{3600 - 3546}{3600} = 0.015 \text{ or } 1.5\%$$

(b) $$T_{dev} = \frac{20 \times 10^3}{3546/60 \times 2\pi} = 53.86 \text{ N} \cdot \text{m}$$

$$n = 1800 \times (1 - 0.0345) = 1737.9 \text{ rpm}$$

(c) If torque is doubled, slip is doubled,

$$s = 0.03$$

$$n = 3600 \times (1 - 0.03) = 3492 \text{ rpm}$$

(d) $$T = 2 \times 53.86 = 107.72 \text{ N} \cdot \text{m}$$

$$\omega = 3492 \times 2\pi$$

$$P = T \cdot \omega = 107.72 \times \frac{3492}{60} \times 2\pi \times 10^{-3} \text{ kW} = 39.39 \text{ kW}$$