# Homework 6 - SOLUTION KEY

**EE-306 – Electromechanical Devices - Semester 172**

## Problem 1

A 3-phase, 10 hp, 208 V, six-pole, 60 Hz, wound-rotor induction machine has a stator-to-rotor turns ratio of 1 : 0.5 and both stator and rotor windings are connected in star.

(a) The stator of the induction machine is connected to a 3-phase, 208 V, 60 Hz supply, and the motor runs at 1140 rpm.

  (i) Determine the operating slip.

  (ii) Determine the voltage induced in the rotor per phase and frequency of the induced voltage.

  (iii) Determine the rpm of the rotor field with respect to the rotor and with respect to the stator.

(b) If the stator terminals are shorted and the rotor terminals are connected to a 3-phase, 208 V, 60 Hz supply and the motor runs at 1164 rpm,

  (i) Determine the direction of rotation of the motor with respect to that of the rotating field.

  (ii) Determine the voltage induced in the stator per phase and its frequency.

# Solution

(a)(i) $n_s = \frac{120 \times 60}{6} = 1200$ rpm

$$s = \frac{1200 - 1140}{1200} = 0.05$$

(ii) $E_{2s} = s E_2 = s \frac{E_1}{a}$

$$a = \frac{1}{0.5} = 2.0$$

$$E_{2s} = 0.05 \times \frac{1}{2.0} \times \frac{208}{\sqrt{3}} = 3 \text{ V}$$

$$f_2 = 0.05 \times 60 = 3 \text{ Hz}$$

(iii) - slip rpm $n_2 = s n_s = 0.05 \times 1200 = 60$ rpm
- with respect to stator $\rightarrow$ 1200 rpm.

(b) Inverted induction motor

(i) opposite

(ii) $E_{1s} = s E_1 = s a E_2 = 0$

$$s = \frac{1200 - 1164}{1200} = 0.03$$

$$E_{1s} = 0.03 \times 2 \times \frac{208}{\sqrt{3}} = 7.2 \text{ V}$$

$$f_1 = 0.03 \times 60 = 1.8 \text{ Hz}$$

## Problem 2

A 3-phase, 460 V, 100 hp, 60 Hz, six-pole induction machine operates at 3% slip (positive) at full load.

(a) Determine the speeds of the motor and its direction relative to the rotating field.

(b) Determine the rotor frequency.

(c) Determine the speed of the stator field.

(d) Determine the speed of the air gap field.

(e) Determine the speed of the rotor field relative to:

(i) the rotor structure.

(ii) the stator structure.

(iii) the stator rotating field.

# Solution

(a) $0.03 = \frac{1200 - n}{1200}$ , $n_s = \frac{120 \times 60}{6} = 1200$ rpm.

$n = 1164$ rpm → direction same as the rotating field.

(b) $f_2 = 0.03 \times 60 = 1.8$ Hz

(c) 1200 rpm

(d) 1200 rpm

(e) (i) $n_{sl} = 0.03 \times 1200 = 36$ rpm → direction same as the rotor motion.

(ii) 1200 rpm

(iii) 0 rpm

## 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) $P_{ag} = P_{in} - P_{core} - P_{cu,stator} = \sqrt{3} \times 460 \times 25 \times 0.9 - 900 - 1100$
$= 17926.2 - 900 - 1100 = 15926.2\ W$

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

(c) $P_{out} = 15376.2 - 300 = 15076.2\ W$
$HP = \frac{15076.2}{746} = 20.2$

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

## Problem 4

A 3-phase, 2.5 hp, 210 V, 60 Hz, 4-pole induction motor runs at 1700 rpm. The rotational losses are 150 W. If the rotor resistance per phase is 0.025 Ω, determine the rotor current.

# Solution

$$P_{out} = 2.5 \times 746 = 1865\ W$$

$$n_s = \frac{120 \times 60}{4} = 1800\ rpm$$

$$s = \frac{1800-1700}{1800} = 0.0555$$

$$P_{mech} = 1865 + 150 = 2015\ W$$

$$P_{ag} = \frac{2015}{1-0.0555} = \frac{2015}{0.9445} = 2133.4\ W$$

$$P_{cu2} = 0.0555 \times 2133.4 = 118.4\ W$$

$$3 \times I_2{}^2 R_2 = 118.4\ W \rightarrow I_2 = \sqrt{\frac{118.4}{3 \times 0.025}} = 39.73\ A$$

## Problem 5

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

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

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

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

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

$s = 0.03$

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

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

$\omega = 3492 \times 2\pi$

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

**!End of Homework Solutions!**