EE3010 ELECTRICAL DEVICES AND MACHINES

TUTORIAL 8 – Induction Motors 1

Q1. A 3-phase, 440-V, 50-Hz, 4-pole, Y-connected induction motor has a stator resistance of 0.12 ohm/phase. The rotational losses, which include the core losses, of the motor are 2.4 kW. At full-load, the motor takes an input power of 42.5 kW at a power factor of 0.85 lagging and runs at 1470 rpm. Determine

a. The input current and stator copper losses.
b. The air-gap power and rotor copper losses.
c. The developed torque, shaft torque and efficiency of the motor.

[Ans : (a) 65.61 A, 1.55 kW (b) 40.95 kW, 0.819 kW, (c) 260.69 N-m, 245.1 N-m, 88.78 %]

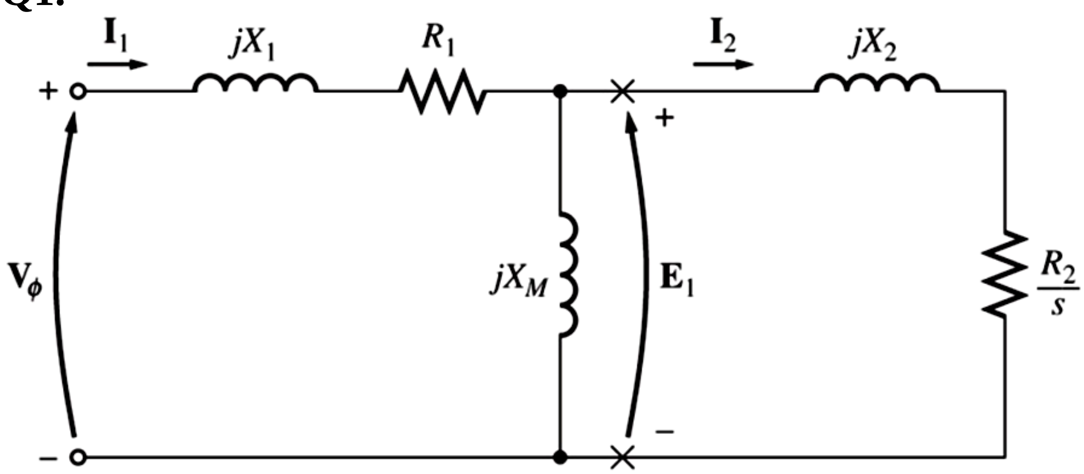
Q2. A 4-pole, 440-V, 50-Hz, Y-connected, 3-phase induction motor has a stator impedance of (0.15 + *j* 0.8) ohm/phase and a rotor impedance (referred to the stator) of (0.2 + *j* 0.8) ohm/phase at standstill. The magnetizing reactance is 30 ohms/phase. The rotational losses, which include the core losses, of the motor are 750 W. Using the equivalent circuit, determine the following when the motor operates at full-load slip of 4 %.

a) Input current and power factor
b) Air-gap power and developed power.
c) Load torque and efficiency of the motor.

[Ans : (a) 47.84 A, 0.899 lag (b) 31.746 kW, 30.476 kW (c) 197.12 N-m, 90.69%]

SUGGESTED SOLUTIONS FOR TUTORIAL - Induction Motors 1

Q1.



The per phase equivalent circuit of an induction motor referred to the stator

The motor is wye-connected. Thus, the line current is the same as the phase current.

(a)

$$P_{in} = \sqrt{3}\ V_L I_L \cos\theta$$

$$42500 = \sqrt{3}\ (440) I_L (0.85)$$

$$\Rightarrow I_L = 65.61\text{A}$$

Stator copper loss

$$P_{SCL} = 3I_1^2 R_1 = 3\left(65.61\right)^2 0.12 = 1550\text{W}$$

(b) Air gap power, $P_{AG} = P_{in} - P_{SCL}$

$= 42500 - 1550 = 40950\text{W}$

$P_{AG} = 3I_2^2\left(\frac{R_2}{s}\right)$ and the rotor copper loss,

$P_{RCL} = 3I_2^2 R_2$. Hence, $P_{RCL} = sP_{AG}$.

$n_{sync} = \frac{120 f_s}{p} = 1500\text{rpm}$. $n_m = 1470\text{rpm}$

slip $s = \frac{n_{sync} - n_m}{n_{sync}} = 0.02$

$\Rightarrow P_{RCL} = 819\text{W}$

(c) Note : The power converted from electrical to mechanical P_{conv} is also known as the power developed P_{dev} and the induced torque T_{ind} is also known as the developed torque $T_{dev.}$
$\left(P_{conv} = T_{ind}\omega_m \text{ and } P_{dev} = T_{dev}\omega_m. \quad P_{conv} = P_{dev}\right)$

$$P_{dev} = P_{AG} - P_{RCL} = (1-s)P_{AG} = 40131\text{W}$$

$$\Rightarrow T_{dev} = \frac{P_{dev}}{\omega_m} = \frac{40131}{1470(2\pi / 60)} = 260.69\text{N-m}$$

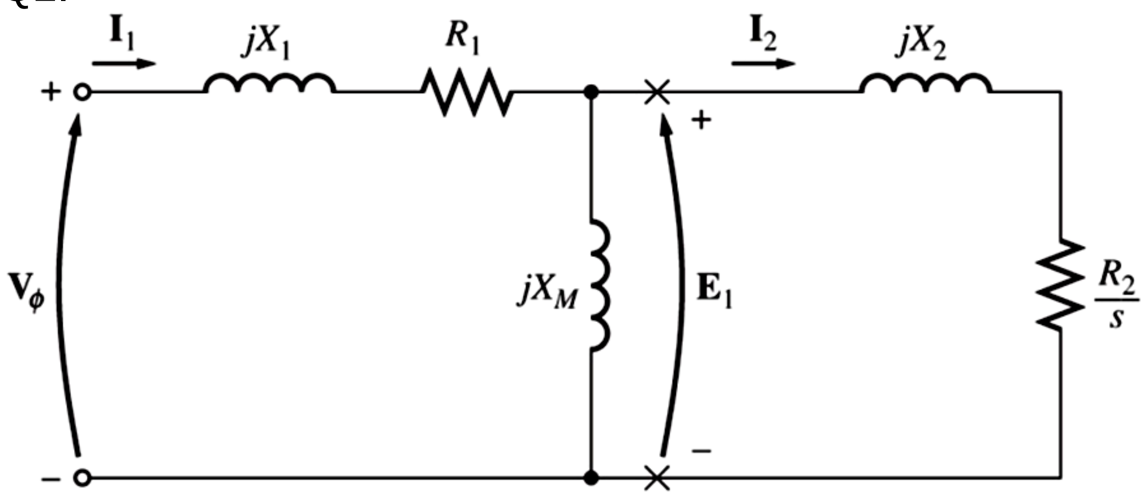
$$P_{out} = P_{dev} - P_{rot} = 40131 - 2400 = 37731\text{W}$$

$$P_{out} = T_{shaft}\omega_m \Rightarrow T_{shaft} = 245.1\text{N-m.}$$

(Note that shaft torque is the same as the load torque).

$$\eta = \frac{P_{out}}{P_{in}} = \frac{37731}{42500} = 88.78\%$$

Q2.



The per phase equivalent circuit of an induction motor referred to the stator

The motor is wye-connected. Thus, the line current is the same as the phase current.

(a) $\mathbf{V}_\phi = \left(440/\sqrt{3}\right)\angle 0^0 = 254.03\angle 0^0\,\text{V}.$

$P_{rot} = 500\text{W}$, slip $s = 4\%$.

$R_1 = 0.15\Omega, X_1 = 0.8\Omega, R_2 = 0.2\Omega, X_2 = 0.8\Omega, X_m = 30\Omega$

Total impedance seen by the source is

$$\mathbf{Z}_T = \left(0.15 + j0.8\right) + (j30//(5 + j0.8)) = 5.31\angle 26.02^0\,\Omega$$

$$\Rightarrow \mathbf{I}_1 = \frac{\mathbf{V}_\phi}{\mathbf{Z}_T} = 47.84\angle -26.02^0 \text{ A}$$

power factor $= \cos(26.02^0) = 0.899$ lagging

(b) $\mathbf{V}_\phi = \left(440/\sqrt{3}\right)\angle 0^0 = 254.03\angle 0^0\,\text{V}.$

$P_{in} = 3V_\phi I_1 \cos\theta = 32776\,\text{W}$

Stator copper loss $P_{SCL} = 3I_1^2 R_1 = 1030\text{W}$

$\Rightarrow$ air gap power $P_{AG} = P_{in} - P_{SCL} = 31746\text{W}$

and

the developed power $P_{dev} = P_{AG}(1-s) = 30476\text{W}$

(c) $P_{out} = P_{dev} - P_{rot} = 30476 - 750 = 29726\text{W}$

$$n_{sync} = \frac{120 f_s}{p} = 1500\text{rpm.}$$

slip $s = 0.04 = \dfrac{n_{sync} - n_m}{n_{sync}} \Rightarrow \; n_m = 1440\text{rpm}$

$$\Rightarrow T_{load} = \frac{P_{out}}{\omega_m} = \frac{29726}{1440(2\pi/60)} = 197.12\,\text{N-m}$$

Efficiency,

$$\eta = \frac{P_{out}}{P_{in}} = \frac{29726}{32776} = 90.69\%$$