Example2: The following are the parameters of a 230V, 50 Hz, 4-pole, single phase induction motor R_1= 2.2Ω; X_1= 3.0 Ω; R'_2 = 3.8 Ω; X'_2 = 2.1 Ω; X_m = 86 Ω

Calculate the input current and power when the motor is operating at full-load speed of 1410 rpm. If the mechanical losses (iron and friction loss) are 60 W, determine gross power developed, useful power at the shaft, shaft torque and efficiency.

Solution

Here, V = 230 V; f = 50 Hz; P = 4; N = 1410 rpm

R_1= 2.2 Ω; X_1= 3.0 Ω; R'_2 = 3.8 Ω; X'_2 = 2.1 Ω; X_m = 86 Ω

$$N_s = \frac{120\,f}{P} = 1500\text{ rpm}$$

$$s = \frac{N_s - N}{N_s} = \frac{1500 - 1410}{1500} = 0.06$$

$$\frac{R'_2}{2S} = \frac{3.8}{2 \times 0.06} = 31.67\ \Omega;\ \frac{X'_2}{2} = \frac{2.1}{2} = 1.05\ \Omega$$

$$\frac{R'_2}{2(2-S)} = \frac{3.8}{2(2-0.06)} = 0.98\ \Omega;\ \frac{X_m}{2} = \frac{86}{2} = 43\ \Omega$$

$$Z_f = \frac{j\frac{X_m}{2}\left(\frac{R'_2}{2S} + j\frac{X'_2}{2}\right)}{\frac{R'_2}{2S} + j\left(\frac{X_m}{2} + \frac{X'_2}{2}\right)} = \frac{j43(31.67 + j1.05)}{31.67 + j(43 + 1.05)}$$

Email (osamah.jaber.ghayyib@uomus.edu.iq)

$$= (25.22 \angle 37.61°)\ \text{ohm} = (19.98 + j\,15.39)\ \Omega$$

$$\bar{Z}_b = \frac{j\dfrac{X_m}{2}\left(\dfrac{R_2'}{2(2-S)} + j\dfrac{X_2'}{2}\right)}{\dfrac{R_2'}{2(2-S)} + j\left(\dfrac{X_m}{2} + \dfrac{X_2'}{2}\right)}$$

$$= \frac{j43(0.98 + j1.05)}{0.98 + j(43 + 1.05)}$$

$$= 1.40\angle 48.3° = (0.933 + j1.05)\,\Omega$$

$$\text{Total impedance, } \bar{Z}_T = \bar{Z}_1 + \bar{Z}_f + \bar{Z}_b$$

$$= (2.2 + j3) + (19.98 + j15.39) + (0.933 + j1.05)$$

$$= (23.11 + j19.44)\ \Omega = 30.2\ \angle 40.1°$$

$$\text{Input current, } \bar{I}_I = \frac{\bar{V}}{\bar{Z}_T} = \frac{230\ \angle 0°}{30.2\ \angle 40.1°} = 7.616\ \angle -40.1°\ \text{A}$$

$$I_I = \mathbf{7.616\ A}\ (Ans.)$$

$$\text{Input power, } P = I_1^2\ R_T = (7.616)^2 \times 23.11 = \mathbf{1340\ W}\ (Ans.)$$

Example3: A 220V, four-pole, 50 Hz, single-phase induction motor has the following Parameters. R1 = 2.3 Ω, X1 = X2′ = 3.2 Ω, R2′ = 4.2 Ω, Xm = 74 Ω. Iron losses is given as 80W.

Windage and Friction loss is 20W. If this motor is running at 1425 rpm at rated voltage and frequency, determine the following

(a) Stator current

(b) Input Power factor

(c) Power output

(d) Output Torque

(e) Efficiency

Assuming auxiliary winding as open circuited.

Solution

Synchronous speed $N_s = \frac{120}{P} = \frac{120(50)}{4} = 1500\text{rpm}$

Slip is calculated as $S = \frac{N_s - N}{N_s} = \frac{1500-142}{1500} = 0.05$

Let us first calculate the impedance

Forward impedance

$$Z_f = \frac{j0.5X_m\left[\frac{0.5R_2'}{s} + j0.5X_2'\right]}{\frac{0.5R_2'}{s} + j0.5X_2' + j0.5X_m} = 17.66 + j20.75\Omega$$

Backward impedance

$$Z_b = \frac{j0.5X_m\left[\frac{0.5R_2'}{2-s} + j0.5X_2'\right]}{\frac{0.5R_2'}{2-s} + j0.5X_2' + j0.5X_m} = 0.99 + j1.562\Omega$$

Total impedance

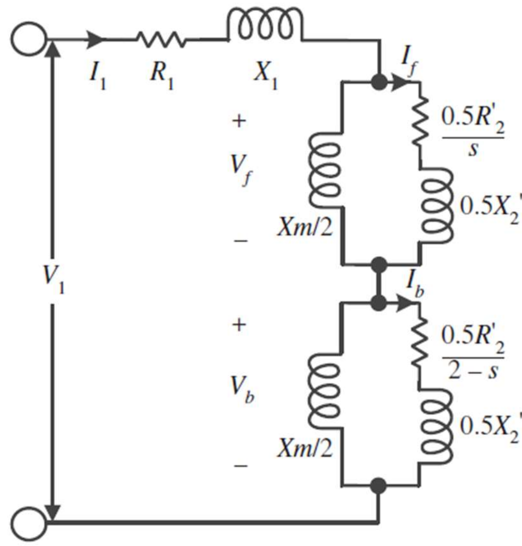
$$Z = Z_f + Z_b = 20.95 + j25.5 = 33.1\angle 50.4$$

(a) Stator current drawn by motor

$$I_1 = \frac{V_1}{Z} = \frac{220\angle 0}{33.1\angle 50.4} = 6.64\angle -50.4$$

(b) Power Factor Cos(50.4) = 0.637 lagging

(c) Power output is calculated by computing the total power input to the rotor side (air gap power)



Air-gap power due to forward field
$(I_1)^2 R_f = (6.64)^2(17.66) =$
Air-gap power due to backward field
$(I_1)^2 R_b = (6.64)^2(0.99) = 43.64$ W
Power Developed by machine

$P_{gf} =$
778.62 W
$P_{gb} =$
Mechanical

$$P_m = (1-s)\left(P_{gf} - P_{gb}\right) = (1-0.05)(778.62 - 43.64) = 698.22 \text{ W}$$

Output power = Mechanical power - Rotational Losses
Rotational Losses = Windage and Friction Losses + Iron Losses = 80 + 20 = 100 W

$$P_{\text{out}} = P_m - \text{ R.Losses } = 698.22 - 100 = 598.22 \text{ W}$$

(d) Output Torque

Angular speed $\omega_r = \frac{2\pi}{60} = \frac{2\pi(1425)}{60} = 149.22\text{rad/s}$

$$T_e = \frac{P_{\text{out}}}{\omega_r} = \frac{598.22}{149.22} = 4\text{Nm}$$

(e) Efficiency is calculated as

Input power $P_{in} = V_1 I_1 \cos(\theta) = 220(6.64)(0.637) = 930.53$ W

Efficiency $\eta = \frac{P_{\text{out}}}{P_{\text{in}}} X100\% = \frac{598.22}{930.53} \times 100\% = 64.3\%$