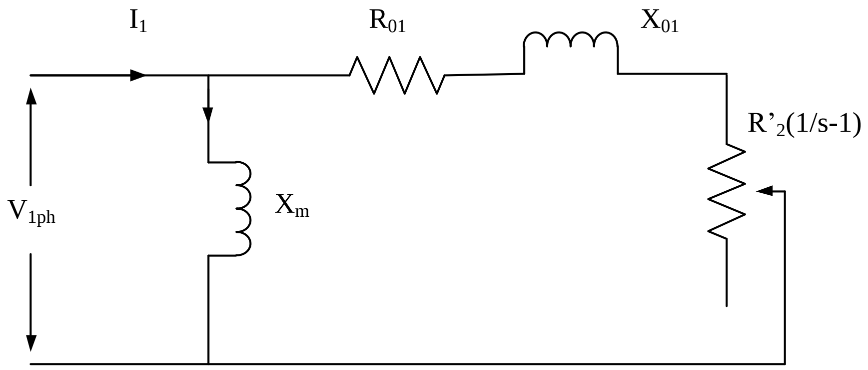
ESO203 Tutorial 8

Q1: A 3-phase, 4-pole, 400 V, 50 Hz, star-connected induction motor has following circuit parameters
$r_1 = 1\Omega, r_2 = 0.5\Omega, x_1 = x_2' = 1.2\Omega, x_m = 35\Omega$

Calculate the starting torque when the motor is started direct-on-line (use approximate equivalent circuit model).

Solution: The approximate equivalent circuit model is



$$X_{01} = X_1 + X_2'$$

$$R_{01} = R_1 + R_2'$$

$$R_2' + R_2'\left(\frac{1}{s} - 1\right) = \frac{R_2'}{s}$$

During starting slip (s) = 1

$$I_r' = \frac{V_{1ph}}{\sqrt{\left(R_2' + \frac{R_2'}{s}\right)^2 + (X_1 + X_2')^2}} = 81.6A$$

Starting torque

$$T_{st} = \frac{60}{2\pi N_s} \times 3(I_r')^2 \times \frac{R_2'}{s} = 63.6\ Nm$$

Here,

$$N_s = \frac{120 f_s}{P} = 1500\ rpm$$

Q2: An 8-pole, 50 Hz, three-phase, slip-ring induction motor has an effective rotor resistance of 0.08Ω per phase. Its speed at maximum torque is 650 RPM. Calculate the additional resistance per phase that must be inserted in the rotor to achieve maximum torque at start. Neglect magnetizing current and stator leakage impedance. Consider equivalent circuit parameters referred to stator.

Solution:

P = 8, f = 50Hz, Ns = 750rpm

Effective rotor resistance R_2 = 0.08 Ω

Rotor speed at maximum torque = 650rpm.

We have slip at maximum torque

$$s_{Tmax} = \frac{750 - 650}{750} = 0.133$$

$$s_{Tmax} = \frac{R_2}{X_{20}}$$

Here, X_{20} is the standstill rotor leakage reactance, so $X_{20} = 0.6\Omega$

Now, additional resistance required to obtain maximum torque at starting

$$R_{additional} = X_{20} - R_2 = 06 - 0.08 = 0.52\Omega$$

Q3: The frequency of stator and rotor currents flowing in 3-phase, 8 pole induction motor are 50 Hz and 1hz respectively. Calculate the motor speed in rpm.

Solution:

Supply frequency $F = 50Hz$

Rotor frequency $F_2 = 1\ Hz$

$$F_2 = sF$$

$$s = \frac{1}{50} = 0.02$$

$$N_s = \frac{120 \times 50}{8} = 750\ rpm$$

$$N_r = N_s(1 - s)$$

$$N_r = 750(1 - 0.2)$$

$$N_r = 600\ rpm$$

Q4: The power input to a 415V, 50Hz, 6 pole, 3-phase induction motor running at 975 rpm is 40 kW. The stator losses are 1 kW and friction and windage losses total 2 kW. Calculate the efficiency of the motor.

Solution:

Power input =40 kW

$$\text{Slip (s)} = \frac{N_s - N}{N_s}$$

$$= \frac{1000 - 975}{1000} = 0.025$$

Stator output = 40 kW-1 kW = 39 kW

∴ Rotor input = 39 kW

Gross mechanical output= Rotor output × (1-s) =39 × 1000 ×(1-s) =38025 W

Net mechanical output= gross mech. Output- windage loss =38025 – 2000 =36025 W

$$\therefore \eta = \frac{output\ power}{input\ power} = \frac{36025}{40000} \times 100 = 90.0\%$$

Q5: A 400 V, 15 kW, 4 pole, 50 Hz, Y- connected induction motor has full load slip of 4%. What will be the output torque of the machine at full load? (**<u>Note: The 15 kW of the rating is here taken as the shaft power</u>**)

Solution:

$$\text{Power output (P)} = \frac{2\pi NT}{60}$$

$$T = \frac{P \times 60}{2\pi N}$$

$$N_s = \frac{120 \times 50}{4} = 1500\ rpm$$

$$N = N_s(1 - s)$$

$$= 1500(1 - 0.04)$$

$$= 1440\ rpm$$

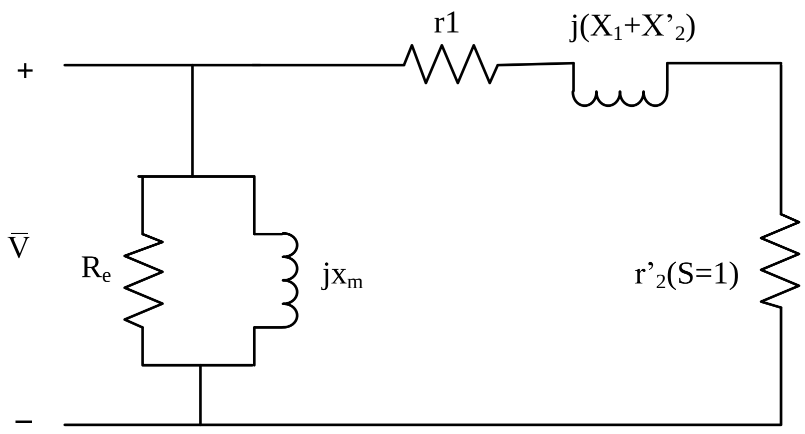
$$T = \frac{15 \times 1000 \times 60}{2\pi \times 1440} = 99.47\ N - m$$

<u>Note: The 15 kW of the rating is here taken as the shaft power</u>.

Q6: The starting line current of a 415 v, 3-phase, delta connected induction motor is 120 A, when the rated voltage is applied to its stator winding. Find the starting line current at a reduced voltage of 110 V.

Solution:

Equivalent circuit per phase at starting



All the equivalent circuit parameters are constants (if frequency is constant)

So, current drawn ∝ voltage applied

$$\text{At 110 V, current} = \frac{110}{415} \times 120 = 31.8\ A$$