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Homework 10: due 3/30/2020

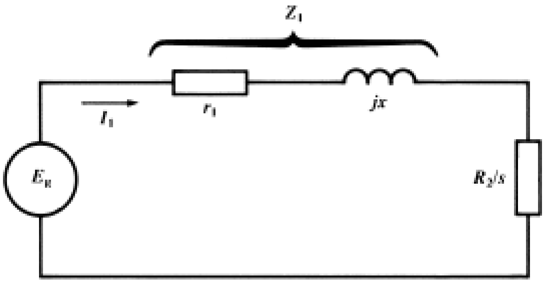
2. A wye-connected squirrel-cage motor having a synchronous speed of 900r/min has a stator resistance of 0.7Ω and an equivalent rotor resistance of 0.5Ω. If the total leakage reactance is 5Ω and the line-to-neutral voltage is 346V, calculate the following:
    1. The value of Z_1 and the angle α

$$Z_1 = \sqrt{R_1^2 + x^2} = \sqrt{0.7^2 + 5^2} \tag{1}$$
$$Z_1 = 5.048\Omega$$
$$\alpha = tan^{-1}(\frac{X}{R_1}) = tan^{-1}(\frac{5\Omega}{0.7\Omega})$$
$$\alpha = 82.03^\circ$$

    2. The speed when the breakdown torque is reached

$$n_b = n_s(1 - (\frac{R_2}{Z_1})) = 900(1 - (\frac{0.5\Omega}{5.048\Omega})) \tag{2}$$
$$\boxed{n_b = 810.85}$$

    3. the current I_1 at the breakdown torque (see below)

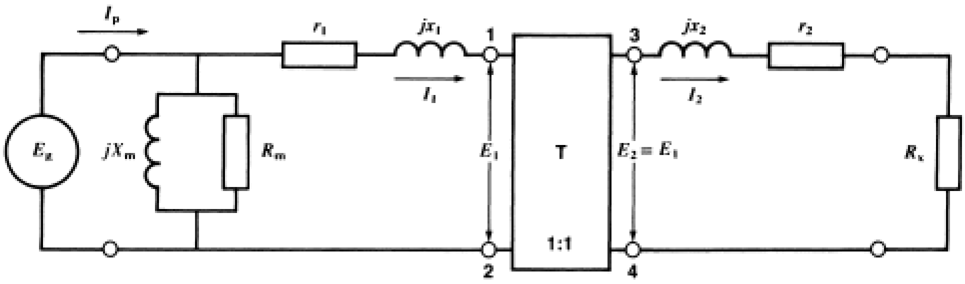


$$I_1 = \frac{E_L}{2Z_1cos(\frac{\alpha}{2})} = \frac{346V}{2 * 5.048 * cos(\frac{82.03^\circ}{2})} \tag{3}$$
$$\boxed{I_1 = 45.419A}$$

    4. The value of the breakdown torque [N*m]

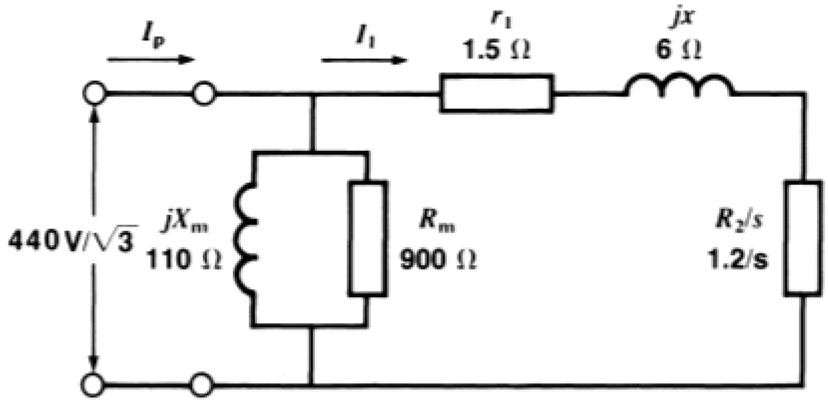
$$T_b = \frac{9.55(I_1^2 Z_1)}{n_s} = \frac{9.55(45.419A^2 * 5.048\Omega)}{900r/min} \tag{4}$$
$$\boxed{T_b = 110.498N * m}$$

4. A 550V, 1780r/min, 3-phase, 60Hz, squirrel cage induction motor running at no-load draws a current of 12A and a total power of 1500W. Calculate the value of X_m and R_m per phase.



$$
\begin{gathered}
S = VA = 550V * 12A = 6.6kVA \\
Q = \sqrt{6.6kVA^2 - 1.5kW^2} = 6.4kVAR \\
R = \frac{V}{P} = \frac{550V}{1500W} \\
X = \frac{V}{Q} = \frac{550V}{6.4kVAR} \\
\hline
|R = 0.3\bar{6}\Omega ; X = 0.09\Omega| \\
\hline
\end{gathered} \tag{5}
$$

9. Consider the 5hp motor whose equivalent circuit shown below.



Motor rating:

5 hp, 60 Hz, 1800 r/min, 440 V, 3-phase
full-load current: 7 A
locked-rotor current: 39 A

r_1 = stator resistance 1.5 Ω
r_2 = rotor resistance 1.2 Ω
jx = total leakage reactance 6 Ω
jX_m = magnetizing reactance 110 Ω
R_m = no-load losses resistance 900 Ω

The no-load losses include the iron losses plus windage and friction losses.

Figure 12
Equivalent circuit of a 5 hp, squirrel-cage induction motor. Because there is no external resistor in the rotor, $R_2 = r_2$.

1. Calculate the values of the inductances (in mH) of the leakage and magnetizing reactances.

$$L_m = \frac{X}{2\pi f} = \frac{110\Omega}{2\pi(60Hz)} \tag{6}$$
$$L_x = \frac{X}{2\pi f} = \frac{6\Omega}{2\pi(60Hz)}$$
$$\boxed{L_x = 15.9mH;\ L_m = 291.8mH}$$

2. Determine the values of the leackage reactance and magnetizing reactance at a frequency of 50Hz.

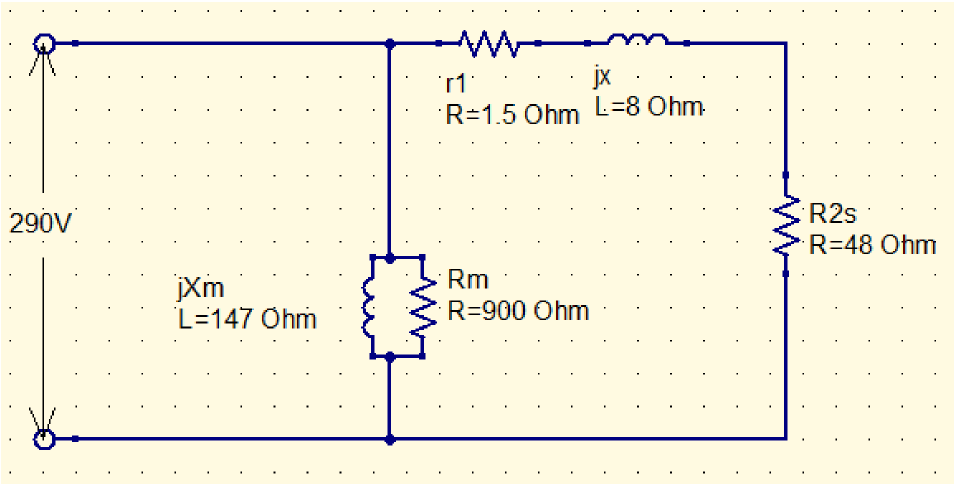
$$X_m = L_m * 2\pi f = 15.9mH * 2\pi * 50Hz \tag{7}$$
$$X_m = L_m * 2\pi f = 291.8mH * 2\pi * 50Hz$$
$$\boxed{X = 5\Omega;\ X_m = 91.6\Omega}$$

3. Calculate the 50Hz line to neutral voltage to obtain the same magnetizing current and compare it with the voltage at 60Hz.

$$V' = V * \frac{f_2}{f_1} = \frac{440}{\sqrt{3}} V * \frac{50Hz}{60Hz} \tag{8}$$
$$V' \approx 212V$$

10. The 5hp motor represented by the equivalent circuit of the image above is connected to a 503V(line-to-line), 3-phase, 80Hz source. The stator and rotor resistances are assumed to remain the same.

    1. Determine the equivalent circuit when the motor runs at 2340r/min.



    2. Calculate the value of the torque [N*m] and the power [hp] developed by the motor.

$$P_r = (\frac{V}{\sqrt{X^2 + R_1^2}})^2 * R_2/s * phases \tag{9}$$
$$P_r = (\frac{290V}{\sqrt{8\Omega^2 + (1.5\Omega + 48\Omega)^2}})^2 * R_2/s * 3\ phases$$
$$P_r = (\frac{290V}{50.14\Omega})^2 * \frac{1.2}{0.025} * 3\ phases$$
$$P_r = (5.78A)^2 * 48\Omega * 3\ phases$$
$$P_r = 3819.39(A^2) * 144\Omega$$
$$T = 9.55 \frac{4817W}{2400rpm}$$
$$P = \frac{nT}{9.55} = \frac{2340rpm * 19.2Nm}{9.55} = 4696W$$
$$\boxed{T = 19.2Nm; P_r = 6.29hp}$$

$$s = \frac{n_s - n}{n_s} \tag{10}$$
$$s * n_s = n_s - n$$