#1 Calculation of equivalent circuit parameters from tests for I.M.

The following test results are obtained from a 3-phase, 60 hp, 2200 V, 6-pole, 50 Hz, Star connected squirrel-cage I.M.

i) No-load test:

Line voltage = 2200 V
Supply frequency = 50 Hz
Line current = 4.5 A
Input power = 1600 W

ii) Blocked-rotor test:

Frequency = 12.5 Hz
Line voltage = 270 V
Line current = 25 A
Input power = 9000 W

iii) Resistance between two terminals = 5.6 Ω.
Ignore skin effect.

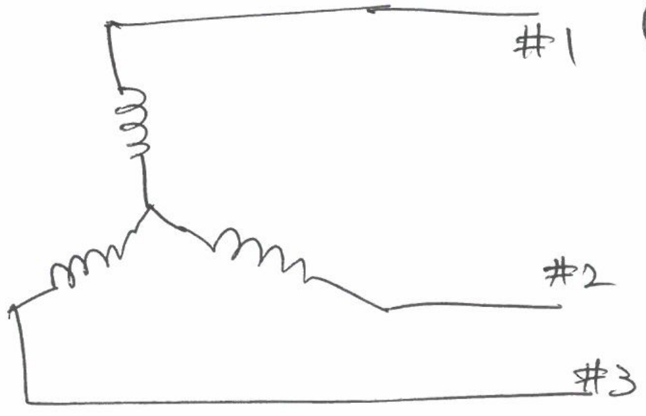
a) Determine the equivalent circuit parameters

b) Determine No-load rotational losses including core-losses.

c) Analyse the performance of the motor.

#2

i) DC resistance :

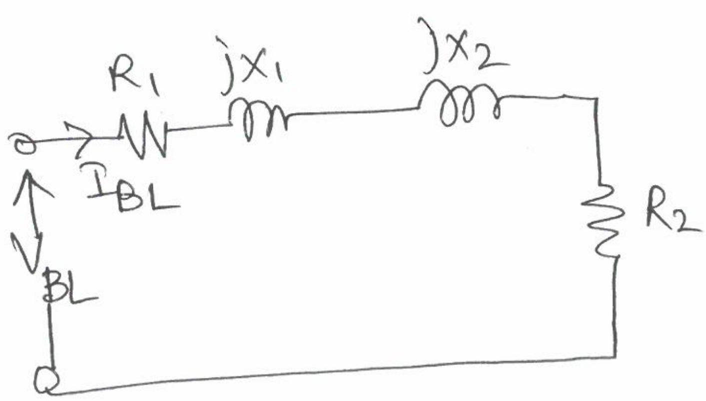


$$R_1 = \frac{5.6}{2} = 2.8\,\Omega$$

$$R_{1,AC} = R_{1,DC} = 2.8\,\Omega$$

(ignoring skin effect)

ii) Blocked-rotor test.



$$V_{BL} = \frac{270}{\sqrt{3}} = 155.88\,V$$

$$I_{BL} = 25A$$

$$Z_{BL} = \frac{V_{BL}}{I_{BL}} = 6.24\,\Omega$$

$$R_{BL} = \frac{P_{BL}}{3\,I_{BL}^2} = \frac{9000}{3 * 25^2} = 4.8\,\Omega$$

$$R_2 = R_{BL} - R_1 = 4.8 - 2.8 = 2.0\,\Omega$$

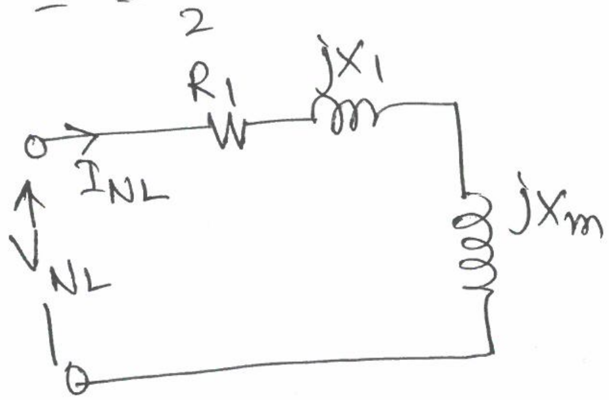
The blocked-rotor reactance at 12.5 Hz

$$X_{BL} = \sqrt{Z_{BL}^2 - R_{BL}^2} = \sqrt{(6.24)^2 - (4.8)^2} = 3.98\,\Omega$$

$$X_{BL} \text{ at } 50Hz = \frac{50}{12.5} * 3.98 = 15.92\,\Omega$$

Hence, $X_1 = X_2 = \frac{X_{BL}}{2} = \frac{15.92}{2} = 7.96\,\Omega$

iii) No-load test:



$$V_{NL} = \frac{2200}{\sqrt{3}} = 1270.2\,V$$

$$I_{NL} = 4.5\,A$$

$$P_{NL} = 1600W$$

$$Z_{NL} = \frac{V_{NL}}{I_{NL}} = \frac{1270.2}{4.5} = 282.27\,\Omega$$

No-load resistance,

$$R_{NL} = \frac{P_{NL}}{3I_{NL}^2} = \frac{1600}{3*(4.5)^2} = 26.34\,\Omega$$

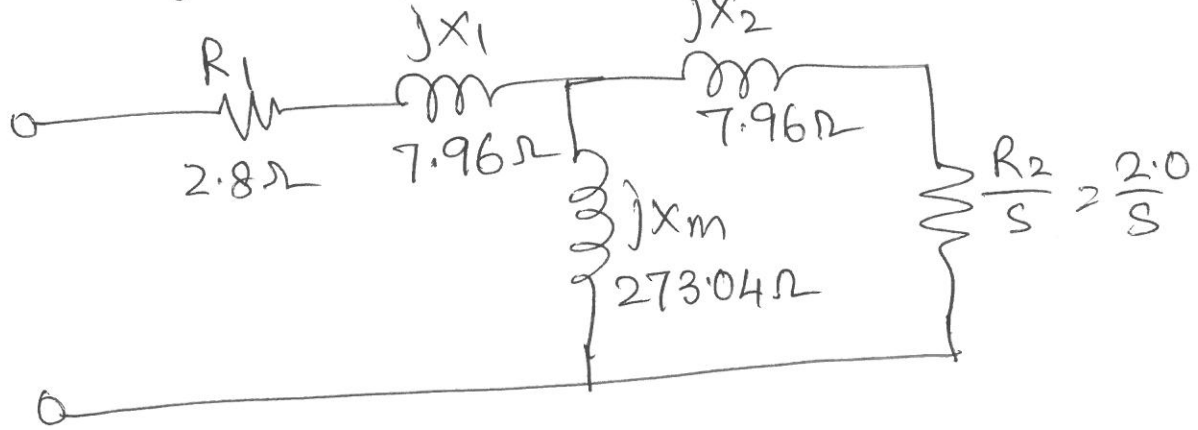
No-load reactance

$$X_{NL} = \sqrt{Z_{NL}^2 - R_{NL}^2} = \sqrt{(282.27)^2 - (26.34)^2}$$

$$= 281.0\,\Omega$$

So, $X_m = X_{NL} - X_1 = 281.0 - 7.96 = 273.04\,\Omega$.

- So the equivalent circuit parameters are



No load power $= 1600\,W$

Rotational losses including core losses

$$= P_{NL} - 3I_1^2 R_1$$

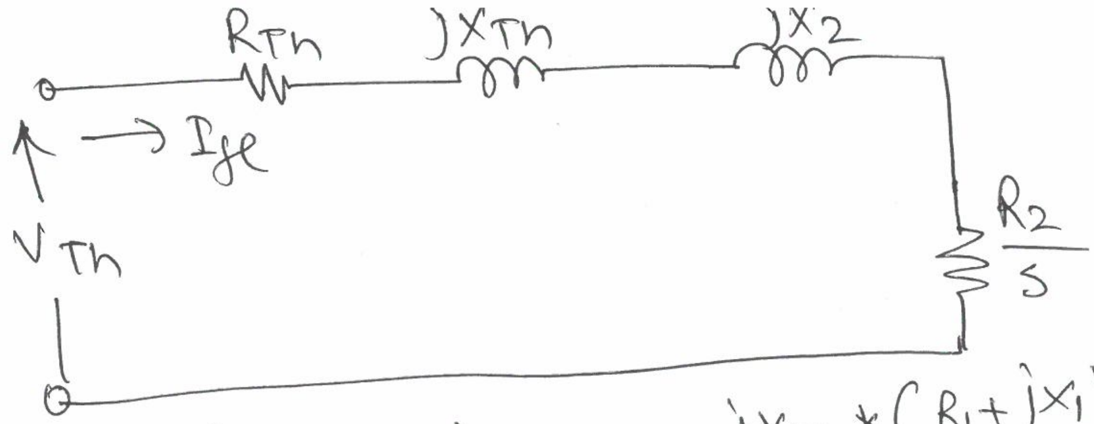
$$= 1600 - 3*(4.5)^2 * 2.8$$

$$= 1429.9\ W.$$

Assuming the full load slip as 5%, the analysis can be carried out as given.

$N_r = (1-S)N_s = (1-0.05)*1000 = 950\,rpm$

#4



$$R_{Th}+jX_{Th} = (R_1+jX_1) \| jX_m = \frac{jX_m * (R_1+jX_1)}{R_1+j(X_1+X_m)}$$

$$= \frac{j\,273.04 * (2.8+j\,7.96)}{2.8+j\,281} =$$

$$= \frac{273.04\angle 90^\circ * 8.438\angle 70.62}{281.01\angle 89.43}$$

$$= 8.198\angle 71.19$$

$$= 2.643 + j\,7.76$$

$$V_{Th} = \frac{jX_m}{R_1+j(X_1+X_m)} \cdot V_1 = \frac{j\,273.04}{2.8+j\,281} * 1270.2$$

$$= 1234.17 \text{ V}$$

$$I_{fl} = \frac{V_{Th}}{\left(R_{Th}+\frac{R_2}{s}\right)+j\,(X_{Th}+X_2)}$$

$$= \frac{1234.17}{\left(2.643+\frac{2}{0.05}\right)+j\,(7.76+7.96)}$$

$$= \frac{1234.17}{42.634+j\,15.72}$$

$$= \frac{1234.17}{45.44\angle 20.24} = 27.16\angle -20.24^\circ$$

#5

Full load current,

$$I_L = I_{ph} = 27.16\ A \quad (\text{Star-connected})$$

Full load power factor

$$\cos(20.24°) = 0.938$$

Full load Input power

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

$$= \sqrt{3} * 2200 * 27.16 * 0.938$$

$$= 97076.9\ W$$

Full load stator cu loss

$$P_{cu} = 3\, I_{fl}^2 \cdot R_1 = 3 * (27.16)^2 * 2.8$$

$$= 6196.39\ W$$

Full load air-gap power

$$P_{ag} = P_{in} - P_{cu} \quad (\text{ignoring stator core loss})$$

$$= 97076.9 - 6196.39$$

$$= 90880.5\ W$$

Full load ~~to~~ rotor cu loss

$$P_{rotor} = s P_{ag} = 0.05 * 90880.5 = 4544.0\ W$$

Full load power developed

$$P_{dev} = P_{ag} - P_{rotor} = 90880.5 - 4544.0$$

$$= 86336.5\ W$$

$$P_{out} = P_{dev} - P_{rotational} = 86336.5 - 1429.9$$

$$= 84906.6\ W$$

$$\eta = \frac{P_{out}}{P_{in}} * 100 = \frac{84906.6}{97076.9} * 100 = 87.46\%.$$

$$T_{fl} = \frac{P_{out}}{\omega} = \frac{84906.6}{2\pi * \frac{950}{60}} = 853.47\ N\text{-}m.$$

#6 By changing the value of slip, s (which means the motor runs at different speeds) it is possible to determine all parameters.

The performance parameters are determined without doing actual load test.

Due to this reason equivalent circuit parameters are very useful.