Example- A design class A, three-phase, 4-pole, Y-connected induction motor is rated for a terminal voltage of 210 V_{rms}, line current of 12.8 A_{rms} (implies motor has a PF of ~0.8 lagging at rated load), and 5 hp at 60 Hz.

To find the equivalent circuit parameters, the following tests were performed:

DC Test: $V_{dc,ab} = 20.1$ V w/ $I_{dc,a} = 12.83$ A, $V_{dc,bc} = 20.0$ V w/ $I_{dc,b} = 12.79$ A, and $V_{dc,ca} = 20.2$ V w/ $I_{dc,c} = 12.84$ A.

No-Load Test: $V_{ab} = 210.2\ V_{rms}$, $V_{bc} = 210.1\ V_{rms}$, & $V_{ca} = 210.0\ V_{rms}$;

$I_a = 4.47\ A_{rms}$, $I_b = 4.43\ A_{rms}$, & $I_c = 4.46\ A_{rms}$;

$P_{in,NL} = 250$ W.

Locker-Rotor Test: $V_{ab} = 28.78\ V_{rms}$, $V_{bc} = 28.92\ V_{rms}$, & $V_{ca} = 28.85\ V_{rms}$;

$I_a = 12.80\ A_{rms}$, $I_b = 12.82\ A_{rms}$, & $I_c = 12.81\ A_{rms}$;

$P_{in,LR} = 480$ W; $f_{test} = 15$ Hz.

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1) Calculate R_1 using **DC Test** results

$V_{dc} = [V_{dc,ab} + V_{dc,bc} + V_{dc,ca}] / 3 = [20.1 + 20 + 20.2]/3 \Rightarrow V_{dc} = 20.1$ V.

$I_{dc} = [I_{dc,a} + I_{dc,b} + I_{dc,c}] / 3 = [12.83 + 12.79 + 12.84]/3 \Rightarrow I_{dc} = 12.82$ A.

$R_T = V_{dc} / I_{dc} = 20.1 / 12.82 \Rightarrow R_T = 1.56786\ \Omega$.

For a Y-connection (7-57), $R_1 = R_T / 2 = 1.56786 / 2 \Rightarrow$ **$R_1 = 0.784\ \Omega$**.

2) **No-Load Test** calculations

$$V_{T,\text{NL}} = V_{LL,\text{NL}} = [V_{ab} + V_{bc} + V_{ca}]/3 = [210.2 + 210.1 + 210]/3$$

$$\Rightarrow V_{T,\text{NL}} = 210.1\ \text{V}_{\text{rms}}.$$

For Y-connection, $V_{\phi,\text{NL}} = V_{T,\text{NL}}/\sqrt{3} = 210.1/\sqrt{3} \Rightarrow V_{\phi,\text{NL}} = 121.3013\ \text{V}_{\text{rms}}.$

$$I_{L,\text{NL}} = [I_a + I_b + I_c]/3 = [4.47 + 4.42 + 4.46]/3 \Rightarrow I_{L,\text{NL}} = 4.45\ \text{A}_{\text{rms}}.$$

For a Y-connection, $I_{\phi,\text{NL}} = I_{1,\text{NL}} = I_{L,\text{NL}} \Rightarrow I_{1,\text{NL}} = 4.45\ \text{A}_{\text{rms}}.$

(7-60), $Z_{\text{NL}} = |\boldsymbol{Z}_{\text{eq}}| = V_{\phi,\text{NL}}/I_{1,\text{NL}} = 121.3/4.45 \approx X_1 + X_M \Rightarrow Z_{\text{NL}} = 27.2587\ \Omega.$

(7-25), $P_{\text{SCL}} = 3I_{1,\text{NL}}^2 R_1 = 3\,(4.45)^2\,0.784 \Rightarrow P_{\text{SCL}} = 46.571\ \text{W}.$

(7-58), $P_{\text{rot}} = P_{\text{in,NL}} - P_{\text{SCL}} = 250 - 46.5713 \Rightarrow \underline{\boldsymbol{P_{\text{rot}} = 203.43\ \text{W}}}.$

3) **Locked-Rotor Test** calculations

$$V_{T,\text{LR}} = V_{LL,\text{LR}} = [V_{ab} + V_{bc} + V_{ca}]/3 = [28.78 + 28.92 + 28.85]/3$$

$$\Rightarrow V_{T,\text{LR}} = 28.85\ \text{V}_{\text{rms}}.$$

For Y-connection, $V_{\phi,\text{LR}} = V_{T,\text{LR}}/\sqrt{3} = 28.85/\sqrt{3} \Rightarrow V_{\phi,\text{LR}} = 16.6566\ \text{V}_{\text{rms}}.$

$$I_{L,\text{LR}} = [I_a + I_b + I_c]/3 = [12.8 + 12.82 + 12.81]/3 \Rightarrow I_{L,\text{LR}} = 12.81\ \text{A}_{\text{rms}}.$$

For a Y-connection, $I_{\phi,\text{LR}} = I_{1,\text{LR}} = I_{L,\text{LR}} \Rightarrow I_{1,\text{NL}} = 12.81\ \text{A}_{\text{rms}}.$

$$\text{Per (7-61)},\ \text{PF} = \cos(\theta_{\text{LR}}) = \frac{P_{\text{in,LR}}}{\sqrt{3}\,V_{T,\text{LR}}I_{L,\text{LR}}} \Rightarrow \theta_{\text{LR}} = \cos^{-1}\left(\frac{P_{\text{in,LR}}}{\sqrt{3}\,V_{T,\text{LR}}I_{L,\text{LR}}}\right)$$

$$\theta_{\text{LR}} = \cos^{-1}\left(\frac{480}{\sqrt{3}\,(28.85)12.81}\right) \Rightarrow \theta_{\text{LR}} = 41.42093°.$$

Per (7-62), $Z_{\text{LR}} = |\boldsymbol{Z}_{\text{LR}}| = V_{\phi,\text{LR}}/I_{1,\text{LR}} = 16.5666/12.81 \Rightarrow Z_{\text{LR}} = 1.30028\ \Omega.$

Per (7-63), $\overline{Z}_{LR} = Z_{LR}\angle\theta_{LR} = Z_{LR}\cos(\theta_{LR}) + jZ_{LR}\sin(\theta_{LR}) = R_{LR} + jX'_{LR}$

$\overline{Z}_{LR} = 1.30028\angle 41.42093° \Rightarrow \overline{Z}_{LR} = R_{LR} + jX'_{LR} = 0.9750 + j0.8602\,\Omega.$

Per (7-66), $R_2 = R_{LR} - R_1 = 0.975 - 0.784 \Rightarrow \underline{\boldsymbol{R_2 = 0.191\ \Omega}}.$

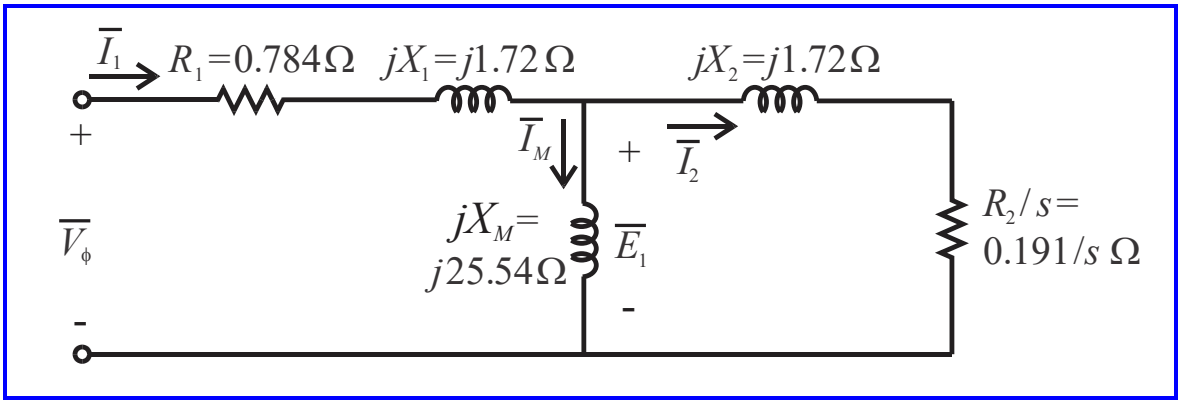
(7-67), $X_{LR} = \frac{f_{rated}}{f_{test}} X'_{LR} \simeq X_1 + X_2 = \frac{60}{15}(0.8602) \Rightarrow X_1 + X_2 = 3.441\ \Omega.$

Using Figure 7-35 and the knowledge that the motor is design class A,

$X_1 = X_2 = 0.5\,X_{LR} = 0.5\,(3.441) \Rightarrow \underline{\boldsymbol{X_1 = X_2 = 1.72\ \Omega}}.$

Per (7-60), $X_M = Z_{NL} - X_1 = 27.2587 - 1.72 \Rightarrow \underline{\boldsymbol{X_M = 25.54\ \Omega}}.$

The rotational losses are $\underline{\boldsymbol{P_{rot} = 203.43\ W}}$ while the core resistance R_C is unknown. These tests yield a per-phase equivalent circuit model of



or

