1. An 8-pole 3-phase alternator is coupled to a prime mover running at 750 rpm. It supplies an induction motor which has full-load speed of 960 rpm. Find the slip of the motor.

Solution –

Output frequency of alternator = 750*8/120

= 50 Hz

= Input frequency of induction motor

Full-load rotor speed of the induction motor = 960 rpm

From this speed, the no of poles of the motor –

P = 120*50/960 = 6.25

Hence p should be as 6. If it is chosen as 8, then the synchronous speed will be 750 rpm which is less than the rotor speed, therefore, is not possible.

So, no of poles of the motor = 6

Hence synchronous speed n_s = 120*50/6 = 1000 rpm

Slip s = (1000-960)/1000 = 0.04

2. A 3-phase induction motor has a starting torque of 80% and a maximum torque of 200% of the full-load torque. Find slip at maximum torque. Neglect stator resistances and reactances.

From eq^{ne}, $T_{max} = \frac{3}{\omega_s}\left(\frac{V_1^2}{2X_2'}\right)$

and $T_{start} = \frac{3}{\omega_s}\left(\frac{V_1^2 R_2'}{(R_2')^2 + X_2'^2}\right)$

$$\frac{T_{max}}{T_{start}} = \frac{0.5\,(R_2^2 + X_2^2)}{X_2 R_2}$$

$$= 0.5\,\frac{(R_2^2/X_2^2 + 1)}{(R_2/X_2)}$$

But $R_2/X_2 = S_{maxT}$

$$\frac{200}{80} = \frac{0.5\,(S_{maxT}^2 + 1)}{S_{maxT}}$$

or $S_{maxT}^2 - 5\,S_{maxT} + 1 = 0$

$S_{maxT} = 0.21,\ 4.79$ rejected

$\boxed{S_{maxT} = 0.21}$

3. Consider a six-pole Y-connected motor having terminal voltage as 208-V and operating frequency as 60 Hz. The motor is having capacity of 25-hp and is a design class B induction motor. The motor is tested in the laboratory, with the following results:

No load:	208 V, 22.0 A, 1200 W, 60 Hz
Locked rotor:	24.6 V, 64.5 A, 2200 W, 15 Hz
DC test:	13.5 V, 64 A

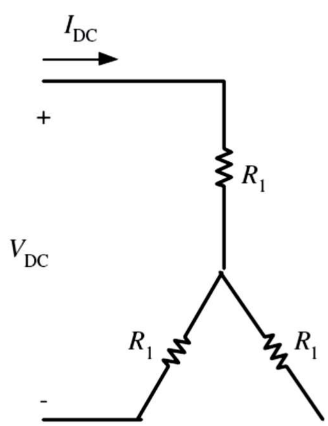
Find the magnetizing reactance of this motor. Consult the following table for reactance distribution between stator and rotor.

	X_1 and X_2 as functions of X_{LR}	
Rotor Design	X_1	X_2
Wound rotor	$0.5\ X_{LR}$	$0.5\ X_{LR}$
Design A	$0.5\ X_{LR}$	$0.5\ X_{LR}$
Design B	$0.4\ X_{LR}$	$0.6\ X_{LR}$
Design C	$0.3\ X_{LR}$	$0.7\ X_{LR}$
Design D	$0.5\ X_{LR}$	$0.5\ X_{LR}$

Solution

From the DC test,

$$2R_1 = \frac{13.5\ \text{V}}{64\ \text{A}} \qquad \Rightarrow \qquad R_1 = 0.105\ \Omega$$



In the no-load test, the line voltage is 208 V, so the phase voltage is 120 V. Therefore,

$$X_1 + X_M = \frac{V_\phi}{I_{A,nl}} = \frac{120\ \text{V}}{22.0\ \text{A}} = 5.455\ \Omega \quad @ \quad 60\ \text{Hz}$$

In the locked-rotor test, the line voltage is 24.6 V, so the phase voltage is 14.2 V. From the locked-rotor test *at 15 Hz*,

$$\left|Z'_{\text{LR}}\right| = \left|R_{\text{LR}} + jX'_{\text{LR}}\right| = \frac{V_\phi}{I_{A,\text{LR}}} = \frac{14.2 \text{ V}}{64.5 \text{ A}} = 0.2202\ \Omega$$

$$\theta'_{\text{LR}} = \cos^{-1}\frac{P_{\text{LR}}}{S_{\text{LR}}} = \cos^{-1}\frac{2200 \text{ W}}{\sqrt{3}(24.6 \text{ V})(64.5 \text{ A})} = 36.82°$$

Therefore,

$$R_{\text{LR}} = \left|Z'_{\text{LR}}\right| \cos\theta_{\text{LR}} = (0.2202\ \Omega)\cos(36.82°) = 0.176\ \Omega$$

$$\Rightarrow \qquad R_1 + R_2 = 0.176\ \Omega$$

$$\Rightarrow \qquad R_2 = 0.071\ \Omega$$

$$X'_{\text{LR}} = \left|Z'_{\text{LR}}\right| \sin\theta_{\text{LR}} = (0.2202\ \Omega)\sin(36.82°) = 0.132\ \Omega$$

At a frequency of 60 Hz,

$$X_{\text{LR}} = \frac{60 \text{ Hz}}{15 \text{ Hz}} X'_{\text{LR}} = 0.528\ \Omega$$

For a Design Class B motor, the split is $X_1 = 0.211\ \Omega$ and $X_2 = 0.317\ \Omega$. Therefore,

$$X_M = 5.455\ \Omega - 0.211\ \Omega = 5.244\ \Omega$$

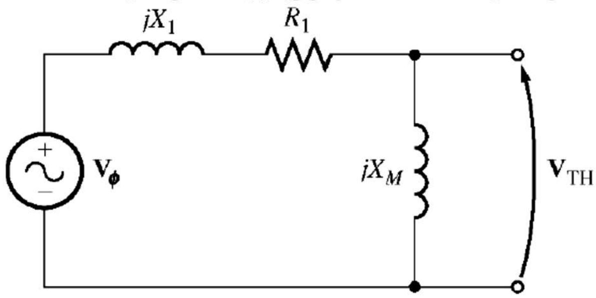
4. Consider a 208-V, two-pole, 60-Hz Y-connected wound-rotor induction motor having rotor to stator turns ratio as 1:1. The motor is rated at 15 hp. Its equivalent circuit components are:

$R_1 = 0.200\ \Omega$	$R_2 = 0.120\ \Omega$	$X_M = 15.0\ \Omega$
$X_1 = 0.410\ \Omega$	$X_2 = 0.410\ \Omega$	
$P_{mech} = 250\ \text{W}$	$P_{misc} \approx 0$	$P_{core} = 180\ \text{W}$

What is the slip at the pullout torque? Use simplified equivalent circuit after neglecting the core loss resistance. (Do not neglect R_1 and X_1 when calculating slip)

Solution

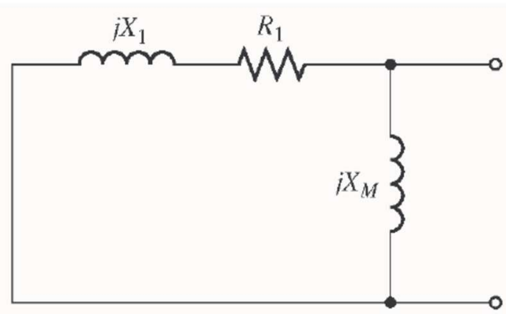
The slip at pullout torque is found by calculating the Thevenin equivalent of the input circuit from the rotor back to the power supply, and then using that with the rotor circuit model.



$$\mathbf{V}_{TH} = \frac{jX_M}{R_1 + jX_1 + jX_M}\mathbf{V}_\phi$$

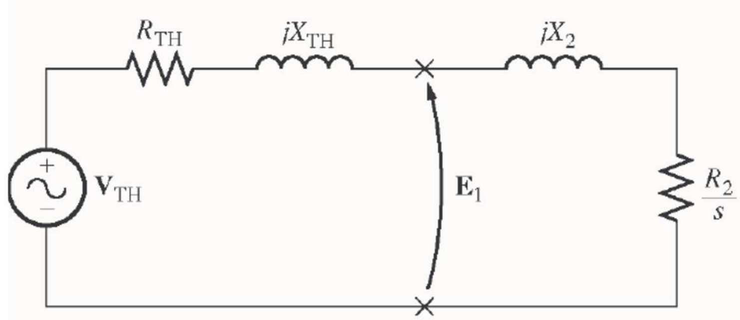
$$V_{TH} = \frac{X_M}{\sqrt{R_1^2 + (X_1 + X_M)^2}}\mathbf{V}_\phi$$

(a)



$$Z_{TH} = \frac{jX_M(R_1 + jX_1)}{R_1 + j(X_1 + X_M)}$$

(b)



(c)

$$Z_{\mathrm{TH}} = \frac{jX_M\left(R_1 + jX_1\right)}{R_1 + j\left(X_1 + X_M\right)} = \frac{\left(j15\ \Omega\right)\left(0.20\ \Omega\ +\ j0.41\ \Omega\right)}{0.20\ \Omega\ +\ j\left(0.41\ \Omega + 15\ \Omega\right)} = 0.1895 + j0.4016\ \Omega = 0.444\angle 64.7^\circ\ \Omega$$

$$\mathbf{V}_{\mathrm{TH}} = \frac{jX_M}{R_1 + j\left(X_1 + X_M\right)}\mathbf{V}_\phi = \frac{\left(j15\ \Omega\right)}{0.22\ \Omega\ +\ j\left(0.43\ \Omega + 15\ \Omega\right)}\ \left(120\angle 0^\circ\ \mathrm{V}\right) = 116.8\angle 0.7^\circ\ \mathrm{V}$$

The slip at pullout torque is

$$s_{\max} = \frac{R_2}{\sqrt{R_{\mathrm{TH}}{}^2 + \left(X_{\mathrm{TH}} + X_2\right)^2}}$$

$$s_{\max} = \frac{0.120\ \Omega}{\sqrt{\left(0.1895\ \Omega\right)^2 + \left(0.4016\ \Omega\ + 0.410\ \Omega\right)^2}} = 0.144$$