ECE 431

Second Exam - Spring 2013 - Closed book, (standard class sheet allowed), 55 min.

Name: Solution

Problem #1 (33 points)

The following test results were found for a balanced, symmetrical, Wye-connected, 3-phase, 60 HZ, 6 pole, 220 V (line-line) induction motor:

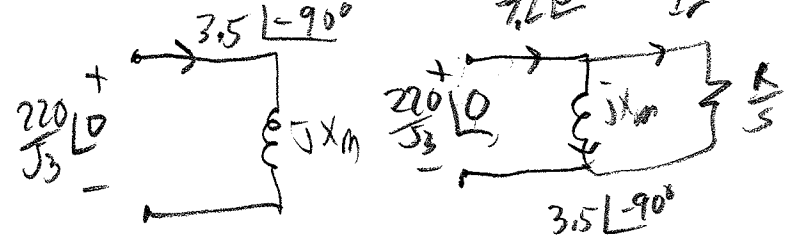
No-load test: V(line-line) = 220 V, I (line) = 3.5 A

Full-load test: V(line-line) = 220 V, I (line) = 7.2 A

(a) Estimate the horsepower rating of this machine (1 HP=746W)

(b) Estimate the power factor of this machine at full load

$7.2\angle\theta = I_r - j3.5$



(a) $\frac{220}{\sqrt{3}} = 3.5 X_m$

$X_m = 36.3\ \Omega$

$7.2 = \sqrt{3.5^2 + I_r^2}$ $\quad I_r = 6.29$

$P_{FL} \approx 3 \times \frac{220}{\sqrt{3}} \times 6.29$

$= 2397\ W$

$P_{FL} \approx 3.2\ HP$

(b) $Q = 3 \times \left(\frac{220}{\sqrt{3}}\right)^2 / X_m = 1333\ VARS$

$PF = \frac{P}{\sqrt{P^2+Q^2}} = 0.87\ lag$

Problem #2 (33 points)

Given the following tests of a 3-phase, 60 Hz, 4-pole synchronous machine running at 1800 RPM (neglect armature resistance):

I_f = 2.3 A	V = 120 V (line to neutral)	I (line) = 0.
I_f = 1.4 A	V = 0 V	I (line) = 7 A.

(a) What field current is needed to make the power factor at the terminals be unity when it is running as a generator with V = 120 V (line to neutral) and I (line) = 7A.

(b) What is the torque angle when the field current from (a) is used and the machine is providing 2,520 Watts (3-phase) as a generator?

(a) $120 = K_f w_s \times 2.3$ $\quad K_f w_s = 52.2\ \Omega$ $\quad 52.2 \times 1.4 = 7 X_s$ $\quad X_s = 10.44\ \Omega$

$52.2\, I_f \angle\delta = j10.44 \times 7\angle 0 + 120\angle 0 = 140.5\angle 31.3^\circ$ $\quad \boxed{I_f = 2.69}$

(b) $2520 = \dfrac{3 \times 120 \times 140.5}{10.44} \sin\delta$ $\quad \boxed{\delta = 31.34^\circ}$

Problem #3 (34 points)

A three-phase, 2-pole, 50 Hz, wye-connected synchronous machine has negligible stator resistance. Assume the machine is connected to the grid and operated as a motor with a terminal voltage of 230 V (RMS, line-to-line) drawing 10,000 Watts (3-phase) from the grid and sending 8,000 Vars (3-phase) into the grid. Assume the phase angle on the per-phase terminal voltage is zero. This motor is driving another three-phase synchronous machine as a generator to produce 400 Hz (3-phase).

(a) How many poles does the generator have?

$RPM = \frac{120 \times 50}{2} = 3000 = \frac{120 \times 400}{P_{Gen}}$ $\quad P_{Gen} = 16$

When a load of 6,000 Watts (3-phase) is added to the generator (and hence the motor), the motor torque angle changes by 15 mechanical degrees.

(b) What was the torque angle of the machine before the load was changed?

$10{,}000 = P_{max} \sin(-\delta_0)$

$16{,}000 = P_{max} \sin(-\delta_0 - 15^\circ)$

$\frac{10}{16} = \frac{\sin(-\delta_0)}{\sin(-\delta_0 - 15^\circ)}$

$10 \sin(-\delta_0 - 15^\circ) = 16 \sin(-\delta_0)$

$16 \sin(+\delta_0)\cos 15^\circ + 10 \cos\delta_0 \sin 15^\circ = 16 \sin\delta_0$

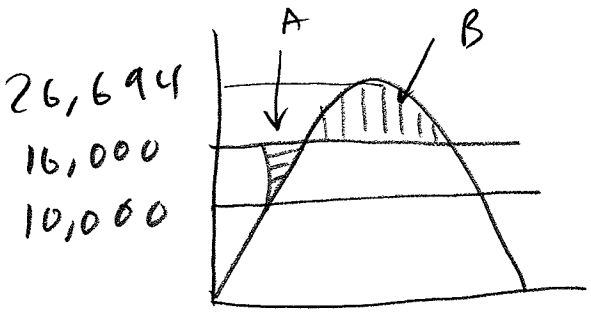
$9.66 \sin\delta_0 + 2.59 \cos\delta_0 = 16 \sin\delta_0$

$6.34 \sin\delta_0 = 2.59 \cos\delta_0 \quad \tan\delta_0 = .4085$

$\delta_0 = 22^\circ \Rightarrow$ -22° for motor

(c) Show with suitable calculations that it was possible to suddenly change the loading from 10,000 Watts to 16,000 Watts.

$P_{max} = \frac{10{,}000}{\sin 22^\circ} = 26{,}694\ W$



B > A