MACHINES II EXAM

FALL-2013

POWER UNIT
ELECTRICAL ENGINEERING

14.5

University of Jordan
Dept. of Elect. Engg.

Electric Machines (0903471)
First Examination

Date:26.10.2013
Time:1 Hour

Name (in Arabic)

Student No.

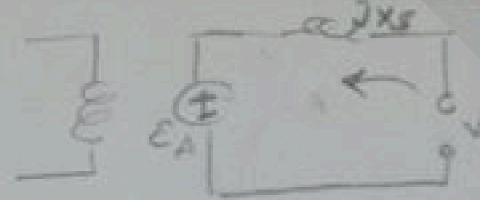
1. Answer the following with √ for correct and **X** for wrong answer.

3marks

1	Damper winding are useful for starting of synchronous motors but are useless in synchronous generators	X	
2	Rotating magnetic field is produced in 3-phase stator winding by windings displaced by mechanical angles = (240°/No. of poles)	X	x
3	To keep unity power factor of current drawn by synchronous motors when more torque is applied, slightly higher field current is needed	X	x
4	Induction motors are similar to transformers in producing rotor current and similar to synchronous motors in their stator windings	X	x
5	Skewing of rotor bars in induction motors results in reduction of current harmonics but does not affect the winding factor	√	x
6	Flux distribution around the rotor of Salient pole synchronous motors is usually sinusoidal	X	

1

$\frac{400}{\sqrt{3}} = 230.94$ But



2. A 400V, 100kW, 50Hz, star connected synchronous motor operating at 0.8 power factor leading with a synchronous reactance of 0.2Ω and negligible resistance. The motor operates at the linear region of the characteristics. The field current adjusted at 20A.

8marks

(i) Calculate the induced emf and the torque angle δ

$P = \sqrt{3}\, V_{LL}\, I_A \cos\theta$

$I_A = \frac{100{,}000}{\sqrt{3} * 400 * 0.8}$

$\therefore I_A = 180.42 \angle +36.87$

$E_A = V_T - I_A * jX_s$

$= \frac{400}{\sqrt{3}} - 180.42\angle 36.87 * j0.2$

$E_A = 254.23 \angle -6.52$

$\therefore |E_A| = 254.23$

$\delta = -6.52$

(ii) Keeping the mechanical load of the motor constant, the field current is adjusted to have 0.9 power factor lagging. Find the value of the necessary field current

$I_{A_2} = \frac{100\,000}{\sqrt{3} * 400 * 0.9}$

$I_{A_2} = 160.37 \angle -25.84°$

$E_{A2} = V_T - I_{A2} * jX_s$

$= \frac{400}{\sqrt{3}} - 160.37\angle -25.84 * j0.2$

$E_{A2} = 219.32 \angle -7.62°$

$\frac{I_{F1}}{I_{F2}} = \frac{E_{A1}}{E_{A2}}$

$\therefore I_{f2} = I_{F1} * \frac{E_{A2}}{E_{A1}}$

$I_{f2} = 17.255$

45

(iii) The torque is reduced by 10% and the field current is adjusted to 15A. What would be the current and the power factor then?

$\frac{I_{F1}}{I_{F3}} = \frac{E_{A1}}{E_{A3}}$

$\therefore E_{A3} = E_{A1} * \frac{I_{F3}}{I_{F1}}$

$E_{A3} = 180.42 * \frac{15}{20}$

$E_{A3} = 135.315$

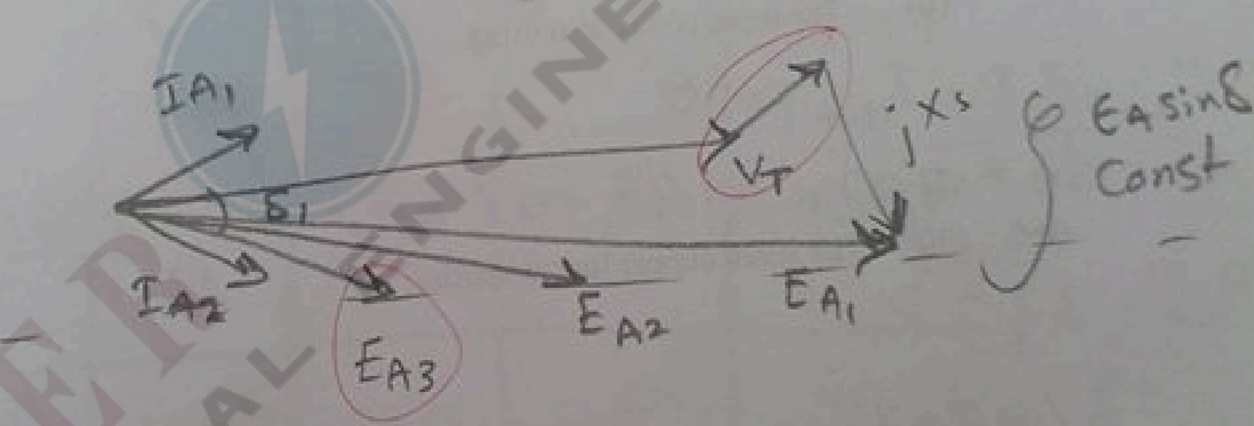
$\sin\delta_3 = 1.1 \sin\delta_1$

$\delta_3 = -7.17°$

$E_{A3} = V_T - I_A + jX_s$

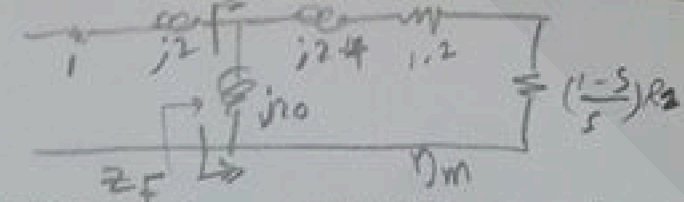
$I_A =$

(iv) Sketch the phasor diagram for the three cases above on the same diagram



(v) For the mechanical load of (i) above, if the field current reduced to 2A; what would happen to the motor? Why?

$\frac{400}{\sqrt{3}} = 230.94$



3. A 3-phase, 400V, 50Hz, Y- connected, 1440rpm, wound rotor induction motor having the following parameters: **5marks**

$R_1 = 1\,\Omega$ $R_2 = 1.2\,\Omega$ $X_1 = 2\,\Omega$ $X_2 = 2.4\,\Omega$ $X_m = 20\,\Omega$ $P_{rotational} = 300$ W

Calculate the following:

(i) The starting current

@ s = 1 "starting"

$Z_F = j20 \parallel 1.2 + j2.4$

$Z_F = 2.39 \angle 66.5^\circ$

$Z_F = 0.95 + j2.19$

$I = \frac{V_T}{(R_1 + jX_1) + Z_F} = \frac{\frac{400}{\sqrt{3}}}{(1 + j2) + (0.95 + j2.19)} = \frac{230.94}{1.95 + j4.19}$

$I = 49.97 \angle -65$

عشان في (s=1) start → $R_2(\frac{1-s}{s}) = 0$

(ii) The input power at starting

$P_{in} = \sqrt{3}\, V_{LL}\, I_{start} \cos\theta$

$= \sqrt{3} * 400 * 49.97 \cos(65) = 14631.14$ W

(iii) The stator cupper loss at starting

$P_{SCL} = 3 I_{start}^2 R_1$

$= 3(49.97^2) * 1 = 7491$ W

(iv) The rotor cupper loss at starting

$P_{RCL} = s P_{AG}$

$P_{AG} = P_{in} - P_{SCL}$

$= 7140$ W

$n_s = 1500 = \frac{120 * 50}{P}$

$P = 4$

$s = \frac{n_s - n_m}{n_s} = 0.04$

$\therefore P_{RCL} = 0.04 * 7140$

$= 285.6$

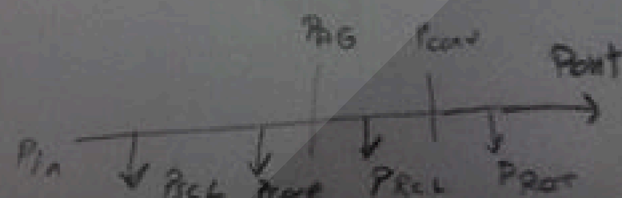
1 ×

(v) The starting torque

$\tau_{start} = \frac{P_{AG}}{\omega_{sync.}} = \frac{7140}{1500 * \frac{2\pi}{60}} = 45.45$ Nm.

4.5

4



4. A factory having the following loads:

a. A 400 hp induction motor of an efficiency of 86% and operating at 0.85 p.f. lagging
b. A 400kVA load at 0.8 p.f. lagging
c. A lighting load of 100kW at unity p.f.
d. A synchronous motor of 600kVA

It is required to get an overall factory power factor of unity. What is the possible mechanical load (in hp) connected to the shaft of the synchronous motor if its efficiency is 90%.

5marks

Loads	P_{in} (KW)	Q (KVAR)	S (KVA)	P.F	θ
IM	347	215	408.2	0.85	31.788
Load 1	320	240	400	0.8	36.87
Lights	100	0	100	1	0
SM	390	455	600	0.65	49.32
Total		0		1	

IM:

$$P_{in} = \frac{400 \times 746}{0.86} = 347 \text{ kW}$$

4.5

SM:

$$P_{out} = P_{in} \times \eta = 390k \times 0.9 = 351 \text{ kW}$$

$$\therefore P_{hp} = \frac{351000}{746} = 470.51 \text{ hp}$$

5