University of Jordan | School of Engineering | Electrical Engineering Department

EE471: Electrical Machines II | First Exam | Summer Session I- 2016-2017 | Tuesday 20/6/2017 | Time: 1 Hour

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Q # 1 (15)	Q # 2 (3)	Q # 3 (7)	GRADE
13	2.5	7	22.5/25

+1

Question # 1 (15 Points)

Select the correct answer of Questions (1.1-1.30) and fill it in the Table provided.

Q #	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Ans	a	b	a	d	a	c	d	b	d	b
Q #	**Q11**	**Q12**	**Q13**	**Q14**	**Q15**	**Q16**	**Q17**	**Q18**	**Q19**	**Q20**
Ans	c	c	b	c	c	b	d	d	a	c
Q #	**Q21**	**Q22**	**Q23**	**Q24**	**Q25**	**Q26**	**Q27**	**Q28**	**Q29**	**Q30**
Ans			a	d	a	a	b	c	b	a

$R_{dc} = 3.75\,\Omega$ $X_s = 4.44\,\Omega$

1.1 As load power factor of a synchronous generator becomes more *lagging*, the value of generated voltage E_a required to give rated terminal voltage ....

(a.) increase b. remains unchanged c. decreases d. varies with rotor speed

1.2 If the field of a synchronous generator is underexcited, the power factor will be ....

a. lagging (b.) leading c. unity d. more than unity

1.3 A synchronous generator connected to infinite bus-bars has at constant full-load, 100% excitation and unity pf. On decreasing the excitation only, the armature current will have ...

(a.) leading PF with underexcitation
b. leading PF with overexcitation
c. lagging PF with overexcitation
d. lagging PF with underexcitation

1.4 If the excitation of a synchronous generator is increased with the load remained unchanged, then ...

a. the excitation voltage increases.
b. the maximum developed power increases.
c. the reactive power increases.
(d.) all of the above.

1.5 An alternator is delivering rated current at rated voltage and 0.8 PF lagging case. If it is required to deliver rated current at rated voltage and 0.8 PF lagging (leading), the required excitation will be ....

(a.) less. b. more. c. more or less. d. the same.

1.6 As the speed of an alternator decreases ....

a. the frequency remains constant but PF decreases
b. the frequency increases
(c.) the frequency decreases
d. none of the above

$n_s = \frac{120 f}{P}$

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1.7 For successful connection of a synchronous generator to an infinite bus system (Grid) using three-lamp method, the following condition(s) must be satisfied:

a. equal voltage magnitudes and phases of the running and incoming generators
b. equal phase sequence of the running and incoming generators
c. equal frequency of the running and incoming generators
d. All of the above

1.8 When two alternators are running in parallel, their KW load share is changed by changing their .... while their kVAR load share is changed by changing their ....

a. excitation, driving torque
b. driving torque, excitation
c. excitation, excitation
d. driving torque, driving torque

1.9 At a particular instant, an alternator is generating 80 MW at 0.8 power factor lagging. Now if the steam supply valve to the steam turbine is further closed and the excitation is not changed, ...

a. the speed of the alternator will decrease but kW delivered will remain unchanged
b. the speed of the alternator will decrease and kW delivered will also increase
c. the speed of the alternator will remain unchanged but it will deliver less kVA
d. the speed of the alternator will remain unchanged but it can meet less kW demand

1.10 Two alternators A and B are sharing a resistive load ($pf=1$) equally. Now if the excitation of alternator A is decreased, ...

a. alternator A will become lagging and alternator B will become leading
b. alternator A will become leading and alternator B will become lagging
c. both alternators will continue to operate on unity power factor
d. both alternators will operate on leading power factor

1.11 When a generator designed for operation at 60 Hz is operated at 50 Hz, ...

a. kVA rating can be upgraded to (60/50) of the rated value
b. operating voltage must be derated to $(50/60)^2$ of its original value
c. operating voltage must be derated to (50/60) of its original value
d. the generator will not take any load.

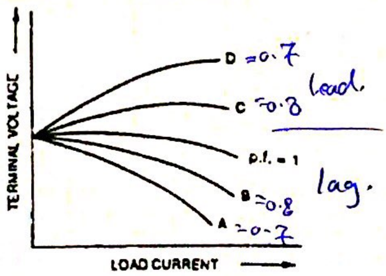
1.12 Two synchronous generators G_1 and G_2 are equally sharing the KVAR of the load while operating in parallel. Keeping the terminal voltage fixed in order to shift part of the KVAR load from G_1 to G_2, ...

a. the field current of G_1 is lowered
b. The field current of G_2 is raised
c. the field current of G_2 is raised and of G_1 is lowered.
d. the field current of G_1 is raised and of G_2 lowered

1.13 The steady-state stability limit of a synchronous generator can be increased by ....

a. an increase in its reactance
b. an increase in the excitation of the machine
c. a decrease in the moment of inertia of the machine
d. an increase in the moment of intertia of the machine

1.14 Load characteristic curves for an alternator are shown. The curves are drawn for 0.9 PF lagging, 0.8 PF lagging, 0.8 PF leading and 0.7 PF leading. Which curve represents the characteristics for 0.8 PF lagging?



a. curve A
b. curve C
c. curve B
d. curve D

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$n_s = \frac{120}{8} * \frac{900}{f} = 900 \Rightarrow f = 60 Hz$ $E = 4.44 N \phi f K_w$, so $\phi = \frac{E_{ph}}{4.44 N f K_w}$

1.15 A 3-phase, 8-pole, 900-rpm, Y-connected synchronous generator has 120 turns per phase and a stator-winding factor K_w=0.90. If a voltage of 200 V is measured across the machine terminals on no load, the flux per pole would be .... mWb.

$\phi = 4$ mWb

a. 1.5   b. 8   c. 4   d. 20.8

1.16 A synchronous generator on open-circuit generates 400 V at 50 Hz when the field current is 4.0 A. Neglecting saturation, the open-circuit EMF when the frequency is 25 Hz and the field current is 6.0 A will be .... V.

$\frac{E_1}{E_2} = \frac{f_1 I_{F1}}{f_2 I_{F2}}$

a. 100   b. 300   c. 800   d. 600

$E_2 = 300$

1.17 A 50-Hz synchronous generator will run at the greatest possible speed if it is wound for ...... poles.

a. 8   b. 6   c. 4   d. 2 $n_s = \frac{120 f}{P}$ min.

1.18 The effective voltage in one phase of an alternator having 480 turns per phase, frequency of 60 Hz and flux per pole of 20.8 mWb will be ..... V.

$E = 4.44 K_w N \phi f$

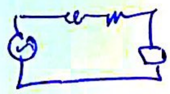
a. 332.5   b. 665   c. 1330   d. 2660 $E = 2660$

1.19 The voltage regulation of a synchronous generator having 0.75 lagging *pf* load, no-load induced EMF voltage of 3000 V and rated terminal voltage of 2400 V is

$VR = +25\%$

a. +25.0%   b. -20.0%   c. +20.0%   d. -25.0%

1.20 A 50 kVA, 440 V, 3-phase, 50 Hz, Y-connected, alternator, has an armature resistance R_a of 0.25 Ω/phase and a synchronous reactance X_s of 3.2 Ω/phase. The % voltage regulation of the alternator at 1.0 PF is approximately ....%.



a. 55   b. 45   c. 35   d. 25

$VR \simeq 35\%$ $|E_A|_{LL} = 593 \angle 27.8°$ $E_A = V_T + I_a Z_s$ $I_A = \frac{50K}{\sqrt{3}(440)} = 65.6 \angle 0°$

1.21 A 3-phase Δ-connected synchronous generator is tested in order to determine its effective armature resistance using DC resistance test. If the DC current and voltage results are I_{dc}=40 A and V_{dc}= 100 V, the armature DC resistance R_{dc} will be .... Ω.

$R_{dc} = \frac{3}{2} \frac{V}{I}$

a. 0.2   b. 0.9   c. 0.6   d. 0.66

$R_{dc} = 3.75$ Ω

1.22 If, in a 3-phase, Y-connected synchronous generator, a field current of 50 A produces a full-load armature current of 200 A on short-circuit and 1730 V on open circuit, then its synchronous reactance X_s is .... Ω

$X_s \simeq \frac{E_{oc}}{I_{sc}} \simeq 4.99$

a. 0.4   b. 2.5   c. 0.6   d. 3.75

$X_s \simeq 4.99$ Ω

1.23 A 10,000 kVA, 6600-V, 60-Hz, 3-Phase, Y-connected synchronous generator operates at full-load at a lagging PF of 0.8 and 80% efficiency. The real and reactive power delivered by the generator per phase is ...... kVA.

a. $8000 + j\,6000$ b. $2667 + j\,2000$ c. $2133 + j\,1600$ d. $6400 + j\,4800$

$I_a = \frac{10 MK}{6.6K \sqrt{3}} = 874.8 A \angle -36.9°$

$P = \sqrt{3} V_T I_a \cos\theta = 8000$ KW.

$Q = \sqrt{3} V_T I_a \sin\theta = 6000$ KVAR.

$S = 8000 + j6000$

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1.24 A 3-phase Y-connected synchronous generator has a synchronous reactance X_s of 4 Ω per phase and a terminal voltage of 2300 V. The field current is adjusted so that the excitation voltage is 2300 V at a power angle δ of 15°. The power developed power by the generator is …… kW

a. 1026.86 b. 3967.5 c. 1322.28 d. 342.23

$P = \frac{3 E_a V_t}{X_s} \sin\delta = 342.3 KW$

1.25 A 3-phase, 6600-V, Y-connected synchronous generator has X_s = 4 Ω and its armature resistance R_a is negligible. If the induced voltage is adjusted to 8000 Vat 0.8 PF lagging, the maximum power developed P_d is ….. MW.

a. 13.2 b. 19.8 c. 6.6 d. 15.84

$P_d = \frac{3 E_a V_t}{X} \sin 90 = 13.2 MW.$

Questions 1.26 to 1.28 refer to the following data:
A 2300 V, 60-Hz, 3-phase, synchronous generator has a synchronous reactance X_s of 4 Ω per phase and a negligible armature resistance R_a. The field current is adjusted so that the excitation voltage is 2300 V at an angle δ of 30°.

1.26 The total output real Power P delivered is ….. kW.

a. 661.25 b. 1983.8 c. 1322.5 d. 2645

$I_a = \frac{E - V_t}{X_s} = 171.8 \angle 15°$ $P = 3 V_t I_a \cos\theta$ $P = 661.1 KW$

1.27 Te total output reactive Power Q delivered is ….. kVAR.

a. -59.1 b. -177.2 c. 1145.3 d. 381.8

$Q = -177.14 KVAR$

1.28 The power factor is …..

a. 0.5 lagging b. 0.866 lagging c. 0.966 leading d. 0.866 leading

$pf = \cos 15 = 0.966$ leading.

Questions 1.29 to 1.30 refer to the following data:
A 3-phase, 50 Hz, 6600 V, alternator is rated at 6000 kW at 0.8 PF and a full load efficiency of 90%.

1.29 kVA is rating of the alternator is … kVA.

a. 4800 b. 7500 c. 6667 d. 5400

$I = 656.1 A.$

1.30 The input power to the alternator is … kW.

a. 6667 b. 8333 c. 5400 d. 7500

$S = \frac{P}{pf} = 7500 KVA.$

$P_{out} = 6000 KW.$

$\eta = \frac{P_{out}}{P_{in}} \Rightarrow P_{in} = \frac{6000K}{0.9} = 6667 KW$

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Question # 2-a (1.5 Points)

A 750-kVA, 1380-V, 60-Hz, Δ-connected 3-phase synchronous generator is tested in order to determine its voltage regulation. The results of these tests are:

Open-Circuit Test	Short-Circuit Test	DC-Resistance Test
I_f= 17.5 A	I_f= 17.5 A	I_{dc}= 100 A
V_{Loc}= 1020 V	I_{Lsc}= 314 A	V_{dc}= 40 V

Assume the effective armature resistance R_a=1.5×R_{dc}, find

0.6*1.5 = 0.9 Ω

2.a.1	the armature resistance, R_a	R_a =	~~0.6~~	Ω
2.a.2	the synchronous impedance, Z_s	Z_s =	5.626 ✓	Ω
2.a.3	the synchronous impedance, X_s	X_s =	5.594 ✓	Ω

$R_a = \frac{3}{2}\frac{V_{dc}}{I_{dc}} = \frac{3}{2}\left(\frac{40}{100}\right) \Rightarrow \boxed{R_a = 0.6\,\Omega}$

$Z_s = \frac{E_{oc}}{I_{sc}} = \frac{1020}{\frac{314}{\sqrt{3}}} = \boxed{5.626\,\Omega}$

$Z_s = \sqrt{R_a^2 + X_s^2}$

$\Rightarrow X_s = (5.626)^2 - 0.6^2$

$\Rightarrow \boxed{X_s = 5.594\,\Omega}$

Question # 2-b (1.5 Points)

A 2300 V, 60-Hz, 3-phase, synchronous generator has a synchronous reactance X_s of 4 Ω per phase and a negligible armature resistance R_a. The field current is adjusted so that the excitation voltage is 2300 V at a power angle δ of 30°.

2.b.1	The total output real Power delivered P_{out}.	P_{out} =	661.25		kW
2.b.2	The total output reactive Power delivered Q_{out}.	Q_{out} =	−177.18		kVAR
2.b.3	The generator operating power factor	Pf =	0.9659	lag	(lead)

①

$P_{out} = P_d = \frac{3 V_t E_A}{X_s} \sin\delta$

$= \frac{V_t E_A}{X_s} \sin\delta$

$= \frac{(2300)(2300)}{4} \sin 30$

$\boxed{P_{out} = 661.25\,KW}$

$Q_{out} = \frac{3V_t}{X_s}\left[E_A \cos\delta - V_t\right]$

$= \frac{(2300)(2300)}{4} \cos 30 - \frac{2300^2}{4}$

$\boxed{Q_{out} = 177.18\,KVAR}$

$P = 3 V_t I_a \cos\theta$ (pf)

$I_a = \frac{E_a - V_t}{j X_s} = 171.8\angle 15°$

$pf = \cos 15° = \boxed{0.9659}$

Leading.

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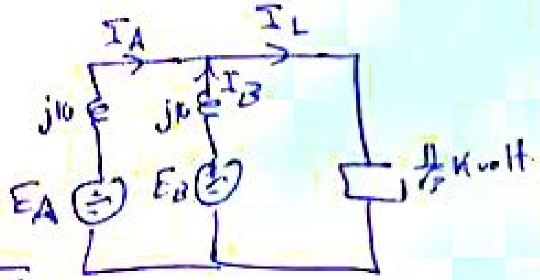
(7)

Question # 3 (7 Points)

Two identical 3-ph, Y-connected alternators (A and B) are connected in parallel and deliver a total load of 2.5 MW at 11 kV and a power factor of 0.866 lagging. Each generator has a per phase synchronous reactance X_s = 10 Ω and a negligible armature resistance. The induced voltage (E_A) and the power angle (δ_A) of **generator A** are adjusted to 12.5 kV and 6.26°, respectively. Determine for **generators A and B** the following:

a.	The magnitude of the load current $\lvert I_L \rvert$	$\lvert I_L \rvert$ =	151.5	A
b.	the real output power P_A and P_B	P_A =	1.5	MW
		P_B =	1	MW
c.	the armature current phasors I_A and I_B	I_A =	113.9 ∠−46.3°	A
		I_B =	52.9 ∠7.2°	A
d.	the power factor PF_A and PF_B and indicate lead or lag	PF_A =	0.6909 lagging	lag
		PF_B =	0.9921 leading	lead
e.	the reactive output power Q_A and Q_B	Q_A =	+1.569	MVAR
		Q_B =	−126.32	kVAR
f.	the magnitude of the induced phase voltage $\lvert E_B \rvert$ and the angle (δ_B)	$\lvert E_B \rvert$ =	6.306	kV_{LN}
		∠δ =	4.77°	°
g.	the percentage voltage regulation of generators A and B.	$\%VR_A$ =	13.6	%
		$\%VR_B$ =	−0.91	%

a) $I_L = \frac{P_{3\phi}}{\sqrt{3} V_L pf} = \frac{2500K}{0.866 \sqrt{3} \times 11K} = 151.5\angle{-30^\circ}$



b) $P_A = \frac{3 V_t E_a}{X_s} \sin\delta$

$= \frac{11K \times 12.5K}{10} \sin 6.26^\circ \Rightarrow \boxed{P_A = 1.5MW}$

$\Rightarrow P_B = P_L - P_A = \boxed{1MW}$

c) $I_A = \frac{E_A - V_t}{jX_s} = \frac{\frac{12.5K}{\sqrt{3}}\angle 6.26 - \frac{11K}{\sqrt{3}}\angle 0}{10\angle 90} \Rightarrow \boxed{I_A = 113.9 \angle{-46.3^\circ} A}$

$I_L = I_A + I_B \Rightarrow I_B = I_L - I_A \Rightarrow \boxed{I_B = 52.9 \angle 7.2^\circ} A$

d) $pf_A = \cos(46.3) = \boxed{0.6909 \text{ lag}}$
$pf_B = \cos(7.2) = \boxed{0.9921 \text{ lead}}$

e) $Q_A = 3 V_\phi I_A \sin\theta$
$= \sqrt{3} V_T I_A \sin\theta_A = 1.569 MVAR$

$Q_B = \sqrt{3} V_T I_B \sin\theta_B = -126.32 KVAR$

f) $E_B = V_t \angle 0 + I_B jX_s$

$\Rightarrow E_{B phase} = 6306.4 \angle 4.8^\circ$ volt.

g) $|E_B|_{LL} = 10.9K$ volt.

$VR_A = \frac{12.5 - 11}{11} \times 100\% = \boxed{13.6\%}$

$VR_B = \frac{10.9 - 11}{11} \times 100\% = \boxed{-0.91\%}$

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