iii. A 12 pole, 3 phase, star-connected alternator has 72 slots. The flux per pole is 0.0988 wb. calculate: **5**

(a) The speed of rotation if frequency of generated e.m.f. is 50 Hz.

(b) The terminal emf for full-pitch coils and 8 conductors per slot.

(c) The emf if the coil span is reduced to 2/3 of pole pitch.

OR iv. Using two reaction theory, develop expression for output power of salient pole synchronous generator **5**

Q.6 Write short notes any two:

i. Stepper motor **5**

ii. Synchronous motors as power factor correcting device **5**

iii. Effect of excitation on armature reaction **5**

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Total No. of Questions: 6 *Total No. of Printed Pages: 4*

Enrollment No....................................

Faculty of Engineering

End Sem (Even) Examination May-2022

EE3CO13 / EX3CO13 Electrical Machines -II

Programme: B.Tech. Branch/Specialisation: EE/EX

Duration: 3 Hrs. **Maximum Marks: 60**

Note: All questions are compulsory. Internal choices, if any, are indicated. Answers of Q.1 (MCQs) should be written in full instead of only a, b, c or d.

Q.1 i. Drop in the terminal voltage of a shunt generator under load conditions is due to: **1**

(a) Armature resistance drop

(b) Armature reaction

(c) Decrease in field current

(d) All of these

ii. A shunt generator do not build up any voltage at no load because: **1**

(a) Shunt coil may be connected in reverse direction

(b) There is no resistance magnetism in the poles

(c) Its shunt field resistance is more than critical resistance

(d) Any one of these

iii. Interpoles in DC motors are used for: **1**

(a) Increasing the speed of motor

(b) Reducing sparking at the commutation

(c) Decreasing the counter emf

(d) Converting armature current to DC

iv. When load is removed, which of the following DC motors will run at excessively high speed? **1**

(a) Shunt motor

(b) Series motor

(c) Cumulative compound motor

(d) Differential compound motor

v. An alternator is said to be overexcited when it is operating at- **1**

(a) Unity power factor (b) Leading power factor

(c) Lagging power factor (d) Either (a) or (b)

vi. Exciting field coil of an alternator is generally excited by: **1**
(a) A separate DC generator driver by some source
(b) A separate ac generator drive by some source
(c) A DC generator coupled directly to the armature shaft
(d) A battery

vii. In an alternator, the armature reaction is completely magnetizing when the load power factor is: **1**
(a) Unity (b) 0.7
(c) Zero lagging (d) Zero leading

viii. The main advantage of using fractional pitch winding in an alternator is to reduce: **1**
(a) Amount of copper in the winding
(b) Size of the machine
(c) Harmonics in the generated emf
(d) Cost of the machine

ix. Short pitch coils are used in alternators: **1**
(a) To reduce the size of the machine
(b) To reduce the stray losses
(c) To reduce harmonic output
(d) To reduce accurate phase shift of 120° between each phase

x. On keeping the input to the prime mover of an alternator constant and increasing the excitation: **1**
(a) kVA becomes leading
(b) kVA become lagging
(c) kW will change
(d) pf of the load remains unaltered

Q.2 i. Explain different type of winding used in DC machine. **2**

ii. Draw and explain the magnetization characteristics of DC shunt generator. **3**

iii. A separately excited DC generator has terminal voltage 250 V with constant field excitation. If load change from 200 kw to 125 kw, find percentage reduction in speed. The Ra= 0.015 ohm total brush voltage drop 2 V. Neglect armature reaction and total armature conductor remain constant. **5**

OR iv. Short shunt compound generator delivers 100A to a load at 250V. generator has shunt field series and armature resistance of 130 ohm, 0.1 ohm and 0.1 ohm respectively. calculate voltage generated in armature winding. assume 1 V drop per brush. **5**

Q.3 i. Write the application of different type of DC motor. **2**

ii. Drive the torque equation of DC motor. **3**

iii. 200V DC shunt series motor takes a current of 100 A and runs at 1000 rpm. The total resistance of motor is 0.1 and field is unsaturated. Calculate: **5**
(a) Percentage change in torque and speed if the load is so changed that motor current if 50 amp.
(b) Motor current and speed if the torque is half.

OR iv. Explain different type of speed control of DC motor. **5**

Q.4 i. Draw the equivalent circuit diagram of alternator. Also define synchronous reactance. **2**

ii. Drive EMF equation for an alternator. Also derive expression for distribution factor and pitch factor. **3**

iii. Explain the term armature reaction of alternator. Also show their effect on operation of alternator with different power factor of load with graphical and phasor representation. **5**

OR iv. A 1500 kVA, 6.6 kV, 3-phase, star-connected alternator has effective armature resistance of 0.5 ohm/phase and a synchronous reactance of 5 ohm/phase. Find the percentage change in terminal voltage when the rated output of 1500 kVA at **5**
(a) unity p.f.
(b) 0.8 lagging p.f.
(c) 0.8 leading p.f. is switched off. The speed and excitation current remain unchanged.

Q.5 i. Why hunting and damper winding is used in synchronous machine. **2**

ii. Explain ZPFC method for determination of voltage regulation of alternator. **3**

Marking Scheme
EE3CO13 / EX3CO13 Electrical Machines -II

Q.1	i.	Drop in the terminal voltage of a shunt generator under load conditions is due to: (d) All of these		1
	ii.	A shunt generator do not build up any voltage at no load because: (d) Any one of these		1
	iii.	Interpoles in DC motors are used for: (b) Reducing sparking at the commutation		1
	iv.	When load is removed, which of the following DC motors will run at excessively high speed? (b) Series motor		1
	v.	An alternator is said to be overexcited when it is operating at- (c) Lagging power factor		1
	vi.	Exciting field coil of an alternator is generally excited by: (c) A DC generator coupled directly to the armature shaft		1
	vii.	In an alternator, the armature reaction is completely magnetizing when the load power factor is: (d) Zero leading		1
	viii.	The main advantage of using fractional pitch winding in an alternator is to reduce: (c) Harmonics in the generated emf		1
	ix.	Short pitch coils are used in alternators: (c) To reduce harmonic output		1
	x.	On keeping the input to the prime mover of an alternator constant and increasing the excitation: (b) kVA become lagging		1
Q.2	i.	Type of winding used in DC machine		2
		1 mark for each	(1 mark * 2)	
	ii.	Magnetization characteristics	2 marks	3
		Explanation	1 mark	
	iii.	A separately excited DC generator has terminal voltage 250 V with constant field excitation. As per the solution each step 1 mark		5
OR	iv.	Calculate voltage generated in armature winding As per the solution each step 1 mark		5
Q.3	i.	Application of different type of DC motor		2
		1 mark for each	(1 mark * 2)	
	ii.	Derive the torque equation of DC motor Each step 1 mark		3
	iii.	(a) Percentage change in torque and speed if the load is so changed that motor current if 50 amp.	2.5 marks	5
		(b) Motor current and speed if the torque is half.	2.5 marks	
OR	iv.	Type of speed control of DC motor		5
		2.5 marks for each	(2.5 marks * 2)	
Q.4	i.	Equivalent circuit diagram of alternator	1 mark	2
		Synchronous reactance	1 mark	
	ii.	Drive EMF equation for an alternator	1 mark	3
		Expression for distribution factor and pitch factor	2 marks	
	iii.	Armature reaction of alternator	2 marks	5
		Effect on operation of alternator	3 marks	
OR	iv.	(a) unity p.f.	1.5 marks	5
		(b) 0.8 lagging p.f.	1.5 marks	
		(c) 0.8 leading p.f. is switched off. The speed and excitation current remain unchanged.	2 marks	
Q.5	i.	Hunting winding	1 mark	2
		Damper winding	2 mark	
	ii.	ZPFC method for determination of voltage regulation of alternator		3
		Derivation	1.5 marks	
		Explanation	1.5 marks	
	iii.	(a) The speed of rotation if frequency of generated e.m.f. is 50 Hz.	1 mark	5
		(b) The terminal emf for full-pitch coils and 8 conductors per slot.	2 marks	
		(c) The emf if the coil span is reduced to 2/3 of pole pitch.	2 marks	
OR	iv.	Using two reaction theory, develop expression for output power of salient pole synchronous generator		5
		Derivation	2 marks	
		Explanation and graph	3 marks	

Q.6		Write short notes any two:		
	i.	Stepper motor		**5**
		Graph / phaser	2.5 marks	
		Explanation	2.5 marks	
	ii.	Synchronous motors as power factor correcting device		**5**
		Graph / phaser	2.5 marks	
		Explanation	2.5 marks	
	iii.	Effect of excitation on armature reaction		**5**
		Graph / phaser	2.5 marks	
		Explanation	2.5 marks	

Q.(2)(iii) Given–

$V_t = 250V$

$R_a = 0.015\,\Omega$

$V_b = 2V$

$L_1 = 200\,kW \quad L_2 = 125\,kW$

$E_{g1} = \frac{P\phi Z N_1}{60A} \quad \therefore E_{g1} \propto N_1$

$I_a = I_L$

For 200kW – $I_{L1} = \frac{200 \times 10^3}{250} = 800\,A$

$E_{g1} = V_t + I_{L1} R_a + 2 = 250 + (800 * 0.015) + 2$

$= 264\,V$

for 125 kW = $I_{L2} = \frac{125 \times 10^3}{250} = 500\,A$

$E_{g2} = V_t + I_{L2} R_a + 2 = 250 + (800 * 0.015) + 2$

$E_{g2} = 259.5 \quad \therefore E_{g2} \propto N_2$

$\frac{E_{g1}}{E_{g2}} = \frac{N_1}{N_2}$

$\therefore$ % speed reduction = $\frac{N_1 - N_2}{N_1} \times 100$

$= \frac{264 - 259.5}{264} \times 100$

$\boxed{\text{\% speed reduction} = 1.704\,\% \quad \text{Ans}}$

Q.(2) (iv) OR Given -

$I_L = 100 A$

$V_t = 250 V$

$R_{sh} = 130 \Omega$

$R_{se} = 0.1 \Omega$

$R_a = 0.1 \Omega$

$V_b = 1 \times 2 = 2V$

$V_a = V_t + I_L R_{se}$

$= 250 + (100 \times 0.1)$

$= 260 V$

$I_{sh} = \frac{V_a}{R_{sh}} = \frac{260}{130} = 2 A$

$I_a = I_{sh} + I_L$

$= 2 + 100$

$I_a = 102 A$

$E_g = V_a + I_a R_a + V_b$

$E_g = 260 + (102 \times 0.1) + 2$

$\boxed{E_g = 272.2 V \text{ Ans.}}$

Q(3)(iii) Given $V_t = 200V$

$I_1 = 100A$

$N_1 = 1000$ rpm

$R = 0.1$

field unsaturated

$\therefore \tau \propto I^2$

(a.) $I_2 = 50A$

$$\frac{\tau_2}{\tau_1} = \frac{I_2^2}{I_1^2} = \frac{50^2}{100^2} = \frac{2500}{10000} = \frac{1}{4}$$

$$\boxed{\tau_2 = \frac{\tau_1}{4}}$$

% change in Torque $= \frac{\tau_2 - \tau_1}{\tau_1} \times 100$

$$\boxed{\text{\% change in } \tau = \frac{\tau_1/4 - \tau_1}{\tau_1} \times 100 = (-75\%) \text{ Torque decreases.}}$$

% change in speed $\Rightarrow E_{b1} = 200 - (100 \times 0.1) = 190V$

$E_{b2} = 200 - (50 \times 0.1) = 195V$

$$\therefore \frac{N_2}{N_1} = \frac{E_{b2}}{E_{b1}} \times \frac{I_{a_1}}{I_{a_2}} \Rightarrow \frac{N_2}{1000} = \frac{195}{190} \times \frac{100}{50}$$

$$\therefore \boxed{N_2 = 2052.63 \approx 2053 \text{ rpm}} \text{ speed}$$

(b.) $\tau_2 = \tau_1/2$

$$\therefore \frac{\tau_1/2}{\tau_1} = \frac{I_2^2}{100^2} \Rightarrow I_2^2 = 5000 \therefore \boxed{I_2 = 70.71A}$$

$$\therefore E_{b2} = 200 - (70.71 - 0.1) = 193V$$

$$\therefore \text{speed} \Rightarrow \frac{N_2}{1000} = \frac{193}{190} \times \frac{100}{70.71}$$

$$\boxed{N_2 = 1436.557 \approx 1437 \text{ rpm}}$$

Q.4.(iv) $V_L = 6.6\ kV$

Rating = 1500 kVA

Connected o/p = 1500 kVA

$R_a = 0.5\ \Omega/\text{phase}$

$X_s = 5\ \Omega/\text{phase}$

$V_{ph} = \frac{V_L}{\sqrt{3}} = \frac{6600}{\sqrt{3}} = 3810.5$ volt

Case-I) $\cos\phi = 1$, $\sin\phi = 0$

then No load voltage $E_0 = \sqrt{(V_p\cos\phi + IR_a)^2 + (V\sin\phi + IX_s)^2}$

$$E_0 = \sqrt{(V_p + IR_a)^2 + (IX_s)^2}$$

Now load current (I) at a load of 1500 kVA at pf of 1 is –

$$\sqrt{3} V_L I_L \cos\phi = 1500 \times 1$$

$$I_L = \frac{1500 \times 1000 \times 1}{\sqrt{3} \times 6600 \times 1} = 131.22\ \text{Amp}$$

$$\therefore E_0 = \sqrt{(3810.5 + 131.21 \times 0.5)^2 + (131.21 \times 5)^2}$$

$E_0 = 3930.7$ volt

percentage regulation $= \frac{E_0 - V}{V} \times 100 = \frac{3930.7 - 3810.5}{3810.5} \times 100$

$= 3.15\ \%$

Case-II: 0.8 lagging pf

$\cos\phi = 0.8$, $\sin\phi = 0.6$

$$E_0 = \sqrt{(3810.5 \times 0.8 + 131.2 \times 0.5)^2 + (3810.5 \times 0.6 + 131.2 \times 5)^2}$$

$= 4284.17$

% regulation $= \frac{4284.17 - 3810.5}{3810.5} \times 100 = 12.43\%$

Case-III. 0.8 leading pf

$\cos\phi = 0.8$, $\sin\phi = 0.6$

$$E_0 = \sqrt{(3810.5 \times 0.8 + 131.2 \times 0.5)^2 + (3810.5 \times 0.6 - 131.2 \times 5)^2}$$

$= 3514.95$

% regulation $= \frac{3514.95 - 3810.5}{3810.5} \times 100$

$= -7.75\ \%$

Q.5. (iii) Pole $P = 12$, Total slots $= 72$

3-ϕ, flux/pole $= 0.0988$ wb

Y – connection, freq $f = 50$ HZ

a) $N_s = \frac{120f}{P} = \frac{120 \times 50}{12} = 500$ rpm

b) No of conductor/phase $(Z_{ph}) = \frac{\text{No. of slots} \times \text{No. of cond per slot}}{\text{No. of phase}}$

$= \frac{72 \times 8}{3} = 192$

No. of turns/phase $T_{ph} = \frac{Z_{ph}}{2} = \frac{192}{2} = 96$

No. of slots/pole $= \frac{72}{12} = 6$

slots/pole/phase $(q) = 6/3 = 2$

Angular displacement b/w the slots $(\beta) = \frac{180°}{6} = 30°$

$K_d = \frac{\sin\left(\frac{q\beta}{2}\right)}{q \sin\beta/2} = \frac{\sin\left(\frac{2 \times 30}{2}\right)}{2 \sin\left(\frac{30}{2}\right)}$

$K_d = \frac{\sin 30°}{2 \sin 15°} = 0.96$

for full pitch coil, $K_p = 1$

$E_{ph} = 4.44 f \phi T_{ph} K_p K_d$

$= 4.44 \times 50 \times 0.0988 \times 1 \times 0.96 \times 96$

$E_{ph} = 2021.4$ volt

c). coil span $= \frac{2}{3} \times 180° = 120°$

Chording angle $= 180° - 120°$
$= 60°$

$K_p = \cos\left(\frac{60}{2}\right) = 0.866$

$E_{ph} = 4.44 f \phi T_{ph} K_p K_d$

$= 4.44 \times 50 \times 0.0988 \times 96 \times 0.866 \times 0.96$

$= 1750.53$ volt