Re-Modified

CBCS SCHEME

USN | | | | | | | | | | 18EE55

Fifth Semester B.E. Degree Examination, Jan./Feb. 2021
Electrical Machine Design

Time: 3 hrs. Max. Marks: 100

Note: 1. Answer any FIVE full questions, choosing ONE full question from each module.
2. Assume any missing data.

Module-1

1 a. Describe the modern trends in electrical machine manufacturing industries. **(10 Marks)**
b. What are the fundamental requirements of high conducting materials? **(07 Marks)**
c. What are the classification high resistivity materials according to their purpose? **(03 Marks)**

OR

2 a. Explain the classification of magnetic material related to the value of permeability and distinguish between soft and hard magnetic materials. **(06 Marks)**
b. Describe the classification of insulating materials based on their thermal consideration. **(08 Marks)**
c. List out the desirable properties of magnetic materials. **(06 Marks)**

Module-2

3 a. Explain the specific loadings of D.C machine and what are advantages and disadvantages of higher values of specific loadings (Base & q). **(08 Marks)**
b. Determine the external diameter and gross core length of armature for a 7.5kW, 220V, 1000rpm shunt motor. Select he number of poles considering the frequency of flux reversal $\ngtr$ 50Hz. Assume average gap density as 0.63wb/m^2, ampere conductors per metre as 30000, ratio of pole arc to pole pitch is 0.7 and the friction windage and iron loss to be 600watts. Check the design for following constraints peripheral speed < 15m/s, armature mmf per pole < 2500. Considering the maximum gap density, $B_q = B_{avg}/0.75$ and mmf required for air gap is 60% of armature mmf and gap contraction factor is 1.15 calculate air gap length. **(12 Marks)**

OR

4 a. Explain the factors to be consider for selecting the number of poles of D.C. machines and write any three advantages of higher values of number of poles of D.C. machine. **(08 Marks)**
b. Design a 4 pole, 10kW, 220V, 1000rpm, d.c. shunt motor, giving following details:
i) The diameter and length of armature
ii) Number of armature conductors
iii) Number of slots
iv) Size of conductor

Assume following design data:
Specific magnetic loading = 0.45T, specific electric loading = 17500 amp cond/m, ratio of pole arc to pole pitch = 0.68, slot pitch = 2.2cm, constant losses = 8% of output, armature voltage drop = 10% of terminal voltage armature is wave wound. **(12 Marks)**

Module-3

5 a. Derive the following design equations for a 3-phase transformer, relating the output to the specific loading and main dimensions, i) EMF per turn ii) Output equation. **(08 Marks)**

b. Design the magnetic frame of 3-phase 250kVA, 6600/400 volts, 50Hz, core type distribution transformer with respect to the following: i) Core section ii) Diameter of circumscribing circle iii) Window area iv) Dimensions of window v) Yoke section and flux density in yoke vi) Yoke dimensions.
Assume; cruciform core section with $A = 0.56d^2$ and $a = 0.85d$, the constant K, in emf per turn is 0.45, maximum flux density in core is 1.2 wb/m^2 and current density is 2.2A/mm^2, the window space factor = 0.3, the ratio of window height to width = 3, yoke section is 10% higher than core section. **(12 Marks)**

OR

6 a. Explain the design of tank with cooling tubes for the transformer, giving the equation to calculate number of tubes to limit temperature rise. **(10 Marks)**

b. Calculate the active and reactive component of no-load current of a 15000kVA, 33.3/6.6kV, 3-phase, star-delta, core type transformer having following data:
net iron area of each limb = 0.15m^2 net iron area of yoke = 0.18m^2, Mean length of each limb = 2.3m, mean length of each yoke = 1.6m, number of turns in h.v. winding = 450. Take maximum flux density same for both limb and yoke, as = 1.2wb/m^2. At this flux density, ampere-turns per meter of the material is 420 AT and specific iron loss is = 1.9w/kg, density = 7.8×10^3kg/m^3 Neglect mmf for joints. **(10 Marks)**

Module-4

7 a. Discuss the factors that affect the
i) Choice of average flux density in air gap
ii) Choice of ampere conductors per meter in the design of 3-phase Induction Motor. **(08 Marks)**

b. Determine the main dimensions, turns per phase number of slots, conductor cross section and slot area of a 250h.p, 3-phase, 50Hz, 400V 1410rpm, slip-ring induction motor. Assume B_{av} = 0.5 wb/m^2, ac = 30000A/m, efficiency = 0.9 and p.f = 0.9, winding factor = 0.955, current density = 3.5A/mm^2, slot space factor is 0.4 and ratio core length to pole pitch = 1.2 take 5 slots per pole per phase motor is delta connected. **(12 Marks)**

OR

8 a. Explain the step-by-step procedure of wound rotor design. **(08 Marks)**

b. During the stator design of a 3-phase, 50Hz, 30kW, 400V, 6 pole, squirrel cage induction motor, the following informations were obtained gross length = 0.17m, internal diameter = 0.33m, number of slots = 45, number of conductors per slot = 12, stator winding is star connected based on above, design a cage rotor giving i) diameter of rotor ii) number of rotor slots iii) rotor bar current iv) size of rotor bar v) end-ring current and section of end ring. Assume: p.f. = 0.86, efficiency = 0.88, k_w = 0.955 current density in bar = 6A/mm^2; current density in end ring = 6.5A/mm^2, take length of air gap = 0.67mm. **(12 Marks)**

Module-5

9 a. Derive the output equation of synchronous machine, that relates output to main dimensions. **(08 Marks)**

b. Determine the main dimensions, number of stator slots, conductors per slot, and conductor area of a 75000kVA, 13.8kV, 50Hz, 187.5rpm, 3-phase, star connected synchronous alternator peripheral speed should be about 60m/sec. Assume average flux density = 0.65wb/m^2, ampere conductors per meter = 40,000 and current density = 6A/mm^2, k_w = 0.955, number of slots per pole per phase = 2.5. **(12 Marks)**

OR

10 a. Define Short Circuit Ratio (SCR) and its effect on machine performance. **(10 Marks)**

b. A 3000rpm, 50Hz, 3-phase, turbo alternator has a core length of 0.94m, the average gap density = 0.45wb/m^2, and ampere conductors per meter = 25000. The peripheral speed of rotor is 100m/s, and length of air gap is 20mm. Find kVA output of the machine when

i) Winding factor k_w = 0.955

ii) Winding factor k_w = 0.827

What is the relation between winding factor and kVA output. **(10 Marks)**

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Fwd: Scheme 18EE55

"nagaraj ms" <msndvg@gmail.com>

March 12, 2021 12:38 PM

To: boe@vtu.ac.in

---------- Forwarded message ---------
From: **nagaraj ms** <msndvg@gmail.com>
Date: Tue, 9 Mar 2021, 2:37 pm
Subject: Scheme 18EE55
To: <boe@vtu.ac.in>

Respected sir,
I have discussed with staff who have handled Electric Machine Design for more than 20 times. I would like to bring following points:
1. All questions are set from syllabus only.
2. Distribution of marks is balanced
3. No discrepancy in the scheme and solution
4. Necessary correction is done during the BOE meeting.

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Thanking You

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Scheme-18EE55 &53

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To: boe@vtu.ac.in

March 4, 2021 9:00 AM

Sir,

No issues in the Scheme and solution of 18EE55 , 18EE53 & 17EE73

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Thanking You

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Scheme & Solutions

Signature of Scrutinizer 18/01/21

Subject Title : Electrical Machine design **Subject Code :** 18EE55

Question Number	Solution	Marks Allocated
	Module-1	
1 a.	(i) The type of construction depends upon the power o/p and the speed. (ii) to build m/cs which are smaller in size at the same time have same η and overload capacity (iii) use of magnetic materials which have a high permeability, low iron loss & high mechanical strength (iv) newer insulating materials being used. (v) use of higher electro-magnetic loadings for active parts and increased mechanical loading for construction materials (vi) in order to have low manufacturing cost, different improved & refined techniques are used for individual m/c parts (vii) The design must be such that m/c operates satisfactorily under the desired environmental conditions. → (explain some points)	7+3 =10
b	(i) high possible conductivity (ii) least possible tempr. co-efficient. (iii) adequate mech. strength (iv) rollability & drawability (v) good weldability & solderability (vi) adequate resistance to corrosion.	07
(c)	(i) materials used in precision measuring instruments (ii) resistance elements for all kinds of rheostats (iii) for high tempr elements, furnace, heating device etc.	03

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Question Number	Solution	Marks Allocated
2 a)	1. Ferro, 2. Para 3. Dia-magnetic materials → define each. Soft magnetic materials have narrow hysteresis loop where as hard mag-materials with broad hysteresis loop. → explain with hysteresis loop figures	03 + 03 = (06)
b	Class: Y → 90°C, B → 130°C, C → >180°C, A → 105°, F → 155°C, E → 120°, H → 180°C → explain giving example to each.	08
c.	(i) high mag. permeability (ii) high electric resistivity (iii) narrow hysteresis loop. (iv) high saturation limit. (v) low losses at higher flux density	06
	Module-2	
~~3 a~~	~~(i) Traction (ii) Drives for process industry (iii) battery driven vehicles (iv) Machine tools (v) appliances~~ (vi) automatic control	~~04~~
3 a	(i) Specific Magnetic loading is defined as ratio of total flux around the air gap to the air gap area, $B_{avg} = \frac{P\phi}{\pi D L}$ Tesla (ii) Specific electric loading is defined as the total number of ampere conductors on the armature per unit circumference of armature $q = \frac{I_a Z_a}{\pi D}$ Advantages of Bav/q, disadvantages of Bav/q	04 02+2=04 =(08)
b	output co-efficient $C_0 = 0.164 B_{av} q \times 10^{-3}$	

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Question Number	Solution	Marks Allocated
	$\therefore C_0 = \pi^2 \times B_{av} \times q \times 10^{-3} = 186.5$, $n_s = 16.67$ rps	
	$P_a = 7.5 + 0.6 = 8.1$ kW	→ (03)
	$\therefore D^2L = \frac{P_a}{C_0 n_s} = 2.6 \times 10^{-3} m^3$ → (01)	
	No. of poles, $P = 6$ $\left[\because f = \frac{6 \times n_s}{2} = 50 Hz\right]$	
	$L/\tau_p = 0.7$ $\therefore$ $L = 0.7 \times \frac{\pi D}{6}$	→ (02)
	Main dimensions $D = 0.19m$, $L = 0.07m$ } → (02)	
	$\tau_p = 0.1m$.	
	Check: (i) peripheral speed $= \pi D n_s = 9.95 m/s < 15 m/s$ within limit.	→ (02)
	(ii) Armature mmf $= \frac{q \times \tau}{2} = 1500 < 2500$ within limit.	
	Length of air gap: $B_g = \frac{0.63}{0.75} = 0.84T$	
	mmf required for air gap $= 0.796 B_g k_f \times 10^{6} \times l_g$	
	$AT_g = 768936 \times l_g$	
	Also air gap mmf/pole, $at_g = 0.6 \times 1500 = 900.00$	→ 02
	$\therefore$ length of air gap $l_g = \frac{900}{768936} = 1.2 \times 10^{-3} m = 1.2 mm$	= 12M
4 a	Advantages of specific magnetic & electric loading. ~~factors & explanations~~	6
	(i) reduction in ~~Advantages, fes, ...~~ low cost.	2
	Disadvantages of magnetic loading:- increased iron loss, higher field cu-loss, increased no-load current, tempr. rise, noise	08
factors & explanation, Advantages 6+2=(08)		

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Question Number	Solution	Marks Allocated
	~~Disadvantages of electric loading :- increased arm. cu-loss, increased reactance drop, inferior commutation, reduced over load capacity.~~	~~4+4~~
b.	$C_0 = 77.72$, $n_s = 16.67$ rps → (01) $P_a = 1.08 \times 10 = 10.8$ kw → (01) ∴ $D^2L = \frac{10.8}{77.72 \times 16.67} = 8.33 \times 10^{-3} m^3$ and $L = 0.68 \times \frac{\pi D}{P} = 0.534D$ ∴ $D = 0.25M$ and $L = 0.13M$ → (03) $P\phi = B_{avg} \times \pi DL = 0.45 \times \pi \times 0.25 \times 0.13$ $= 0.046$ wb Emf $E = 220 - 22$ (motor) $= 198$ volts } → (02) ∴ No. of conductors $Z = \frac{E \times 60 \times A}{\phi P \times N}$ $= 516$ → (01) Slot pitch $\tau_s = \frac{\pi D}{\text{no. of slots}}$ ∴ No. of slots $= \frac{\pi \times 25}{2.2} = 36$ } → (02) Cond/slot $= \frac{516}{36} \simeq 14$ ∴ Revised no. of conductors $Z = 14 \times 36$ $= 504$ → (01) ~~Mean length~~ of armature current $I_a = \frac{10 \times 10^3}{220} = 45.45$ Amp (01) and $I_a/A = 11.36$. ∴ $a_c = \frac{11.36}{4.5} = 2.52 mm^2$	12

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Question Number	Solution	Marks Allocated
5 a	(i) $E_t = K\sqrt{(kVA/phase)}$; $K = \sqrt{4.44 f r \times 10^3}$ (ii) $Q = 3.33 f B_m \delta k_\omega A_\omega A_i \times 10^{-3}$ --- kVA → (4+4)M	08
b.	$E_t = K\sqrt{kVA/3} = 0.45\sqrt{250/3} = 4.1$ Volt $A_i = \frac{E_t}{4.44 f B_m} = 0.0154\ m^2$ $d = \sqrt{A_i/0.56} = 0.166m$, $a = 0.85d = 0.14m$ $A_w = \frac{250}{3.33 \times 1.2 \times 2.2 \times 10^6 \times 0.3 \times 0.0154 \times 10^{-3}} = 0.123\ m^2$ $H_w/W_w = 3$ ∴ $H_w = 0.6m$; $W_w = 0.2m$ $D = W_w + d = 0.366m$; $A_y = 1.1 A_i = 0.0169\ m^2$ $d_y = a = 0.14m$ ∴ $h_y = 0.12m$. flux in core $\phi_i = B_m \times A_i = 0.0185 wb$ ∴ flux density in yoke $= B_y = \frac{\phi}{A_y} = 1.09\ wb/m^2$	12M
6 a	width of tank $W = 2D + D_e + 2b$ (3-φ) $= D + D_e + 2b$ (1-φ) Length of tank $L = D_e + 2L$; height of tank $H = H + h$.; $\theta_t = \frac{P_i + P_c}{S_t(12.6 + 8.8x)}$ No. of tubes $= \frac{1}{8.8\pi d l_t}\left[\frac{P_i + P_c}{\theta} - 12.5 S_t\right]$ → with explanation.	- 10 -
b	Total flux path in 3 limbs $= 3 \times 2.3 = 6.9m$ " — " — 2 yoke $= 2 \times 1.6 = 3.2M$ ∴ Total length $= 10.1m$.; ∴ total mmf for iron parts $AT_t = 10.1 \times 420 = 4242$ A; AT/phase $= 4242/3 = 1414$ ∴ reactive component, I_μ $I_\mu = 1414/(450 \times \sqrt{2}) = 2.22$ Amp	10

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Question Number	Solution	Marks Allocated
	loss component I_w:– Volume of core = 6.9×0.15 = 1.035 m^3; volume of yoke = 0.576 m^3 ∴ Total volume = 1.611 m^3; ∴ weight of transformer = volume×density = 1.611 × 7.8×10^3 = 12565.8 kg ∴ Total iron loss = P_i = 12565.8 × 1.9 = 23875.02 watt Iron loss / phase = $P_i/3$ = 7958.4 watt. ∴ loss component of current $I_w = \frac{7958.4}{(33.3\times10^3)/\sqrt{3}} = 0.414$ Amp ∴ No-load current $I_0 = \sqrt{I_\mu^2 + I_w^2}$ $= \sqrt{(2.22)^2 + (0.414)^2} = 2.258$ Amp	
	Module-4	
7(a)	choice of B_{av}:– (i) P.f (ii) Iron loss (iii) over load capacity choice of ac:– (i) Cu-loss & Tempr. rise (ii) Voltages. (iii) over load capacity :– (explain each)	(4+4) = 08
(b)	Nearest synchronous speed to 1410 is 1500 rpm ∴ n_s = 1500/60 = 25 rps. P = 2×50/25 = 4 ∴ $C_0 = 11 k_w B_{av}\, ac \times 10^{-3}$ = 157.57 ; ∴ $Q = \frac{250\times0.746}{0.9\times0.9}$ ∴ $D^2L = \frac{Q}{C_0 n_s} = 0.0584 m^3$ But $L/\tau_p = 1.2$; L = 0.942 D, ∴ D = 0.395 m L = 0.373 m ; $\phi = 0.5\times\frac{\pi DL}{P} = 0.0578$ wb ∴ Stator turns/phase, $T_{ph} = \frac{400}{4.44\times50\times\phi\times k_w} = 32.6 \simeq 32$ ∴ Total conductors Z_s = 6×32 = 192 No. of slots S_s = 5×3×4 = 60 ; cond/slot = 3.2 Taking 3 cond/slot ; revised no. of conductors Z = 3×60 = 180 ; T_{ph} = 30 I_{ph} = 192 Amp. ∴ conductor section = 55 mm^2 slot dimension = $\frac{55\times3}{0.4}$ = 412.5 mm^2	12

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Question Number	Solution	Marks Allocated
8 a	Explanation + equations.	08
b)	Length of air gap = 0.67; rotor dia $D_r = D - 2l_g$ $D_r = 0.328\,m$; No. of rotor slots = 42 Rotor bar-current: stator current $I_s = \frac{Q}{3 \times 400}$ $I_s = \frac{30 \times 10^3}{0.88 \times 0.86 \times 3 \times 400} = 33\,A$ ∴ equivalent current $I_b' = 0.85 \times 33 = 28.1$ Amp ∴ $I_b = 28.1 \times \frac{0.955}{1} \times \frac{45}{42} \times \frac{12}{1} = 345$ Amp bar section $= \frac{345}{6} = 57.5\,mm^2$ End ring current $I_e = \frac{345 \times 42/6}{\pi} = 768.7$ Amp End ring section $= \frac{768.7}{6.5} = 118.26\,mm^2$	12
9 a	Module-5 $D^2L = \frac{Q}{C_o n_s}$; $C_o = 11\, B_{av}\, K_w\, ac \times 10^{-3}$	08
b	Synchronous speed $n_s = \frac{187.5}{60} = 3.125$ rps. $C_o = 11 \times 0.65 \times 40000 \times 0.955 \times 10^{-3} = 273$. ∴ $D^2L = \frac{75000}{273 \times 3.125} = 87.9\,m^3$; $P = \frac{2 \times 50}{3.125} = 32$ Diameter with a peripheral speed of 40 m/s $D = \frac{60}{\pi n_s} = 6.07 \simeq 6\,m$ ∴ $L = 2.44\,m$ $E_{ph} = 13.8/\sqrt{3} = 7.967\,kV = 7967.4$ volts $\phi = \frac{0.65 \times \pi \times 6 \times 2.44}{32} = 0.93\,wb$ ∴ $T_{ph} = 40.40 \simeq 40$ turns ∴ $Z = 240$ No. of slots $= 2.5 \times 3 \times 32 = 240$ slots Conductors/slot = 1	12

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Question Number	Solution	Marks Allocated
	$I_{ph} = \frac{75000 \times 1000}{3 \times 7967.4} = 3137.8$ Amp. section of conductor $= \frac{3137.8}{6} = 522.96\ mm^2$	
10 a	$S.C.R = \frac{1}{X_d}$; define ⟹ (04) M (with graph) It effects: (i) Vg-regulation (ii) stability (iii) parallel operation (iv) short ckt. current (v) Self excitation ; Explain each (06 M)	10
b)	synchronous speed $n_s = \frac{3000}{60} = 50$ rps. (01M) peripheral speed $= \pi D_r n_s = 100$ m/s ∴ $D_r = 0.637$ m →(02M) Then stator diameter $D = D_r + 2l_g = 0.677$ m. → (01M) Then $Q = D^2 L \times n_s \times C_0$ ∵ $C_0 = 11 k_w B_{av}\, ac \times 10^{-3}$ ∴ (i) when $k_w = 0.95$ $C_0 = 118.18$ ∴ $Q = 0.677^2 \times 0.94 \times 50 \times 118.18 = 2545$ kVA → (0.2M) when $k_w = 0.827$ $C_0 = 102.34$ ∴ $Q = 2204.5$ kVA → (02M) As specific loading and speed remaining same, the output of the machine is directly proportional to the winding factor. → (02M)	10 M

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