Modified

CBCS SCHEME

USN | | | | | | | | | |

18EE55

Fifth Semester B.E. Degree Examination, Feb./Mar.2022

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 suitably.

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

Module-1

1 a. What are the important considerations for the design of electrical machines? Explain in brief and what are its limitations? **(10 Marks)**

b. Mention the desirable properties of electrical insulating materials. Also give the classification of insulating material based on temperature with an example for each. **(10 Marks)**

OR

2 a. What are the desirable properties of magnetic materials? Explain in brief magnetic material and its classification. **(10 Marks)**

b. Write brief note on modern manufacturing techniques in the design of electrical machines. **(10 Marks)**

Module-2

3 a. Discuss the various factors which govern the choice of number of poles in a DC machine. And what are the advantages of choosing larger number of poles. **(10 Marks)**

b. Calculate the diameter and length of armature for a 7.5 kW, 4 pole, 1000 rpm, 220 V shunt motor. Given : Full load efficiency 83%, Maximum gap flux density = 0.9 wb/m^2; Specific electric loading = 30000 ampere conduction per metre ; field form factor = 0.7. Assume that the maximum efficiency occurs at full load and the field current is 2.5% of rated current. The pole face is square. **(10 Marks)**

OR

4 a. The following particulars refer to the shunt field coil for a 440 V, 6 pole, DC generator : MMF per pole = 7000 A, Depth of winding = 50 mm, Length of inner turn = 1.1 m; Length of outer turn = 1.4 m, Loss radiated from outer surface excluding ends = 1400 W/m^2, Space factor = 0.62 ; Resistivity = 0.02 Ω/m and mm^2. Calculate

(i) The diameter of the wire (ii) Length of coil
(iii) Number of turns and (iv) Exciting current **(10 Marks)**

b. Define specific electric and magnetic loadings of a DC machines. What are the merits and demerits of selecting higher value of specific loadings? Mention the factors to be consider during the choice of specific loading. **(10 Marks)**

Module-3

5 a. Derive the output equation of a 3 phase core type transformer and hence deduce an expression for output-emf/turn. **(10 Marks)**

b. Determine the dimension of core and yoke for a 200 KVA, 50 Hz single phase core type transformer. A cruciform core is used with distance between adjacent limbs equal to 1.6 times the width of core laminations. Assume voltage per turn 14 V, maximum flux density 1.1 wb/m^2, windows space factor 0.32, current density 3 A/mm^2 and stacking factor = 0.9. The net iron area is 0.56 d^2 in a cruiciform core where d is diameter of circumscribing circle. Also the width of largest stamping is 0.85 d. **(10 Marks)**

OR

6 a. Explain the procedure to calculate the no load current for a single phase transformer. **(10 Marks)**

b. A 250 KVA, 6600/400 V, 3 phase core type transformer has a total loss of 4800 W at full load. The transformer tanks is 1.25 m in height and $1m \times 0.5m$ in plan. Design a suitable scheme for tubes if the average temperature rise is to be limited to 35°C. The diameter of tubes is 50 mm and are spaced 75 mm from each other. The average height of tubes is 1.05 m. Specific heat dissipation due to radiation and convection is respectively 6 and 6.5 W/m^2 - °C. Assume that convection is improved by 35 percent due to provision of tubes. **(10 Marks)**

Module-4

7 a. Derive expression for rotor bar and end ring current of squirrel cage induction motor. **(10 Marks)**

b. Find the main dimension of a 15 kW, 3 phase, 400 V, 50 Hz, 2810 rpm squirrel cage induction motor having an efficiency of 0.88 and a full load power factor of 0.9.
Assume :
Specific magnetic loading = 0.5 wb/m^2
Specific electric loading = 25000 A/m
Take the rotor peripheral speed as approximately 20 m/s at synchronous speed. **(10 Marks)**

OR

8 a. With usual notations, derive the output equations of a 3 phase induction machine. **(10 Marks)**

b. Discuss the factors to be considered while deciding the length of air gap, number of stator and rotor slots in an induction motor. **(10 Marks)**

Module-5

9 a. What is SCR of a synchronous machine? What are the effects of SCR on machine performance? **(10 Marks)**

b. Determine the main dimensions for a 1000 KVA, 50 Hz, 3 phase, 375 rpm alternator. The average air gap flux density is 0.55 wb/m^2 and the ampere conductors per meter are 28000. Use rectangular poles and assume a suitable value for ratio of core length of pole pitch in order that bolted on pole construction is used for which the maximum permissible peripheral speed is 50 m/s. The runaway speed is 1.8 times the synchronous speed. **(10 Marks)**

OR

10 a. The fields coils of a salient pole alternator are wound with a single layer winding of bare copper strip 30 mm deep, with separating insulation 0.15 mm thick. Determine a suitable winding length, number of turns and thickness of conductor to develop an mmf of 12000 A with a potential difference of 5 V per coil and with a loss of 1200 W/m^2 of total coil surface. The mean length of turn is 1.2 m. The resistivity of copper is 0.021 Ω/m and mm^2 **(10 Marks)**

b. Explain the factors to be considered in the selection of number of armature slots of a synchronous machine. **(10 Marks)**

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Comments from BOE EEE, to the following Subjects Scheme & Solutions

"SURESH HL" <dr.hlsuresh_eee@sirmvit.edu> March 16, 2022 5:30 PM

To: boe@vtu.ac.in

Dear Sir,

Please find the attached file for **Comments from BOE EEE, to the following Subjects Scheme & Solutions of 18EE55**

Regards

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Comments from BOE EEE, to the following Subjects Scheme & Solutions		
Subject Code	Name of Subject	Comments from BOE EEE
18EE55	Electrical Machine Design	As per the Scrutiny of same from BOE members no corrections are required

Hence the may be considered for the further Process.

BOE Chairman 16/03/2022
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18EE55

Signature of Scrutinizer 16/1/2-21

Scheme & Solutions

Subject Title : ELECTRICAL MACHINE DESIGN **Subject Code :** 18EE55

Question Number	Solution	Marks Allocated
1a,	Major Consideration 1, Cost, 2, Durability, 3, Magnetic circuit, 4, Electric circuit 5, Dielectric circuit, 6 Thermal circuit, 7, Mechanical Parts. With Explanation for Each 1×7M – 7M Limitation in design. 1, Saturation, 2, Temperature rise, 3, Insulation 4, Efficency, 5, Mechanical parts, 6, Commutation 7, Power factor – With Explanation for Each ½×6 = 3M	10 M
b,	Desirable properties of Insulating materials 1, High dielectric strength. ii, High resistivity iii, Low dielectric hysteresis iv, Good thermal conductivity vi High degree of thermal stability with Explanation for Each property 5×1M = 5M classification based on thermal Consideration Class Y – 90° Class A – 105° Class E – 120° Class B – 130° Class F – 155° Class H – 180° Class C above 180°. Explanation with Example of material 5M	10M

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Question Number	Solution	Marks Allocated
2a	Desirable properties of magnetic materials i, Low reluctance or should have high permeable. (ii) High saturation index. (iii) High Electrical resistivity iv, Narrow hysteresis loop. v, High curie point } with Explanation 5 x 1M = 5M i, Diamagnetic ii, Paramagnetic iii, Ferromagnetic iv, Antiferromagnetic v, Ferrimagnetic material. } with Explanation 5 x 1m = 5M	10M
b,	Modern machine manufacturing techniques * from fraction of watts to several hundred of Megawatts in a single unit. *. Rotational speed from few revolution to several thousand revolution. — (2m) *. Small size m/c, Medium size. Large size, Larger size with specifications — (2m) *. Smaller m/c with less material. * Magnetic material with high permeability. *. Significant improvement in insulating. *. Higher Electro magnetic loading *. reduced cost. *. Machine work with operates satisfactory under the desired environmental condition. For Each point 1x6m = 6m	10M
	MODULE-2	
3a.	Choice of number of poles i, Length and diameter of the machine ii, Consider hysteresis losses	

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Question Number	Solution	Marks Allocated
	iii, Weight of the copper iv, Length of commutator v, Labour charges vi, Flash over vii, Distortion of field form } For each point $1M \times 7 = 7M$ Advantages of larger no of poles i, weight armature core & yoke ii, cost of armature and field conductors — (3 m) iii, Overall length and diameter of machine	10M
b,	Power i/p $= \frac{P}{\eta} = \frac{7500}{0.83} = 9040\,W$ Total loss $= 9040 - 7500 = 1540\,W$ constant loss $= \frac{1540}{2} = 770\,W$ motor current at full load $= \frac{7500}{0.83 \times 220} = 41.1\,A.$ Field current $= 0.025 \times 41.1 = 1.03\,A.$ Friction and windage loss $= 770 - 227 = 543\,W$ $B_{av} = K_f B_g = 0.7 \times 0.9 = 0.63\,Wb/m^2$ $C_0 = \pi^2 \times 0.63 \times 30000 \times 10^{-3} = 186.5$ $n = \frac{1000}{60} = 16.67\,rps$ $D^2L = \frac{P_a}{C_0 n} = \frac{8.1}{186.5 \times 16.6} = 2.6 \times 10^{-3}\,m^3$ For sqr. pole $\frac{L}{\psi\tau} = 1$ $L = 0.7 \times \frac{\pi D}{4} = 0.55D$ $0.55D^3 = 2.61 \times 10^{-3}$ $D = 0.17\,m$ $L = 0.09\,m$ For each point $1M \times 10 = 10M$	10M

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Question Number	Solution	Marks Allocated
4a	Voltage across the shunt field winding $= 0.8 \times 440 = 352V$ voltage across each field coil $= 352/6 = 58.7V$ Length of mean turn $L_{mt} = \frac{L_o + L_i}{2} = \frac{1.4+1.1}{2} = 1.25m$ Area of field conductor $a_f = \frac{AT_{fp} L_{mt}}{E_f} = 2.98\ mm^2$ Diameter of bare conductor $d = 1.95mm$ no. of turns $T_f = \frac{S_f h_f d_f}{E_f} \times 10^6 = 1.04 \times 10^{+4} h_f$ Area of outer surface $L_o h_f = 1.4 h_f$ Permissible loss $Q_f = 1960 h_f$ Field current $I_f = \frac{Q_f}{E_f} = 33.4 h_f$ $AT_f = I_f T_f = 33.4 h_f T_f = 7000$ (or) $T_f = 210/h_f$ $T_f^2 = 1.04 \times 10^4 h_f \times \frac{210}{h_f} = 21.84 \times 10^6$ $T_f = 1475$ $R_f = 12.4\Omega$ $I_f = 4.73A$ $h_f = \frac{T_f}{1.04 \times 10^4} = 0.142m$ For each value 1m x10	10M
b.	Specific Electric loading: The no of armature ampere conductors per meter $ac = \frac{I_z Z}{\pi D}$ – (2M) Specific Magnetic loading: Average flux density over the air gap of a machine. – (1M) $B_{av} = \frac{P\phi}{\pi DL}$ – (1M). Advantage of higher value – (2M) Demerits of high values – (2M) factors to be considered (2M)	10M

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Question Number	Solution	Marks Allocated
5a.	$Q = 3V_pI_p \times 10^{-3}$ $= 3E_pI_p \times 10^{-3} = 3E_t T_p I_p \times 10^{-3}$ $= 3E_t AT \times 10^{-3}$ $= 3 \times 4.44 f\phi_m \times \frac{K_w A_w \delta}{4} \times 10^{-3}$ ← (7m) $= 3.33 f \phi_m K_w A_w \delta \times 10^{-3}$ $= 3.33 f B_m \delta K_w A_w A_i \times 10^{-3}$ (KVA) Voltage per turn $= E_t = 4.44 f \phi_m$ $\sqrt{4.44 f r \cdot 10^{3}} \cdot \sqrt{Q} = K\sqrt{Q}$. $K = \sqrt{4.44 f r\, 10^{3}} = \left[4.44 f \frac{\phi_m}{AT} \times 10^{3}\right]^{1/2}$ – (3m)	10M
b.	Net area $A_i = 0.0573\ m^2$ Diameter $d = \sqrt{A_i/0.56} = 0.32m$ Width of largest stamping $a = 0.85d = 0.272\ m$ Distance between core centre $D = 1.69 = 0.435\ m$ $W_w = D - d = 0.115\ m$ $Q = 2.22 f B_m K_w \delta A_w A_i \times 10^{-3}$ $200 = 2.22 \times 50 \times 1.1 \times 0.32 \times 3 \times 10^{6} \times A_w \times 0.0573 \times 10^{-3}$ $A_w = 0.0298 m^2$ $H_w = \frac{0.0298}{0.115} = 0.26m$ $D_y = 0.272\ m$ $H_y = 0.272m$ over all height of frame $H = H_w + 2H_y$ $= 26 + 2 \times 0.272 = 0.804\ m$ over all length of frame $W = D + a$ $= 43.5 + 0.272 = 0.737\ m$ For finding each value 1M × 10 = 10 M	10M

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Question Number	Solution	Marks Allocated
6a	l_c - length of flux path through core l_y - length of flux path through yoke. $l_c = H_w$, $l_y = W$ $I_m = \frac{AT_0}{\sqrt{2} \cdot T_P}$ with steps & Explanation 10m $I_0 = \sqrt{I_m^2 + I_l^2}$	10m
b,	Total no. of tubes provided $= 62 + 2 = 64$ — (2m) dissipating surface $(1+x)S_t = 3.75(1+x)$. Specific loss dissipation $= \frac{36.5}{1+x}$ $W/m^2 - °C$. loss dissipation $= \frac{12.5 + 8.8x}{1+x}$ $W/m^2 - °C$ $x = 2.73$ — (3m) diagram — (3m) Explanation (2m).	10m
7a.	Expression for rotor bar — (5m) Design of End ring - diagram - 3m Explanation - 2m	10m
b.	$Q = \frac{15}{0.88 \times 0.9} = 18.94$ $C_0 = 11 K_w B_{av} ac \times 10^{-3} = 131.3$ The rotor speed is 2880 rpm nearest sync. speed is 3000rpm. $n_s = 50 rps$ $D^2L = \frac{Q}{C_0 n_s} = 2.88 \times 10^{-3} m^3$ The rotor diameter is an almost equal to stator bore. $\pi D n_s = 20 \Rightarrow D = 0.1257 m$ $L = \frac{2.88 \times 10^{-3}}{(0.1257)^2} = 0.177 m$	10m

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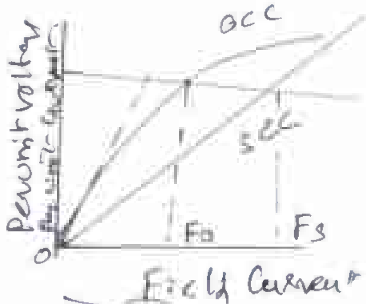
Question Number	Solution	Marks Allocated
8a	Output Equation of 3φ Induction motor $Q = 1.11 K_w \, p \phi \, I_z \, Z \, n_s \times 10^{-3}$ $Q = (11 B_{av} \, ac \, K_w \times 10^{-3}) D^2 L n_s$ $Q = C_0 D^2 L n_s$ with usual notation derivation for o/p equation	10M
b,	Power factor, Iron loss, overloading Capacity — for airgap, with Explanation (4m) No of stator slots & rotor slots i, Tooth pulse losses ii, Leakage reactance iii, Ventilation iv, Magnetizing Current & Iron losses v, Cost — for each condition $1 \times 6m = 6m$ with Explanation	10m
9a	Short circuit ratio $SCR = \frac{OF_0}{OF_s} = \frac{CF_0}{bF_s}$ $SCR = \frac{1}{X_d}$ — (2m) (2m) with Explanation (1m) Effect of SCR i, voltage regulation ii, Stability iii, Parallel operation iv, Short Circuit currents v, Self Excitation — For Each point with Explanation $1 \times 5 = 5m$	10M

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Question Number	Solution	Marks Allocated
9b	$n_s = \frac{375}{60} = 6.25$ rps. $p = \frac{2 \times 50}{6.25} = 16$ Assume a winding factor of 0.995 $C_0 = 11 K_w B_{av}\, ac \times 10^{-3} = 162.$ $D^2L = 0.987\, m^2$ Taking $\frac{L}{\tau} = 2$ $L = 0.393 D$ $0.393 D^3 = 0.987$ $D = 1.36m$ and $L = 0.535\, m$ Peripheral speed $= \pi D n_s = 26.7\, m/s$ 1×10m	10m
10a.	Field conductor $a_f = 60.4 mm^2$ Height of conductor $= \frac{60.4}{30} = 2$ mm Area of conductor $= 30 \times 2 = 60 mm^2$ Heat dissipating Surface $= 2 L_{mtf} (h_f + d_f)$ $= 2.4 h_f + 0.272$ $Q_f = 1200 (2.4 h_f + 0.072) = 2880 h_f + 86.4$ $I_f = \frac{Q_f}{E_f} = \frac{2880 h_f + 86.4}{5}$ $= 5.76 h_f + 17.3$ Field mmf $= I_f T_f = (5.76 h_f + 17.3) T_f$ $T_f = 91$ $h_f = 186 mm$	10m

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Question Number	Solution	Marks Allocated
10b.	Factors considered for armature slots. i, Balanced winding. ii, Cost iii, Hot spot temperature. iv, Leakage reactance. v, Tooth ripples vi, Flux density in Iron. Each factors with explanation 2×5 = 10M	10M
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