Electrical Machine Design
VTU Question Paper Set

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10EE63

Sixth Semester B.E. Degree Examination, Dec.2016/Jan.2017
Electrical Machine Design

Time: 3 hrs. Max. Marks:100

Note: ***Answer FIVE full questions, selecting at least TWO questions from each part.***

PART – A

1 a. What are the limitations in the design of electrical machines? Explain. **(06 Marks)**

b. Derive the output equation of a D.C machine. **(06 Marks)**

c. Determine the main dimensions and number of poles of a 1000kW, 500 volts, 450 RPM D.C generator. Assume the air gap density as 0.62 Tesla and ampere conductors per meter as 40,000. The ratios of pole arc to pole pitch is 0.65. The ratio of length to pole pitch is 0.75. Assume efficiency as 90% current per brush arm not to exceed 400 amperes and frequency of the reversals in the armature not to exceed 50Hz. **(08 Marks)**

2 a. The field coils of a D.C machine are wound with a single layer winding of bare copper strip 3 cm deep with a separating insulation 0.15mm thick. Determine a suitable winding length, number of turns and thickness of conductor to develop an mmf of 12000 ampere-turns with a potential difference of 5V/coil and with a loss of 1200 Watts /m^2 of total coil surface. The mean length of turn is 1.2m. **(10 Marks)**

b. Estimate the ampere turns per pole required for the air-gap of a 500V, 6 pole, 300 rpm, lap connected D.C machine. The armature core having 90 slots is 30cm long. The pole pitch is 50cm while pole arc is 33cm. The air gap length may be taken as 5mm. There are 16 conductors per slot of width 1.3cm. Assume 5 ventilating ducts, each 1cm wide. The carter's co-efficient is 0.66 and 0.72 for slot width/gap of 2.6 and 2.0 respectively. **(10 Marks)**

3 a. With neat sketch derive the expression for leakage reactance of core type transformer with respect to primary side. State the assumption made. **(12 Marks)**

b. A 100KVA, 200/400V, 50Hz, 1ϕ shell type transformer has the following particular; B_{max} = 1.1wb/m^2, current density = 2.2 A/mm^2, window area constant = 0.33, volt/turn =11, core is rectangular and stampings are 7cm wide. Height of window = 2 * width of window. Obtain :

i) Net iron area and Area of window

ii) Dimensions and weight of core. Specific gravity of Iron = 7.8 gm/cm^2. **(08 Marks)**

4 a. Derive output equation for a 3 phase transformer. **(10 Marks)**

b. A 15000KVA, 33/6.6kV, 3-phase, Y -Δ core type transformer has the following data : Area of cross section of core limb = 0.16m, Area of cross section of yoke = 0.17m. length of flux path in each limb 2.3m in each yoke is 1.6m ; number of turns in h.v winding = 450. AT/m in core leg is 540 AT/m and in yoke is 260 AT/m as obtained from magnetization curves. Loss per kg in iron is 2.6 Watts/kg in limb and 1.5 watts/kg in yoke. Density of iron is 7.8 g/c.c. Estimate the No-Load current/phase. **(10 Marks)**

PART – B

5 a. Explain the factors which influence the length of air gap of 3 – phase induction motor. **(08 Marks)**

b. Calculate : i) Diameter ii) Length iii) Number of turns per phase iv) Full load current and cross – section of conductors and v) Total I^2 R loss of stator of 3ϕ, 120kW 2200 volts, 50Hz, 750rpm [synchronous speed], star connected slip ring Induction motor from the following data :
B_{ar} = 0.48 Tesla, (ac) = 26000 ampere/mt, efficiency = 92%, power factor = 0.88. Assume L = 1.25T_p, winding factor =0.95, current density = 5A/mm² mean length of stator conductors = 0.75m, resistivity of copper ρ = 0.021Ω/mt and mm². **(12 Marks)**

6 a. Explain crawling an cogging of induction motor. **(10 Marks)**

b. A 120 HP, 500V, 3ϕ, 50Hz, 8 pole induction motor has a star connected stator winding accommodated in 63 slots with 6 conductors per slot. If the slip ring voltage on open circuit is to be about 400V, find a suitable rotor winding stating
i) Number of slots ii) Number of conductors per slot iii) Coil span
iv) Slip ring voltage on open circuit v) Approximate full load current per phase in rotor. Assume efficiency = 0.9 and power factor = 0.86. **(10 Marks)**

7 a. From first principles derive the output equation of a 3 phase alternator. **(06 Marks)**

b. Define short circuit ratio in connection with 3 phase alternator. Explain the factors affecting the SCR. **(06 Marks)**

c. A 1250 KVA, 3phase, 50Hz, 3300V, start connected 300rpm salient pole alternator has the following data : Diameter = 1.9 mt ; length = 0.335 mt ; pole arc/pole pitch = 0.66. turns/phase = 150. Single layer winding with full pitched coils having 5 conductors per slot is used SCR = 1.2. Assume the distribution of gap flux is rectangular under the pole arc with zero value at inter-poler region. Determine :
i) Specific magnetic loading ii) Armature mmf per pole iii) Gap flux density over pole arc
iv) current per phase v) length of air gap.
Assume gap contraction factor = 1.15 and Air gap mmf = 88% of no load field mmf. **(08 Marks)**

8 a. Explain the design procedure for designing the field winding of a salient pole alternator. **(10 Marks)**

b. A 2500KVA, 225 rpm, 3 phase, 60Hz, 2400V, Star connected salient pole alternator has the following data :

Stator bore diameter = 250cm, Core length = 44cm, Slots/pole/phase = $3\frac{1}{2}$, Conductors per slot = 4, Circuits per phase = 2, Leakage factor = 1.2, Winding factor = 0.95. The flux density in pole core is 1.5 wb/m², the winding depth is 3cm. the ratio of full load field mmf to armature mmf is 2, field winding space factor is 0.84 and the field winding dissipates 1800 Watts/m² of inner and outer surface without the temperature rise exceeding the limits. Leave 3cm for insulation, flanges and height of pole shoe along the height of pole.
Find :
i) The flux per pole
ii) Length and width of pole
iii) Winding height and
iv) Pole height **(10 Marks)**

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Sixth Semester B.E. Degree Examination, June/July 2016
Electrical Machine Design

Time: 3 hrs. Max. Marks:100

Note: 1. *Answer FIVE full questions, selecting at least TWO questions from each part.*
2. *Design data manual may be used, if necessary.*

PART – A

1 a. Define 'Specific Magnetic loading' and 'Specific electric loading'. What are advantages and disadvantages of using higher specific loadings? **(10 Marks)**

b. What are desirable properties of insulating materials? Explain classification of insulating materials based on maximum temperature rise mentioning at least 2 examples in each. **(10 Marks)**

2 a. With usual notations, derive output equation for a d.c. machine. **(06 Marks)**

b. A 5 KW, 250 V, 4 pole, 1500 rpm shunt generator is designed to have a square pole face. The specific loadings are – average flux density in the gap = 0.42 Wb/m^2; Ampere conductors per meter length of armature periphery = 15000 Amp.cond/m; Full load efficiency = 87%; Ratio of pole arc to pole pitch = 0.66. Calculate the main dimensions of the machine. **(06 Marks)**

c. During the design of a 1000 KW, 500 V, 10 pole, 300 rpm compound generator, the following data have been obtained. External diameter of armature = 1.4 m. Gross core length = 0.35 m. Flux per pole = 0.105 Wb. Based on above design data, calculate the following details referring to design of field system:
i) Axial length of the pole ii) Width of the pole iii) Height of the pole
iv) Pole arc.
Permissible loss per cooling surface may be assumed as 700 watts/m^2; Assume leakage coefficient for the pole K_l = 1.2 ; Flux density in the pole = 1.6 Tesla; Iron factor K_i = 0.95; Voltage drop as 2% of terminal voltage; $AT_f = 1.2\ AT_a$; Copper space factor = 0.6 and depth of field winding as 0.05 mt. Thickness of pole shoe = 4 cm. Ratio of pole arc to pole pitch = 0.68. Axial length of pole 1 cm less than gross length of armature. Winding is lap connected. **(08 Marks)**

3 a. Derive the output equation for a 3 phase transformer. **(10 Marks)**

b. Calculate dimensions of the core, number of turns and area of cross section of the conductors for the primary and secondary windings of a 125 KVA, 6600 V/460 V, 50 Hz single phase core type distribution transformer. The data are B_m in core = 1.2 Wb/m^2 and current density $\delta = 250\ A/cm^2$. Assume cruciform (or stepped core) for the assembled core allowing 8% for the insultation between laminations. Take yoke cross section 15% higher than the core. Net cross section of copper = 0.225 times net cross section of iron in the core and window space factor K_W = 0.3. Assume ratio of height of window to width of window = 2. Draw a neat sketch of core indicating the dimensions. **(10 Marks)**

4 a. Derive the equation for calculation of no load current of single phase transformer. (08 Marks)

b. A single phase 400 V, 50 Hz, transformer is built from core stampings having a relative permeability of 1000. The length of the flux path is 2.5 m. The gross area of cross section of the core is $2.5\times10^{-3}\,m^2$ and the primary winding has 800 turns. Calculate the maximum flux and the no load current of transformer. The iron loss at the maximum flux density is 2.6 W/kg. Iron weighs 7.8×10^3 kg/m^3 and stacking factor is 0.9. (07 Marks)

c. A 300 KVA, 6600 V/ 400 V, 50 Hz delta-star, 3 phase, core type transformer has the following data:
Width of HV winding = 25 mm; Width of LV winding = 16 mm; Height of coils 0.5 m; Length of mean turn = 0.9 m; hv winding turns = 830. Width of duct between hv and lv winding = 15 mm.
Calculate the leakage reactance of the transformer referred to the hv side. (05 Marks)

PART – B

5 a. With usual notations, derive output equation for a 3 phase induction motor. (10 Marks)

b. Calculate the following design information for a 30 kW, 440 V, 3 phase, 6 pole, 50 Hz, delta connected squirrel cage induction motor. (i) Main dimensions (ii) Number of stator slots. (iii) Number of turns/phase in stator winding (iv) Number of conductors per slot.
The available data are:
Specific magnetic loading = 0.48 Tesla; Specific Electric loading = 26000 Amp Conductors/m; Full load efficiency = 88%; Full load power factor = 0.86; Winding factor K_{WS} = 0.955; No. of slots / pole / phase = 3. (10 Marks)

6 a. What are factors to be considered for estimating the length of air gap for induction motors? Explain these factors. (10 Marks)

b. A 15 kW, 3 phase, 6 pole, 50 Hz, squirrel cage induction motor has the following data:
Stator bore diameter = 0.32 m; Axial length of stator core = 0.125 m; Number of stator slots = 54; Number of conductors per stator slot = 24; Current in each conductor = 17.5 A; Full load power factor = 0.85 lag. Design for a suitable cage rotor, number of rotor slots, Section of each bar and section of each end ring. The full load speed is about 950 rpm approximately. Use copper for rotor bars and the end rings. Resistivity of copper is 0.02 Ω mm^2/m. Assume current density in rotor bars and end rings 7 A/mm^2. (10 Marks)

7 a. Explain the factors that influence the selection of "Specific magnetic loading" and "Specific electric loading" for synchronous machines. (10 Marks)

b. Calculate the main dimensions of a 1000 KVA, 50 Hz, 3 phase, 375 rpm alternator. The average air gap flux density is 0.55 Wb/m^2; Ampere conductors/meter are 28,000. Assume ratio of core length to pole pitch = 2 and winding factor = 0.955. Permitted maximum peripheral speed is 50 m/s. (10 Marks)

8 a. Define "Short Circuit Ratio" (SCR) for a synchronous generator. Explain effects of SCR on synchronous machine performance. (10 Marks)

b. A 500 KVA, 3.3 KV, 50 Hz, 600 rpm, 3 phase salient pole alternator has 180 turns / phase. Calculate the length of the air gap, if the average flux density is 0.54 Wb/m^2; ratio of pole arc to pole pitch 0.66; SCR is 1.2 ; the gap contraction factor is 1.15 and winding factor is 0.955. The mmf required for air gap is 80% of no load field mmf. (10 Marks)

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Sixth Semester B.E. Degree Examination, Dec.2015/Jan.2016

Electrical Machine Design

Time: 3 hrs. Max. Marks:100

Note: 1. ***Answer FIVE full questions, selecting at least TWO questions from each part.***
2. ***Draw figures wherever necessary.***
3. ***Assume suitable values for any missing data.***

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.

PART – A

1 a. What are the desired properties of insulation materials used in electrical machines? Name some insulation materials and state where they are utilized. **(04 Marks)**

b. Derive the output equation of a D.C. machine. **(06 Marks)**

c. Calculate the diameter and length of armature core of a 70 kW, 240 V, 900 rpm, 4 pole D.C. shunt generator. The average flux density is 0.7 webers/metre^2 and AC/m is 34,000. The ratio of core length to pole pitch is 0.8. Full load armature drop is 9.6 V and field current is 3.0 Amperes. **(10 Marks)**

2 a. Discuss the factors which influence the selection of, i) number of poles ii) number of slots iii) air gap of a DC machine. **(06 Marks)**

b. Discuss why the armature core, field poles of a D.C. machine are laminated, while yoke is not normally laminated. **(04 Marks)**

c. A shunt field coil has to develop an mmf of 9000 AT. The voltage drop in the coil is 40 V and resistivity of round wire used is 0.021 ohms/meters/mm^2. Depth of winding is 35 mm approximately and length of mean turn is 1.4 m. Design a coil so that the power dissipated is 700 W/m^2 of the total coil surface (outer, inner top and bottom). Take the diameter of the insulated wire to be 0.2 mm greater than the bare copper. **(10 Marks)**

3 a. Show that the output of a 3 phase core type transformer is $5.23\ f.B_mH.d^2H_W \times 10^{-3}$ KVA where 'f' is the frequency, B_m – the maximum value of flux density in webers/m^2, d is the effective diameter of the core in meters, H is the magnetic potential gradient in the limit in amperes/metre and H_W is the height of window in meteres. **(10 Marks)**

b. The ratio of flux to full load mmf in a 400 KVA 50 Hz, single phase core type power transformer is 2.4×10^{-6}. Calculate the net cross area and the window area of the transformer maximum flux density in the core is 1.3 weber/metre^2, current density 2.7 A/mm^2 and window space factor is 0.26. Also calculate the full load mmf. **(10 Marks)**

4 a. For a constant total volume of conductors in a transformer. Show that for a minimum copper loss, current densities in the windings must be equal. **(04 Marks)**

b. A single phase, 400 V, 50 Hz transformer is built from stampings having a relative permeability of 1000. Length of flux path is 2.5 m, area of cross section of the arc is 2.5×10^{-3} metre^2 and the primary winding has 800 turns. Estimate the maximum flux and no load current of the transformer. Given loss at working flux density is 2.6 w/kg. Given weighs 7.8×10^3 kg/m^3. Stacking factor is 0.9. **(08 Marks)**

c. A 3 phase, 50 Hz oil cooled core type transformer has the following dimensions. Distance between core centres 0.2 m, height of window 0.24 m. Diameter of circumscribing circle is 0.14 m. Flux density in the core is 1.25 Wb/m^2 and the current density in the conductors is 2.5 A/mm^2. Estimate the KVA rating. Assume a window space factor of 0.2 and a core area factor of 0.56, core is 2 stepped. **(08 Marks)**

PART – B

5 a. Discuss the factors to be considered while choosing the number of slots for the rotor of an induction motor. **(04 Marks)**

b. What are the effects of increasing the air gap of an induction motor? **(04 Marks)**

c. A 30 H.P., 3 phase, 440 V, 960 rpm, 50 Hz delta connected induction motor, has a specific, electric loading of 25,000 AC/m and a specific magnetic loading of 0.46 webers/metre^2. The full load efficiency is 86%, pf is 0.87, Pole pitch core length = 1. Find following : i) Stator core dimensions ii) Number of stator slots and the number of turns in the stator winding. **(12 Marks)**

6 a. Discuss the advantages of skewing the rotor slots in an induction motor. **(04 Marks)**

b. What are the factors to be considered while designing the rotor of a slip ring induction motor? **(04 Marks)**

c. A 90 kw, 500 V, 50 Hz, 3 phase induction motor has a star connected, stator winding accommodated in 63 slots with 6 conductors/slot. If the slip ring voltage on open circuit is to be about 400 V, find a suitable rotor winding stating,
i) Number of slots ii) Number of conductors/slot iii) Coil span iv) Approximate full load current per phase in rotor. Assume efficiency of 90% and p.f. of 0.86. **(12 Marks)**

7 a. Discuss the factors which influence the selection of stator (armature) slots in an alternator. **(05 Marks)**

b. Derive the output equation of an alternator. **(05 Marks)**

c. Design suitable values of diameter and length of a 75 MVA, 11 KV, 50 Hz, 3000 rpm, 3 phase star connected alternator. Also determine the value of flux, conductors / slot, number of turns / phase and size of armature conductors.
Given :
Average gap density = 0.6 webers/meter^2
Ampere conductors/meter = 50,000
Peripheral speed = 180 metres/sec
Winding factor = 0.95
Current density = 6 A/mm^2 **(10 Marks)**

8 a. Define SCR and explain its effect on machine performance. **(08 Marks)**

b. The field coils of a salient pole alternator are wound with a single layer winding of a bare copper strip of 30 mm deep, with separating insulation of 0.15 mm thick. Determine a suitable winding length, number of turns and thickness of conductors to develop an mmf of 12000 AT with a potential difference of 5 volts per coil and with a loss of 1200 watts/metre^2 of total coil surface. The mean length of turn is 1.2 m and resistivity of copper is 0.021 Ω/m/mm^2. **(12 Marks)**

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Sixth Semester B.E. Degree Examination, June/July 2015
Electrical Machine Design

Time: 3 hrs. Max. Marks:100

Note: ***1. Answer any FIVE full questions, selecting atleast TWO questions from each part.***
2. Missing data, if any, may be suitably assumed.
3. Design data handbook may be permitted.

PART – A

1 a. Describe how specific magnetic and electric loading play an important role in the design of electrical machines. **(08 Marks)**

b. Determine the main dimensions, number of poles, number of armature conductors, number of slots, conductors per slot and the size of armature conductors and cross sectoral area of armature conductor for a 250 KW, 400 V, 625 A, 600 rpm lap wound compound generator, assuming the following data :
Average flux density in the gap = 0.63 Tesla ; specific electric loading = 33000 amp conductors /mh ; field and armature copper losses = 5% of output ; ratio of pole arc to pole pitch = 0.7 ; pole arc = gross length of armature. Armature drop = 3% of terminal voltage, current density $\delta = 5 A/mm^2$; slot pitch = 2.6 cm. **(12 Marks)**

2 a. Obtain an expression for field ampere turns per meter height, of a DC machine in terms, permissible loss, copper space factor and depth of winding. **(10 Marks)**

b. A 50 hp, 4–pole, 480 V, 600 rpm shunt motor has a wave wound armature with 770 conductors. The leakage factor for the poles is 1.2. The poles are to be of circular in cross section the field coils are 70 mm thick and produce an mmf of 10,000 A per pole. The flux density in the poles is 1.5 Wb/m^2 calculate :

i) diameter of poles
ii) diameter of field wire
iii) length of field coil
iv) turns per pole and
v) field current. **(10 Marks)**

3 a. Determine the following for a 200 KVA, 50Hz 6600/250V, single phase, shell type, oil immersed distribution transformer, i) net cross section of core ii) gross area of core iii) core dimensions iv) window area v) dimensions of window.
Assume :

Window space factor	= 0.28
Maximum fluxdensity in core	= 1.1 Tesla
Average current density	= 2.2 A/mm^2
Window proportions	= 2.5 : 1
Rectangular core proportions	= 1.8 : 1
Stacking factor	= 0.9

Net cross – section of copper in the window is 0.2 times the net cross section of iron in the core, do not attempt the problem using emf per turn equation. **(10 Marks)**

b. Explain the procedure to determine the no-load current of transformer with relevant expressions. **(10 Marks)**

4 a. Derive the expression for leakage reactance of core type transformer. **(10 Marks)**

b. Explain the design of tank with tubes for the transformer, starting from the determination of temperature rise of transformer. **(10 Marks)**

PART – B

5 a. Determine the main dimensions, turns per phase, number of slots, conductor cross section, and slot area, of a 250 hp, 3 -- phase, 50 Hz, 400V, 1500 rpm, slip ring induction motor. Assume :
$B_{avg} = 0.5\ Wb/m^2$
ac = 30000 A/m
Efficiency = 0.9
Power factor = 0.9
Winding factor = 0.955
Current density = 3.5 A/mm^2
Slot space factor = 0.4
Ratio of core length to pole pitch = 1.2
The number of slots per pole per phase = 5
The machine is delta connected. **(10 Marks)**

b. Describe the factors that affect the estimation of length of airgap in the design of induction motor. **(10 Marks)**

6 a. Explain the step–by–step design procedure of designing squirrel cage rotor for induction motor. **(10 Marks)**

b. Design a wound rotor for a 3–phase, 850 KW 6600V, 50Hz, 12 pole, induction motor with full load efficiency of 92% and power factors of 0.91, based on the following informations :

Gross length of stator	= 45 cm
Internal diameter of stator	= 122 cm
Number of stator slots	= 144
Number of conductors per slot	= 10
Number of rotor slots per pole per phase	= 3½
Voltage between slip rings at starting	= 600V
Current density	= 5A /mm^2

The machine is star connected. **(10 Marks)**

7 a. Derive the output equation in terms of specific loadings for a synchronous machine. **(10 Marks)**

b. Calculate : i) flux per pole, ii) specific magnetic loading, iii) specific electrical loading, iv) current density for a stator winding of 3–phase 7.5 KVA, 6.6 KV, 50 Hz, 3000 rpm, turbo generators based on following design information.

Internal diameter of stator	= 0.75 m.
Gross length of core	= 0.9 m
Number of stator slots per pole per phase	= 7
Sectional area of stator conductor	= 190 mm^2
Number conductors per slot	= 4
K_W	=0.955. The machine is star connected.

(10 Marks)

8 a. Explain the step-by-step procedure to design field winding for salient pole alternator. **(10 Marks)**

b. Design the field coil of a 3 – phase, 16 poles 50Hz salient pole alternator, based on the following design information :

Diameter of stator at the gap surface	= 1.0 m
Gross length of stator core	= 0.3 m
Section of pole body	= 0.15 m × 0.3 m
Height of pole	= 0.15 m
Ampere turns per pole	= 6500
Exciter voltage	= 110 V

Assume ; 30 volts as reserve ; depth of field coil, $d_f = 0.03$ m and insulation of pole = 0.01 m ; current density = 2.6 A/mm^2. **(10 Marks)**

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10EE63

Sixth Semester B.E. Degree Examination, Dec.2014/Jan.2015
Electrical Machine Design

Time: 3 hrs. Max. Marks:100

Note: ***Answer any FIVE full questions, selecting atleast TWO questions from each part.***

PART – A

1 a. What are the limitations involved, in design of electrical machines? **(06 Marks)**

b. Derive the out-put equation of a D.C. machine. **(06 Marks)**

c. A 350kW, 500V, 450rpm, 6-pole d.c. generator is built with an armature diameter of 0.87m and core-length of 0.32m. The lap wound armature has 660 conductors. Calculate B_{arc} and ac. **(08 Marks)**

2 a. Prove that in a D.C. machine, the volume of active-parts is proportional to torque developed by the machine. **(05 Marks)**

b. State the factors effecting in selecting the value of electric-loading, in case of a D.C. machine. **(05 Marks)**

c. Determine the main dimensions, number of poles and length of air-gap for a 600kW, 500V, 900rpm generator. Assume:
$B_{arc} = 0.6 Wb/m^2$, $(MMF)_{A4} = 50\% (MMF)_{Arm}$
ac ≠ meter = 35000
$\frac{\text{Pole - Arc}}{\text{Pole - Pitch}} = 0.75$, efficiency = 91% kg = 1.15. **(10 Marks)**

3 a. Derive the out-put equation of a 3ϕ, core-type transformer. **(06 Marks)**

b. Discuss the factors involved in "optimum design" of a transformer. **(04 Marks)**

c. A 1ϕ, 440V, 50Hz transformer is built in form of stampings having a relative permeability of 1000. The length of the flux-path is 2.5m the area of cross-section of the core is $2.5 \times 10^{-3} m^2$ and the primary wdg has 800 turns. Estimate the max. flux and 'no-load' current of the transformer. Assume: Iron-loss i) working flux density = 2.6 W/kg; ii) Iron wt = 7.8×10^3 kg/m^3; iii) Stacking factor = 0.9. **(10 Marks)**

4 a. Derive an expression for the total leakage reactance of a transformer, reffered to primary. **(10 Marks)**

b. A 250KVA, 6600/400V, 3ϕ, core-type transformer has a total loss of 4800W at full load. The transformer tank is 1.25mtrs in height and 1m × 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 the tubes is 50mm and are spaced 75mm from each other. The average height of tubes is 1.05m. **(10 Marks)**

PART – B

5 a. State the factors affecting, length of air-gap in case of a 3ϕ induction motor. **(05 Marks)**

b. Briefly give the design procedure of stator teeth and stator core of a 3ϕ induction motor. **(05 Marks)**

c. Determine the main dimensions, turns/phase, number of slots, conductor cross-section and slot area of a 250HD, 3ϕ, 50Hz, 400V, 1410rpm, slip-ring induction motor. Assume:
   i) $B_{arc} = 0.5$ wb/m^2
   ii) Ac/meter = 30000 A/m
   iii) Efficiency = 0.9
   iv) Power factor = 0.9
   v) Winding factor = 0.955
   vi) Current density = 3.5 A/mm^2
   vii) Slot-space factor = 0.4
   viii) $\frac{\text{Core} - \text{length}}{\text{Pole} - \text{pitch}} = 1.2$.
   Assume Machine Delta connected. **(10 Marks)**

6 a. Discuss briefly the design of 'End-ring' and 'Rotor bar' of a squirrel cage motor. **(08 Marks)**

b. A 11kW, 3ϕ, 6-pole, 50Hz, 220V, $\curlywedge$- connected induction motor has 54 stator slots, each-containing 9 conductors. Calculate the values of bar and end-ring currents. The number of stator bars is 64. The machine has an efficiency of 0.86 and cosϕ = 0.85. The rotor MMF may be assumed as 85% of stator MMF. Also find the bar and end-ring sections if the current density is 5A/mm^2. **(12 Marks)**

7 a. Discuss the factors affecting choice of magnetic-loading in case of a synchronous machine. **(06 Marks)**

b. Compare round-poles v/s rectangular poles. **(04 Marks)**

c. Determine the main dimensions of 1000KVA, 50Hz, 3ϕ, 375 rpm alternator. The average air-gap density is 0.55 Wb/m^2, ampere conductors per meter is 28000. Use rectangular poles of assume ratio of core length to pole-pitch as 2. Maximum permissible peripheral speed is 50m/s. The run away speed is 1.8 times the synchronous speed. Assume $k_W = 0.955$. **(10 Marks)**

8 a. Define SCR of a synchronous machine. Discuss its effect on performance of the machine. **(06 Marks)**

b. What are steps involved, in design of field windings of a synchronous machine? **(08 Marks)**

c. What are the factors, that effect, selection of armature slots? **(06 Marks)**

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10EE63

Sixth Semester B.E. Degree Examination, June/July 2014

Electrical Machine Design

Time: 3 hrs.

Max. Marks:100

Note: 1. ***Answer FIVE full questions, selecting at least TWO questions from each part.***
2. ***Use of design data handbook is permitted.***

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.

PART – A

1 a. List the desirable properties of insulating materials. Give the classification of insulating materials based on thermal considerations with examples of materials used in each class. **(10 Marks)**

b. A design is required for a 50 KW, 4 pole, 600 rpm D.C. shunt generator, the full load terminal voltage being 220 V. If the maximum gap density is 0.83 wb/mt^2 and the armature ampere conductors per metre are 30,000, calculate suitable dimensions of armature core. Assume that the full load armature voltage drop is 3 percent of the rated terminal voltage and that the field current is 1 percent of rated full load current. Ratio of pole arc to pole pitch is 0.67. **(10 Marks)**

2 a. Discuss the factors that should be given due considerations while selecting number of poles for DC machine. **(06 Marks)**

b. Define specific loadings and mention the advantages of choice of higher values of specific loadings in the design of any machine. **(04 Marks)**

c. During the design of armature of a 1000 KW, 500 V, 10 pole, 300 rpm DC compound generator, following information has been obtained:

External diameter of armature, 1.4 m
Gross core length, 0.35 m
Flux per pole 0.105 wb.

Based on the above design information, find out the following details regarding the design of field system:

i) Axial length of the pole ii) Width of the pole iii) Height of the pole

Permissible loss per square meter of the cooling surface may be assumed as 700 W/mt^2. Assume leakage factor of the pole k_f = 1.2, flux density in the pole B_p = 1.6 tesla, iron factor k_i = 0.95, voltage drop as 2% of terminal voltage, AT_f = 1.2 AT_a, copper space factor S_f = 0.6 and depth of the winding as 0.05 mt and thickness of pole shoe = 4 cm. **(10 Marks)**

3 a. Derive the output equation of a 3-ϕ core type transformer. **(06 Marks)**

b. Derive an expression for the no load current of a 3 phase transformer. **(04 Marks)**

c. Calculate: i) net cross section of core, ii) gross area of the core, iii) core dimensions, iv) window area, v) dimensions of the window, for a 200 KVA, 6600/250 V, 50 Hz, single phase, shell type, oil immersed, self cooled, distribution transformer based on the following design parameters:

Window space factor, K_w = 0.28 Maximum flux density in core, B_m = 1.1 Tesla
Average current density, δ = 2.2 A/mm^2 Stacking factor = 0.9
Window proportion = 2.5 : 1 Rectangular core proportion = 1.8 : 1

Net cross section of copper in the window is 0.2 time the net cross section of iron in the core. **(10 Marks)**

4 a. Obtain an expression for the leakage reactance of a transformer with primary and secondary coils of equal length. **(08 Marks)**

b. A 300 KVA, 11000/440 V, 50 Hz, 3 phase, delta/star, core type oil immersed, self cooled transformer gave the following results during the design calculations of magnetic frame and windings.

Centre to centre distance between the cores = 36 cm
Height of the window = 44 cm
Height of the yoke = 17 cm
Total weight of the magnetic frame = 700 kg
Average specific iron loss = 2.1 W/kg
Outer dia of HV winding = 35 cm
Resistance of LV winding per phase = 0.0047 Ω
Resistance of HV winding per phase = 9.74 Ω

Based on the above design data, calculate the following:

i) The dimensions of the tank with clearance; $\Delta L = 8$ cm; $\Delta W = 10$ cm; $\Delta H = 45$ cm.
ii) The temperature rise of the transformer with plain tank.
iii) Number of cooling tubes, if the temperature rise not to exceed 35°C. Assuming diameter of cooling tube as 5 cm and length of cooling tube = 95 cm. **(12 Marks)**

PART – B

5 a. Discuss the various factors considered when estimating length of air gap of a 3-phase induction motor. Give the expressions used in calculations of length of air gap. **(10 Marks)**

b. Calculate the following design information for a 30 KW, 440 V, 3-phase, 6 pole, 50 Hz delta connected, sq. cage induction motor.

i) Main dimensions of stator frame
ii) No. of turns per phase in state winding
iii) No. of stator slots
iv) No. of conductors per slot.

The various data required for the design calculations are:

Specific magnetic loading, $B_{av} = 0.48$ Tesla
Specific electric loading, q = 26000 AC/mt
Full load efficiency, y = 0.88
Full load p.f. $\cos\phi = 0.86$
Winding factor, $K_w = 0.955$
Slots per pole per phase = 3 **(10 Marks)**

6 a. What is meant by the terms 'crawling' and 'cogging' in case of 3 phase induction motors? What steps would you take in the design procedure, so as to minimize these tendencies? **(08 Marks)**

b. During the design of a 3-phase, 5 KW, 400 V, 50 Hz, 4 pole squirrel cage induction motor designed for star-delta starting, following data have been obtained.

Rotor diameter = 0.14 m, Core length = 0.11 m, Turns per phase on stator = 360, Air gap length = 0.45 mm, Coater's gap contraction coefficient = 1.25.

Assuming that the ampere turns required for the iron parts are about 32% of that needed for the gap, calculate the magnetizing current drawn by the motor and comment, upon its value. Assume, winding factor, $K_w = 0.955$, efficiency = 85% and p.f. = 0.85. **(12 Marks)**

7 a. Explain the term 'short-circuit ratio' as applied in synchronous machines. How does the value of short circuit ratio affects the design of alternators? **(06 Marks)**

b. Derive the output equation of a synchronous machine. **(08 Marks)**

c. Calculate the stator core dimensions for a 10 MVA, 11 KV, 50 Hz, 3 phase, 2 pole turbo alternator, based on the following information:
Specific magnetic loading B_{av} = 0.63 Tesla
Specific electric loading q = 48,000 amp.cond./mt
Limiting peripheral speed, v = 120 m/sec
Length of air gap = ℓ_g = 2.0 cm
Stator wdg. Factor, K_w = 0.955 **(06 Marks)**

8 a. It is advisable to have field system rotating and armature stationary for large synchronous machines. Justify the above statement. **(06 Marks)**
b. Enumerate the advantages and disadvantages of providing a large airgap in synchronous machines. **(06 Marks)**
c. A 500 KVA, 33 KV, 50 Hz, 600 rpm, 3 phase salient pole alternator has 180 turns per phase. Estimate the length of air gap if the average flux density is 0.54 wb/mt^2. The ratio of pole arc to pole pitch, 0.65. the short circuit ratio, 1.2, the gap contraction factor 1.15, and the winding factor, 0.955. The mmf required for gap is 80% of no load field mmf and the winding factor 0.955. **(08 Marks)**

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