# ***VETRI VINAYAHA COLLEGE OF ENGINEERING AND TECHNOLOGY***

## ***DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING***

## III-YEAR/VI-SEMESTER- EEE

## EE6404- DESIGN OF ELECTRICAL MACHINES

## Two Marks with Answers

*PREPARED BY:**Mr.A.Thirukkumaran, AP/EEE***

### ***UNIT I – INTRODUCTION***

**1. What are the main dimensions of a rotating machine?**

Armature or rotor diameter Stator core length

**2. Define specific magnetic loading**

It is defined as the ratio of total flux around the air gap and the area of flux path at the air gap.

**3. Define specific electric loading.**

It is defined as the ratio of total number of ampere conductors and the armature periphery at the air gap.

**4. What is magnetic circuit?**

It is the path of magnetic flux. The mmf of the circuit creates flux in the path by overcoming the reluctance of the path.

**5. What is leakage flux?**

It is the flux passing through unwanted path. The leakage flux will not help either for transfer or conversion of energy.

**6. What is leakage coefficient?**

It is defined as the ratio of total flux to useful flux.

**7. What is fringing flux?**

The bulging of magnetic path at the air gap is called fringing. The fluxes in the bulged portion are called fringing effect.

**8. What are the factors that modify the reluctance of air gap.**

It is modified by slots, radial ventilating ducts and non uniform air gaps.

**9. Define gap contraction factor for slots.**

It is defined as the ratio of reluctance of air gap of slotted armature to reluctance of air gap of smooth armature.

**10. Define gap contraction factor for ducts**.

It is defined as the ratio of reluctance of air gap with ducts to reluctance of air gap without ducts.

**11. Define total gap contraction factor.**

It is defined as the ratio of reluctance of slotted armature with ducts to reluctance of smooth armature without ducts.

**12. Define field form factor.**

It is the ratio of average gap density over the pole pitch to maximum flux density in the air gap.

**13. List the methods used for estimating the mmf for teeth.**

i) Graphical method

ii) Three ordinate method

iii) $B_{t/3}$ method

**14. What is real and apparent flux density?**

The real flux density is due to the actual flux through a tooth. The apparent flux density is due to total flux that has to be passing through the tooth. Since some of the fluxes pass through slot so that the real flux density is always less than the apparent flux density.

**15. Define specific permeance.**

It is defined as the permeance per unit length of field.

**16. What are the factors to be considered for estimating the length of air gap in dc machines?**

Armature reaction, cooling, iron losses, distortion of field form and noise.

**17. What is the fundamental requirement of a good insulating material?**

High dielectric strength, high insulating resistance with low dielectric loss, good mechanical strength, good thermal conductivity and high degree of thermal stability.

**18. Why silicon content in electrical sheet steel is limited to four to five percent?**

If silicon content in electrical sheet steel exceeds five percent then it acts brittle and creates difficulties in punching.

**19. Why short time rating of an electrical machine is much higher than the continuous rating?**

To reach the maximum permissible temperature rise in a short duration, the machine can be loaded to higher than the continuous ratings.

**20. What are the assumptions made to calculate tire slot leakage?**

i)Current in the conductors of a slot is uniformly distributed over the cross section.

ii)Leakage path is straight across the slot and around the iron at the bottom

iii)Presence of air path is only considered reluctance iron path is assumed as zero.

**21. How is leakage magnetic flux different from useful magnetic flux?**

The leakage flux is not useful for energy transfer or conversion.But the fringing flux is useful flux. the leakage flux is the unwanted path. But the fringing flux flows in the magnetic path. The effect of leakage flux on machine performance is accounted by leakage reactance. The fringing flux increases the slot reactance.

**22. How is heat produced in a rotating electrical machine?**

i) Over loaded

ii)Poor ventilation

iii) Continuous duty

## ***UNIT- II- DC MACHINES***

**1. What are the factors to be considered for the selection of no. of poles in a dc machine?**

Frequency of flux reversal, current per brush arm and armature mmf per pole.

**2. What is output equation?**

The equation describing the relation between the output and main dimensions, specific loadings and speed of the machine is known as output equation.

**3. State the relationship between number of armature coils and number of commutator segments in d.c. machine.**

Relationship between number of armature coils and number of commutators segments in a d.c. machine where $\beta_C$ is commutator segment pitch C is Number of coils $D_C$ is Diameter of commutators

**4. State different losses in a d.c. generator.**

1) Losses in a d.c. generator

i) Copper losses

ii) Armature copper loss = $I_a{}^2R_a$.

iii) Field copper loss = ($I^2_{sh}R_{sh}$, $I^2_{se}R_{se}$)

2) Magnetic losses (iron (or) copper loss)

i) Hysteresis loss, $W_h$ $B^{1.6}_{max}f$

ii) Eddy current loss $W_e$ $B^2_{max}$ f

iii) Mechanical loss

**5. State different losses in a machine.**

The losses in a d.c. machine can be classified into two general types. They are

1. Rotational losses

i) frictional and windage losses

ii) Iron losses

**6. What are the main parts of a DC generator?**

The DC generator essentially has three major parts

i. Field system
ii. Armature
iii. Commutators

The field system includes main poles, interlopes and frame.

**7. Give the main parts of a d. c. motor.**

i) Field system (stator)
ii) Armature (Rotor)
iii) Commutators
iv) Main poles
v) Inter poles and
vi) Frame

**8. State the relation between the number of commutators segments and number of armature coils in a d.c, generator.**

The number of commutators segment is equal to the number of coils in a d.c. generator, is Commutators Segment pitch C is No. of coils $D_c$ is Diameter of commutators

## *UNIT- III – TRANSFORMERS*

**1. What are the types of windings commonly used for LV winding?**

Cylindrical winding with rectangular conductors and helical winding.

**2. What are the drawbacks of sandwich winding?**

Requires more labour in its maintenance, more difficult to insulate different coils from each other and from yoke.

**3. Name few insulating materials used in transformer.**

Press board, cable paper, varnished silk, transformer oil, porcelain, insulating warmish.

**4. How iron losses occur in transformer minimized?**

By laminating magnetic cores and yokes.

**5. Why the efficiency of transformer is so high?**

Mechanical losses zero and iron losses are comparatively less.

**6. Mention clearly the condition for maximum efficiency?**

Efficiency is maximum at a load at which copper losses are equal to iron losses.

**7. Mention the main function of cooling medium used in transformer.**

i) To transfer heat from convection from the heated surface to tank surface.
ii) To create good level of insulation between various conducting parts.

**8. What is window space factor in design of transformer?**

It is defined as the ratio of copper area in window to total area of window.

**9. What are the different losses in a transformer?**

Losses in a transformer:
a) Core (or) iron loss.
b) Copper loss

**10. State merits of three phase transformer over single phase transformers.**

Merits of three phase transformers:
a) A three phase transformer occupies less space for same rating compared to a bank of three single phase transformers.
b) It is less weight.
c) Cost is less.
d) The core will be smaller size and the material required for the loss is less.

**11. Why is the core of the transformer laminated?**

The cores of transformer are laminate in order to reduce the eddy current losses. The eddy current loss Is proportional to the square of the thickness of laminations. This apparently implies that the thickness of the laminations should be extremely small in order to reduce the eddy current losses to a minimum.

**12. What are the advantages of three phase transformers over single phase transformers?**

i) A three phase transformers is lighter, occupies lesser space, cheaper and more efficient than a bank of single phase transformers.

ii) In case of three phase transformers than is only one unit to install and operate. Hence the installation and operational costs are smaller for three phase units.

**13. Write the relation between core area and with of iron and copper for a single phase transformer..**

$Ac = T_p \delta_p + T_s \delta_s$

**14. State different losses in a transformer.**

i) Iron losses (or) Core losses

ii) Copper losses

## ***UNIT- IV- INDUCTION MOTORS***

**1. What is rotating transformer?**

The principle of operation of induction motor is similar to that a transformer. The stator winding is equivalent to primary of a transformer and the rotor winding is equivalent to short circuited secondary of a transformer. In transformer the secondary is fixed but in induction motor it is allowed to rotate.

**2. Why wound rotor construction is adopted?**

The wound rotor has the facility of increasing the rotor resistance through slip rings. Higher values of rotor resistance are needed during starting to get a high value of starting torque.

**3. What are the main dimensions of induction motor?**

The main dimensions of induction motor are stator core internal diameter and stator core length.

**4. What are the different types of induction motor? How they differ from each other?**

The two different types of induction motor are squirrel cage and slip ring type. The stator is identical for both types but they differ in the construction of rotor.

**5. How the slip-ring motor is started?**

The slip-ring motor is started by using rotor resistance starter. The starter consists of star connected variable resistances and protection circuits. The resistances are connected to sliprings.While starting the full resistance is included in the rotor circuit to get high starting torque. Once the rotor starts rotating, the resistances are gradually reduced in steps. At running condition slip-rings are shorted and so it is equivalent to squirrel cage rotor.

**6. What type of starter cannot be used for squirrel-cage motors?**

The starter which cannot be used for squirrel cage motor is rotor resistance starter.

**7. What type of connection is preferred for stator of induction motor?**

Under running condition the stator of induction motor is normally connected in delta. (In delta connection the torque developed will be higher than the star connection). But for reducing the starting current, the stator can be connected in star while starting and then changed to delta.

**8. Write the expression for output equation and output coefficient of induction motor.**

The equation for input KVA is considered as output equation in induction motor.

The input KVA, $Q = C_o D^2 L n_s$ in KVA

Output coefficient, $C_o = 11 K_{ws} B_{av} ac \times 10^{-3}$ in KVA/m $^3$-rps

**9. What are the different losses in an induction motor?**

The various power losses in an induction motor can be classified as i) Constant loss: These can be further classified as core losses and mechanical losses. ii)Variable loss: This includes the copper losses in stator and rotor winding due to current flowing in the winding.

**10. What are the merits of slip-ring induction motor over cage-induction motor?**

i)It is possible to insert resistances in the rotor circuit for the purpose of increasing the starting torque.

ii)The starting current is low when compared to the cage induction motor.

**11. How does the external resistance of slip-ring induction motor influence the motor performance?**

The starting torque of a slip ring motor is increased by improving its power factor by adding external resistance in the rotor circuit from the star connected rheostat resistance being progressively cut out as the motor gathers speed. Addition of external resistance, however increases the rotor impedances and so reduces the rotor current.

**12. State the effect of change of air gap length in a 3 phase Induction motor -.**

i) The length of the air gap determines the magnetizing current.

ii) Greater the length 'Of the air gap, greater will be the over load capacity.

## ***<u>UNIT -V SYNCHRONOUS MACHINES</u>***

1**. What are the constructional differences between salient pole type alternator and cylindrical rotor type alternator?**

Salient pole Alternator:

The term salient pole means projected pole. This type of rotor is used for low and medium speed machines. the prime mover used is water turbine which gives low speed 50 to 500 rpm. In order to get standard frequency 50 Hz, the number of poles lies in the range 12 to 120. Because of low speed such machines are characterized by large diameter and small length. Since water turbine is used' as a prime mover type of alternator is also called hydro electric generator.

**2. Define short circuit ratio of a synchronous gemerator.**

The short circuit ratio (SCR) of a synchromous machine is define as the ratio of field current required to produce rated voltage or open circuit to field current required to circulate rated current at short circuit.

**3. State merits of Computer Aided Design of electrical machines.**

i) It is possible to select an optimized design with a reduction in cost and improvement in performance.

ii) Reduces the probability of error with the result likely accurate and reliable.

iii)All simple arithmetic operations are performed at a high speed and makes possible to provide design in a short time.

**4. State the merits of computer aided design of electrical machines.**

(i) Easy to access

(ii) Time consumption

(iii) Accuracy

**5. How is cylindrical pole different from salient pole in a synchronous machine?**

i) Cylindrical pole are non, projecting pole whereas the salient pole machines are projecting pole.

ii) Cylindrical rotor construction is used for turbo alternators which are driven by high speed steam or gas turbines where as salient pole construction is used for generators driven by hydraulic turbine since these turbines 'operate at relatively low speeds.

**6. How is computer aided design different from conventional design in the case of electrical apparatus?**

i) Easy to access

ii) Time consumption

iii) Accuracy

**7. Name the two types of synchronous machines.** .

Based on construction the synchronous machines may be classified as,

i) Salient pole machines.

ii)Cylindrical rotor machines.

**8. What are the factors to be considered for the choice of specific magnetic loading?**

The factors to be considered for the choice of specific magnetic loading are

1. Iron loss
2. Voltage rating
3. Transient short circuit current
4. Stability
5. Parallel operation

**9. What is runaway speed?**

The runaway speed is defined as the speed which the prime mover should have, if it is suddenly unloaded, when working at its rated load.

**10. What are the two types of poles used in salient pole machines?**

The two types of poles used in salient pole machines are Round poles and Rectangular poles.

**11. What is short circuit Ratio (SCR)?**

The Short Circuit Ratio (SCR) is defined as the ratio of field current required to produce rated voltage on open circuit to field current required to circulate rated current at short circuit. It is also given by the reciprocal of synchronous reactance, $X_d$ in p.u (per unit). For turbo - alternators *SCR* is normally between 0.5 to 0.7. For salient pole alternator SCR varies from 1.0 to 1.5.

## ***UNIT I – INTRODUCTION***

## *Part-B*

1.(i) What are the main groups of electrical conducting materials? Describe the properties and application of those materials.

(ii)Write a note on classification of insulating materials and also derive an expression for the thermal resistivity of winding.

2.Explain the choice of specific electric and magnetic loading.

3.(i) Derive the equation of temperature rise of a machine when it is run under steady load conditions starting from conditions starting from cold condition

(ii)The temperature rise of a transformer is 25degree Celsius after one hour and 37.5degree Celsius after two hours of starting from cold conditions. Calculate its final steady temperature rise and heating time constant if its temperature falls from the final steady value to 40degree Celsius in 1.5 hour when disconnected. Calculate its cooling time constant. The ambient temperature is 30 degree Celsius.

4.(i) A 350 KW, 500V, 450rpm, 6-pole, dc generator is built with an armature diameter of 0.87m and core length of 0.32m.The lap wound armature has 660 conductors. Calculate the specific electric and magnetic loadings.

(ii)The exciting coil of an electromagnet has a cross section of 120*50 mm2 and a length of mean turn 08m. It dissipates 150w continuously. Its cooling surface is 0.125m2 and specific heat dissipation is 30 W/m2 degreeCelsius. Calculate the final steady temperature rise of the coil surface. Also calculate the hot spot temperature rise of the coil if the thermal resistivity of is 0.56.

5. Discuss in detail about various ratings and duties of electrical macines.

## ***UNIT- II- DC MACHINES***

## *Part-B*

1.(i) Derive the output equation of a DC machines.

(ii) A 5kW, 250V, 4 pole, 1500rpm DC shunt generator is designed to have a square pole face. The specific magnetic loading and specific electric loading are 0.42 Wb/m2 and 15000AC/m respectively. Find the main dimensions of the machine. Assume full load efficiency = 0.87 and pole arc to pole pitch ratio is 0.66.

2.A design is required for a 50Kw, 4 pole, and 600 rpm DC shunt generator. The full load terminal voltage being 220V. If the maximum gap density is 0.83 Wb/m2 and the armature ampere conductors per meter are 30,000, calculate the suitable dimensions of the armature core to give a square pole face. Assume the full load armature drop is 3% of the rated terminal voltage and the field current is 1% of the full load current. Ratio of pole arc to pole pitch is 0.67.

3. Determine the diameter and length of armature core for a 55kW, 110V, 1000rpm, 4 pole shunt generator assuming specific electric and magnetic loadings of 26000ac/m and 0.5Wb/m2 respectively. The pole arc should be about 70% of pole pitch and length of core about 1.1 times the pole arc. Allow 10 A for the field current and assume a voltage of 4V for the armature circuit. Specify the winding used and also determine the suitable values for the number of armature conductors &number of slots

4. (i) Explain the various factors that are affected by the selection of poles in a DC machine

(ii) Calculate the mmf required for the air-gap of machine having core length = 0.32m including 4 ducts of 10mm each, pole arc = 0.19m, slot pitch = 65.4mm, slot opening = 5mm, air-gap length =5mm, flux per pole = 52mWb. Given carter's coefficient is 0.18 for opening / gap= 1, and is 0.28 for opening / gap = 2.

5.(i) Explain the various factors that are affected by the selection of poles in a DC machine

(ii) Derive an expression for real and apparent flux density.

***UNIT- III – TRANSFORMERS***

## *Part-B*

1.(i)Derive the output equation of a three phase transformer.

(ii)And also calculate the net iron area and the window area of a single phase transformer if the ratio of flux to full loadmmf in a 400KVA, 50Hz single phase transformer is 2.4*10-6, maximum flux density is 1.3 Wb/m2, current density is 2.7A/mm2 and window space factor is 0.26. Also calculate full load mmf

2. A 1Φ, 400V, 50Hz transformer is built from stamping having a relative permeability of 1000. The length of flux path is 2.5m. Area of cross section of core is 2.5* 10-3 m2. The primary winding has 800 turns. Estimate the maximum flux and no load current of the transformer. The iron loss at working flux density is 2.6 watts/kg. Density of iron is 7.8*103 kg/m3. Stacking factor is 0.9.

3.(i) Calculate the approximate the overall dimension for a 200 KVA, 6600/440V, 50Hz, 3Φ core type transformer. The following data may be assumed; emf per turn=10V, maximum flux density=1.3Wb/m2 current density= 2.5A/mm2; window space factor=0.3; 0verall height=overall width; stacking factor=0.9; use a 3 stepped core.

(ii) Explain the different cooling methods of a transformer.

4.Determine the dimensions of core and yoke for a 200KVA, 50Hz, single phase core type transformer. A cruciform core is used with a distance between adjacent limbs= 1.65 times the width of core laminations. Assume voltage per turn 14V, maximum flux density 1.1Wb/m2, window space factor 0.32, current density 3A/m2 and stacking factor =0.9. The net iron area is 0.56d2 in a cruciform core where d is a diameter of circumscibing circle. Also the width of largest stamping is 0.85d.

5. The tank of a 1250 KVA natural oil cooled transformer has the dimensions length,width,heigtht are 1.55m,0.65m,1.85m.The full load torque is 13.1KW.find the no of tubes for the transformer.Assumewb /sqr-m-per degree celcious due to radiations=6 and the due to convection is 6.5.The improvement in the convection due to provision of tubes is 40%,maximum temperature raise is 40 degree celcious,length of each tube is 1m,diameter of the tubes is 50mm regarding to cooling.Neglect the top and bottom surface of the tank as regard to cooling.

## ***UNIT- IV- INDUCTION MOTORS***

## *Part-B*

1.Estimate the stator core dimensions, number of stator slots and number of stator conductors per slot for a 100 KW, 300V, 50 Hz, 12 pole, star connected slip ring induction motor. Bav= 0.4 Wb/m2, ac = 25000 amp.cond/m, $\eta$ = 0.9, PF = 0.9.Choose main dimensions to give best power factor. The slot loading should not exceed 500 amp. Conductors.

2.(i) Derive the output equation of AC machines in terms of its main dimensions.

(ii)Find the main dimensions, net length of iron of a 3.7KW, 400V, 3Φ, 4 pole, 50Hz, Squirrel cage Induction Motor which is to be started by a star delta starter. Specific magnetic loading 0.45Wb/m2, Specific electric loading 23000 AC/m, efficiency=0.85. power factor=0.84, winding factor=0.955, L/$\tau$ ratio is 1.5.

3.A 15KW, 400V,4 pole, 50 Hz, 3 phase induction motor is built with stator bore 0.25m and a core length of 0.16m. The specific electric loading is 23000 ampere conductors per metre. Using the data of this machine, determine the core dimensions, number of stator slots and number of stator conductors for a 11KW,460V,6pole,50Hz motor. Assume a full load efficiency of 84 percent and power factor of 0.82 for each machine. The winding factor is 0.955.

4. Describe the procedure for design of rotor bars and end rings of an induction motor.

5. (i) Discuss the step by step procedure to design the rotor of a squirrel cage induction motor.

(ii)Find the main dimensions, of a 15KW, 400V, 3Φ, 4 pole, 50Hz, 2810 rpm, Squirrel cage Induction Motor having efficiency of 0.88 and full load power factor of 0.9. Assume: Specific magnetic loading 0.5Wb/m2, Specific electric loading 25000 AC/m. Take the rotor peripheral speed as Approximately 20m/s at synchronous speed.

## ***UNIT -V SYNCHRONOUS MACHINES***

## *Part-B*

1. Determine for a 250 KVA, 1100 V, 12 pole, 500 rpm, 3-phase alternator(1) air gap diameter, (2) core length, (3) Number of stator conductors, (4) Number of stator slots and (5) cross-section of stator conductors. Assuming average gap density as 0.6 Wb/m2 and specific electric loading of 30,000 amp cond/m. L/ $\tau$ = 1.5.

2.Determine the output coefficient for a 1500 KVA, 2200 volt, 3-phase, 10-pole, 50 Hz, star connected alternator with sinusoidal flux density distribution. The winding has 600 phase spread and full pitch coils. ac = 30000 amp.cond/m, Bav = 0.6Wb/m2. If the peripheral speed of the rotor must not exceed 100 m/sec and the ratio pole pitch to core length is to bebetween 0.6 and 1, find D and L. Assume an air gap length of 6 mm. Find also the approximate number of stator conductors.

3.Explain the step by step procedure for the design of field winding of synchronous machine.

4. Explain the armature winding and rotor design of turbo alternator.

5.(i) Find the main dimensions of a 2500 KVA, 3KV, 50Hz, 187.5rpm, 3 phase salient pole synchronous generator. The generator is to be vertical wheel type. Use circular pole with ratio of core length to pole pitch = 0.65. Specify the type of pole construction used if the runaway speed is about 2 times the normal speed

(ii) Find the main dimensions of a 100MVA, 11KV, 50Hz, 150rpm, 3 phase water wheel generator. The average gap density is 0.65Wb/m2 and ampere conductors per meter are 40,000. The peripheral speed should not exceed 65m/s at normal running speed in order to limit the run-away speed.

************   All the Best   ***********