## SYLLABUS

**EE2355 DESIGN OF ELECTRICAL MACHINES L T P C 3 1 0 4**

**UNIT I INTRODUCTION 9**

Major considerations in Electrical Machine Design - Electrical Engineering Materials – Space factor – Choice of Specific Electrical and Magnetic loadings - Thermal Considerations - Heat flow – Temperature rise - Rating of machines – Standard Specifications.

**UNIT II DC MACHINES 9**

Output Equations – Main Dimensions - Magnetic circuit calculations – Carter's Coefficient - Net length of Iron –Real & Apparent flux densities – Selection of number of poles – Design of Armature – Design of commutator and brushes – performance prediction using design values.

**UNIT III TRANSFORMERS 9**

Output Equations – Main Dimensions - KVA output for single and three phase transformers – Window space factor – Overall dimensions – Operating characteristics – Regulation – No load current – Temperature rise in Transformers – Design of Tank - Methods of cooling of Transformers.

**UNIT IV INDUCTION MOTORS 9**

Output equation of Induction motor – Main dimensions – Length of air gap- Rules for selecting rotor slots of squirrel cage machines – Design of rotor bars & slots – Design of end rings – Design of wound rotor -– Magnetic leakage calculations – Leakage reactance of polyphase machines- Magnetizing current - Short circuit current – Circle diagram - Operating characteristics.

**UNIT V SYNCHRONOUS MACHINES 9**

Output equations – choice of loadings – Design of salient pole machines – Short circuit ratio – shape of pole face – Armature design – Armature parameters – Estimation of air gap length – Design of rotor –Design of damper winding – Determination of full load field mmf – Design of field winding – Design of turbo alternators – Rotor design.

**L = 45 T = 15 TOTAL = 60 PERIODS**

**TEXT BOOKS**

1. Sawhney, A.K., 'A Course in Electrical Machine Design', Dhanpat Rai & Sons, New Delhi, 1984.
2. Sen, S.K., 'Principles of Electrical Machine Designs with Computer Programmes', Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, 1987.

**REFERENCES**

1. A.Shanmugasundaram, G.Gangadharan, R.Palani 'Electrical Machine Design Data Book', New Age Intenational Pvt. Ltd., Reprint 2007.
2. 'Electrical Machine Design', Balbir Singh, Brite Publications, Pune.

## UNIT-1 INTRODUCTION

## PART-A

**1. What are the major considerations to evolve a good design of electric machine?**

The **major considerations** to evolve a good design are

i. Cost

ii. Durability

iii. Compliance with performance criteria as laid down in specifications.

**2. What are the different types of electrical engineering materials?**

1. Electrical conducting materials.

a. High conductivity materials

i. copper

ii aluminium

iii. Iron and steel

iv. Alloys of copper b.

Materials of high resistivity

i. materials used for precision work

ii. materials used for rheostats

iii. materials used for heating devices

2. Electrical carbon materials

3. Super conductivity

4. Magnetic material i. soft ii. hard magnetic material

5. Insulating material

**3. Define space factor of a coil.**

In an electro magnetic coil the ratio of the volume occupied by the wire in the winding or the iron in the core to the total volume of the winding or the core.

**4.Write down the classification of the magnetic material.**

i. Ferro magnetic materials. ii. Para magnetic materials. iii. Dia magnetic materials.

**5. What is specific magnetic and electric loading?**

**Specific Magnetic loading** **Specific Electric loading**

**6. What are the factors that decide the choice of specific magnetic & electric loading?**

The value of **magnetic loading** is determined by

i. Maximum flux density in iron parts.
ii. Magnetising current
iii. Core losses

The value of **electric loading** is determined by

i. Permissible temperature rise.
ii. Voltage rating of machine.
iii. Size of machine.
iv. Current density.

**7. State the properties which determine the suitability of a material for insulating material.**

There are many properties which determine the suitability of a material for use as an insulating material.

i. resistivity or specific resistance
ii. electric strength or breakdown voltage
iii. permittivity
iv. dielectric hysteresis

**8. What is thermal consideration and heat flow?**

The **thermal circuit** is concerned with mode and media for dissipation of heat produced inside the machine on account of losses.

The **heated** parts of an electrical machine dissipate heat in to their surroundings by conduction, confection and radiation from the outer surface.

**9. What is temperature rise and rating of machines?**

**Temperature rise**

The operating life of a machine depends upon the type of insulating materials used in its contruction and the life of the insulating in turns materials depends upon the temperature rise of the machine.

**Rating of machine**

The rating of an electrical machine is the power output or the designated operating power limit based upon the certain definite conditions assigned to it by the manufacturer.

**10. Write a short note on standard specifications.**

The standard specifications are the specifications issued by the standards organization of a country. The standard specifications serve as guideline for the manufacturers to produce quality products at economical prices.

The standard specifications for electrical machines include ratings, types of enclosure, dimensions of conductors, name plate details, performance indicies, permissible temperature rise, permissible loss, efficiency, etc…..

## PART B

**1. What are the main groups of electrical conducting materials? Describe the properties and applications of those materials.**

**Electrical conducting materials.**

i. High conductivity materials
ii. Materials of high resistivity

**Properties**

The fundamental requirements

i. Highest possible conductivity
ii. Least possible temperature co-efficient of resistance
iii. Adequate mechanical strength
iv. Rollability and drawability
v. Good weldability and solderability
vi. Adequate resistance to corrosion

a . copper b. alluminium c. Iron and steel d.alloys of copper

**Applications**

i. **High conductivity materials**

Making all types of winding required in electrical machine, apparatus and devices.

ii. **High resistivity materials.**

Making resistance and heating device.

**2. Discuss about various duties and ratings of Rotating Machines and give their respective temperature — time curves.**

**Types of duties and ratings**

i. continuous duty
ii. short time duty
iii. intermittent periodic duty
iv. intermittent periodic duty with starting
v. intermittent periodic duty with starting and braking
vi. continuous duty with intermittent periodic loading
vii. continuous duty with starting and braking
viii. continuous duty with periodic speed changes

\ draw temperature- time curves

**3. Explain the methods used for determination of motor rating for variable load drives with suitable diagram.**

**The four commonly used methods are**

i. Method of average losses
ii. Equivalent current method
iii. Equivalent torque method
iv. Eqivalent power method

Diagram and equation

4. **A field coil has a heat dissipating surface of 0.15 $m^2$ and length of mean turn 1 m. It dissipates loss of 150 W, the emissivity being 34 $W/m^2$°C. Estimate the final steady temperature rise of the coil and its time constant if the cross section of the coil is 100*50 $mm^2$. Specific heat of copper is 390 J/kg° C. The space factor is 0.56. Copper weighs 8900 $kg/m^3$.**

**Solution**

**Formula used**

$\theta_m = Q/s\lambda$

$Th = Gh/s\lambda$

G=Volume of copper*Copper weights Volume of copper=l*coil*sf

**Answer**

**Volume of copper=$2.8*10^{-3} m^3$**
**Copper of weights(G)=24.92 kg**
**$\theta_m$ = 29.4° C**
**Th=1906 s**

5. **Determine the rated current of a transformer for the following data cycle :500 A for 3 minutes, a sharp increase 1000 A and constant at this value for 1 minute, gradually decreasing for 2 minutes to 200 A and constant at this value for 2 minutes gradually increasing to 500 A. A during 2 minutes and repetition of the cycle.**

**Solution**

Draw load diagram

**Formula used**

**Answer**

**$I_{eq}$=539.5 A**

**6. Explain about standard specification also give Indian standard specification for different electric machine.**

IS 325-1966 : Specifications for 3ph induction motor

IS 4029-1967 : Guide for testing 3ph induction motor

IS12615-1986 : Specifications for energy efficient induction motor

IS13555-1993 : Guide for selection & application of 3ph induction motor for different types of driven equipment

IS8789-1996 : Values of performance characteristics for 3ph induction

motor IS 12066-1986: 3ph induction motors for machine tools

## UNIT-II DC MACHINE

## PART-A

**1. What is meant by apparent and real flux density?**

**Apparent flux density** $B_{app}$ = ——————————

**Real flux density** $B_{real}$ = ——————————

**2. Define field form factor**

**Field form factor '$k_f$' is defined as**

$k_f$ = —————————————————— =——

**3. What is carter's gap co-efficient?**

The **Carter's gap co-efficient** ($k_{cs}$) is the ratio of slot width to gap length.
The formula which gives the value of $k_{cs}$ directly is

———— Where $l_g$ = gap length

$W_s$ = width of slot

**4. Mention any two guiding factors for the choice of number of poles.**

The frequency of the flux reversal in the armature core generally lies between 25 to 50HZ.

The value of current per parallel path is limited to about 200 A. Thus the current/brush arm should not be more than 400 A.

**5. Name any two methods to reduce the armature reaction?**

*Compensating windings are provided to neutralize the effect of armature reaction.
*By increasing the length of air gap at pole tips.

**6. What is slot loading?**

The **slot loading** is the number of ampere conductors per slot. This value should not exceeds 1500 A. $I_{z.z} \leq 1500$ A [$I_s$ = No of conductors/slot]

**7. What are the effect of armature reaction?**

i. Reduction in emf
ii. Increase in iron loss
iii. Sparking & ring fire
iv. Delayed commutation

**8. Show how specific magnetic & electric loading interdependent.**

The output of a dc machine is proportional to the product of their specific loadings.

$$P_a \alpha (B_{av} * ac)$$

For a particular output values of specific & magnetic loadings are interdependent. (i.e) If one is chosen higher the valve of either has belower.

**9. Derive the output equation of the dc machine.**

$$P_a = (\pi DL B_{av})(\pi D_{ac}) n * 10^{-3} = (\pi^2 B_{av} ac\ 10^{-3}) D^2 Ln$$

Where

$$C_0 = \pi^2 B_{av} ac\ 10^{-3}$$

**10. What are the guiding factor for the choice of number of armature slots.**

i. Slot pith
ii. Slot loading
iii. Flux pulsation
iv. Commutation

## PART B

1. **Explain the effects of choice of number of poles in a DC machine on 1. Frequency of the flux reversal 2. Weight of iron 3. Weight of copper and 4. Length of commutator.**

The **choice of number of poles** consider that the length and the diameter of the machine . The specific magnetic and electric loading are fixed and number of poles can be verified.

This means that

$T$ = total flux around the airgap

$= P = B_{av} * \pi DL$

AC = total armature conductor over the armature periphery

$= I_Z Z = I_a/a.z = ac\pi D$

**i. Frequency**

$f = P_n/2$
frequency lies - 25 – 50 HZ

**ii. Weight of iron parts**

a. Yoke area
b. Armature core area
c. Over all diameter

**iii. Weight of copper**

a. Armature copper
b. Field copper

**iv. Length of commutator**

2 pole machine $I_b = 2I_Z = I_a$
4 pole machine $I_b = 2I_Z = I_a/2$

**2. A 5 KW, 250 V, 4 pole, 1500 rpm shunt generator is designed to have a square pole face. The loading are: average flux density in the gap = 0.42wb/$m^2$ and armature conductors per meter = 15000 AC/m. Find the main dimensions of the machine. Assume full load efficiency = 0.87 and ratio of pole arc to pole pitch = 0.66.**

**Solution**

**Formula used**

L = $D^2L =$ ——

O/P Co-efficient $C_0 = \pi^2 B_{av} ac * 10^{-3}$ $P_a =$ ————

For a square pole face ———— ——

Speed(n) = ——

**Result**

$P_a$ = 5.75 KW
n = 25 rps
$C_0$ = 62.1
$D^2L = 3.7 * 10^{-3}$ $m^3$
L = 0.518 D $0.518 D^3 = 3.7 * 10^{-3}$

**D = 0.193 m**
**L = 0.1 m**

**3. Derive the output equation of the dc machine.**

$P_a = (\pi DL B_{av})(\pi D_{ac})n*10^{-3} =$ (
$\pi^2 B_{av} ac 10^{-3})D^2 Ln$

Where
$C_0 = \pi^2 B_{av} ac 10^{-3}$ = Output co efficient

**4. Explain the various steps involved in design of armature winding of DC machine.**

**Design of armature**

i. **Main dimensions** D,L

**ii. Number of armature slots**

It depends on the following factors

a. Slot width
b. Cooling of armature conductors
c. Flux pulsation
d. Commutation
e. Cost

Guiding factor for selecting armature slots :

a. Slot pitch should lie between 25 to 35 mm
b. Slot loading not exceed 1500 ampere conductor
c. Slot per pole varies from 9 to 16

**iii. Types of winding:**

a. Lap winding
b. Wave winding

**iv. Slot dimensions :**

Slot area = ——————

**v. Depth of armature core**

Dc = – ——

5. **A design is required for a 50 KW , 4 poles, 600 rpm, d.c shunt generator, the full load terminal voltage being 220 V. If the maximum gap density is 0.83 Wb/m$^2$ and the armature ampere conductors per meter are 30,000. Calculate suitable dimensions of armature core to give a square pole face. 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 the pole pitch is 0.67.**

**Solution**

**Formula used**

O/P Co-efficient $C_0 = \pi^2 \mathbf{B_{av}}$ ac $10^{-3}$ ($\mathbf{B_{av} = B_g\psi}$)

$$C_0 = \pi^2 \mathbf{B_g\psi} \text{ ac } 10^{-3}$$

Speed n = 600/60 = 10 r.p.s

Back emf at full load E = 220 + (0.03*220) = 226.6 V

Full load current = (50*100)/220 = 227 A

Field current = 0.01 * 227 = 2.27 A

Armature current $I_a$ = 227 + 2.27 = 229.27 A

Power developed by armature $P_a = E I_a * 10^{-3}$

$D^3L =$ ——

For a square pole face

—

**Result**

| | | |
|---|---|---|
| $C_0 = 167$ | $L = 0.526\ D$ | $D^3L = 0.0311\ m^3$ |
| $P_a = 518$ kW | $D^3 = 0.0591\ m^3$ | **D = 0.39 m L = 0.21 m** |

## UNIT III TRANSFORMERS

## PART A

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

**window space factor**

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

**2. 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.

**3. What are the important properties of transformer steel?**

**Properties**

**i.** High permeability
**ii.** high resistivity
**iii.** low coercive force

**4. 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.

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

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

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

**Losses in a transformer:**

Core (or) iron loss.
Copper loss

**7. 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.

**8. Differentiate core and shell type transformers.**

| Core type | Shell type |
|---|---|
| Easy in design and construction | Comparatively complex |
| Has low mechanical strength due to non-bracing of windings | High mechanical strength |

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

$$Ac=T_p\ \delta_p+ T_s\ \delta_s$$

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

**Insulating materials**

i. Press board
ii. cable paper
iii. varnished silk
iv. transformer oil
v. porcelain
vi. insulating warmish.

## PART B

**1. Determine the dimensions 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 of 14 volts, maximum flux density of 1.1 wb/$m^2$, window space face of 0.32, current density of 3 A/$mm^2$ and stacking factor equal to 0.9. the net iron area is 0.56 $d^2$ wher d is diameter of circumscribing circle. Width of the large-stamping is 0.85d.**

**Solution**

**Formula used**

Voltage per turn $E_i = 4.44f_m = 4.44fB_mA_i$

$A_i =$ ———

———

Diameter of circumscribing circle d = √

Width of largest stamping (a) = 0.85d

Distance between core centers D = 1.6a

Width of window $W_w = D - d$

For a single phase transformer,

$Q = 2.22fB_m K_w \delta A_w A_i * 10^{-3}$ $A_w$ (Window area)

Height of window ($H_w$) = $A_w / W_w$

Using the same stepped section for the yoke as for core

Depth of yoke $D_y = a$ Height of yoke $H_y = a$

Overall height of frame $H = H_w + 2H_w$

Over all length of frame W = D + a

**Result**

| | | | |
|---|---|---|---|
| **$A_i = 0.0573m^2$** | **d = 0.32 m** | **a = 0.272 m** | **D = 0.435 m** |
| **$W_w = 0.115$ m** | **$A_w = 0.0293\ m^2$** | **$H_w = 0.26$ m** | **$D_y = 0.272$ m** |
| **$H_y = 0.272$ m** | **H = 0.804** | **W = 0.737** | |

2. **A 250 KVA 6600/400, 3 phase core type transformer has a total loss of 4800 W at full load. The transformer tank is l.25 m in height and 1m x 0.5m in plan. Design a suitable scheme for tubes if the average temperature rise is to be limited to 35 $^{o}$C. The diameter of tubes is 50mm and are spaced 75 mm from each other. The average height of tubes is1.05m.**

**Solution**

Heat dissipating surface of tank ($S_t$) = Total area of vertical sides = $2h(W+l)$

Loss dissipated by tank walls by radiation and converction = $(6 + 6.5)\ S_t$

Let heat dissipating area of tubes = $xS_t$

**Result**

| $N_t$ = 62 tubes | $S_t = 3.75\ m^2$ | $xS_t = 10.2577\ m^2$ |
|---|---|---|

3. **Derive output equation of a three phase transformer. Three phase transformer in kVA**

$$Q = 3.33 f B_m \delta A_w K_w A_i * 10^{-3}$$

4. **A 250 KVA, 6600/400 volts, three phase core type transformer has a total loss of 4800 watts at full load. The transformer tank is 1.25 m in height and 1m x 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$^2$ / $^{o}$C. Assume that convection is improved by 35 percent due to provision of tubes.**

**Solution**

**Result**

$S_t = 3.75\ m^2$

Wall area of each tube = $\pi d_t l_t$

Total numbers of tubes to be provided = 62

## UNIT IV INDUCTION MOTORS

### PART A

**1. 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, $Q=C_oD^2Ln_s$ in KVA

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

**2. 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.

**3. What are the ranges of efficiency and power factor in induction motor?**

Squirrel cage motors
Efficiency = 0.72 to 0.91
Power factor = 0.66 to 0.9
Slip ring motors

Efficiency = 0.84 to 0.91

Power factor = 0.7 to 0.92

The ISI specification says that the product of efficiency and power factor shall be in the range of 0.83 to 0.88.

**4. What are the materials used for slip-rings and brushes in induction motor?**

The **slip-rings** are made of brass or phosphor bronze. The brushes are made of metal graphite which is an alloy of copper and carbon.

**5. 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.

**6. What is slot space factor?**

The **slot space factor** is the ratio of conductor (or copper) area per slot and slot area. It gives an indication of the space occupied by the conductors and the space available for insulation. The slot space factor for induction motor varies from 0.25 to 0.4.

**7. What are the factors to be considered for estimating the length of air-gap in induction motor?**

The **following factors are to be considered** for estimating the length of air-gap.

i. Power factor
ii. Overload capacity
iii. Pulsation loss
iv. Unbalanced magnetic pull
v. Cooling
vi. Noise

**8. What are the advantages and disadvantages of large air-gap length, in induction motor?**

**Advantages**

A large air-gap length results in higher overload capacity, better cooling, reduction in noise and reduction in unbalanced magnetic pull.

**Disadvantages**

The disadvantage of large air-gap length is that it results in high value of magnetizing current.

**9. What is skewing?**

**Skewing** is twisting either the stator or rotor core. The motor noise, vibrations, clogging and synchronous cusps can be reduced or even entirely eliminated by skewing.

In order to eliminate the effect of any harmonic, the rotor bars should be skewed through an angle so that the bars lie under alternate harmonic poles of the same polarity or in other words the bars must be skewed through two pitches.

10. **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.

## PART B

1. **Find the main dimensions of a 15 kW, three phase, 400 volts, 50 Hz, 2810 rpm squirrel cage induction. motor having all efficiency of 88 percent and full load power factor of 0.9. Specific magnetic loading is 0.5 Wb/ $m^2$. Specific electric loading = 25000 A/m. Take rotor peripheral speed 'as approximately 20 m/sec synchronous speed.**

**Solution**

**Result**

$Q = 18.94$

$C_o = 131.3$

$n_s = 50$ r.p.s

**D = 0.1275 m**

**L = 0.177 m**

2. **Derive the output equation of a three phase induction motor.**

$$\mathbf{Q = C_0 D^2 L n_s}$$

$$\mathbf{C_o = 11 B_{av} a_c K_w * 10^{-3}}$$

3. **Write notes on:**
   i. **Design of rotor bars and slots.**
   ii. **Design of end rings.**

**Design of rotor bars and slots**

a. rotor bus current
b. area of rotor bus
c. shape and size of rotor slots

**Design of end rings**

a. end ring current
b. area of end ring

**4. A 11 kW, three phase 6 pole, 50 Hz; 220 volts star connected induction motor has 54 stator slots, each containing 9 conductors. Calculate the value of bar and end ring currents. The number of rotor bars is 64. The machine has an efficiency of 8.6 percent and a powerfactor of 0.85. The rotor MMF may be assumed to be 85 percent of stator MM F. Also find the bar 'and the end ring sections if the current density is 5 A/mm$^2$**

**Solution**

**Formula used and answer**

Stator current per phase ($I_s$) = 40 A

Number of stator conductor = 486

Stator turns / phase ($T_s$) = 81

Stator mmf = $3I_sT_s$ = 9720 A

But rotor emf = $S_rI_s/2 = 32\ I_b$

$32I_s$ = 8250 or current in rotor bars $I_b$ = 258 A

End rind current $I_s$ = ——

Area of each bars $a_b = I_b / I$

Each end ring $a_s = I_s / I$

**Result**

**Area of each bars $a_b$ = 51.6 mm$^2$**

**Each end ring $a_s$ = 176.6 mm$^2$**

## UNIT V SYNCHRONOUS MACHINES

### PART A

**1. 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.

**2. 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.

***3.*** **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.

**4. Write the expressions for length of air-gap. in salient pole synchronous machine?**

**Length of air-gap,**

(Or)

**5. What are the advantages of large air-gap in synchronous machine?**

**The advantages of large air-gap** are

i. Reduction in armature reaction
ii. Small value of regulation
iii. Higher value of stability
iv. A higher synchronizing power which makes the machine less sensitive to load variation.
v. Better cooling
vi. Lower tooth pulsation loss
vii. Loss noise
viii. Smaller unbalanced magnetic pull.

**6. What is the limiting factor for the diameter of synchronous machine?**

The **limiting factor** for the diameter of synchronous machine is the peripheral speed. The limiting value of peripheral speed is 175 m/sec for cylindrical rotor machines and 80 m/sec for salient pole machines.

**7. Write the expression for air-gap length in cylindrical rotor machine**.

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**8. 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.

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

i) Easy to access ii) Time consumption iii) Accuracy

**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.

## PART B

1. **Determine the main dimensions of a 75000 KVA, 13.8 kV, 50 Hz, 62.5 rpm, three phase star connected alternator. The peripheral speed of rotor should be about 40 m/sec. Assume average gap density equal to 0.65 Wb/ $m^2$, ampere conductors per metre equal to 40,000 and current density =4 A/ $mm^2$. Assume $K_w$ = 0.955.**

**Solution**

**Formula used and answer**

Synchronous speed $n_s$ = 1.0417 r.p.s

Number of poles = 96

Output coefficient = 273

**D = 12.2 m**

**L = 1.77 m**

$\tau$ = 0.4 m

flux per pole = 0.46 Wb voltage

per phase $E_{ph}$ = 7960 V

With one circuit per phase

**Turns per phase $T_{ph}$ = 81.8**

**Slots per pole phase q = 2.42**

2. **Derive the output equation of a synchronous machine.**

$$Q = C_0 D^2 L n_s$$

$$C_o = 11 B_{av} a_c K_w * 10^{-3}$$

**3. Explain the design of turbo-alternator Design of turbo- alternator**

i. Main dimensions

ii. Length of air gap

iii. Stator design

iv. Rotor design

**Procedure for rotor winding design**

a. Full load field
b. Voltage across each field coil
c. The length of mean turn
d. Total area of field conductors
e. Number of field conductors
f. Conductors per slot

**4. Explain the role of digital computers in the design of electrical machine.**

**role of digital computer**

**5.** State and explain the salient features of Computer Aided design of electrical apparatus.

**Computer Aided design of electrical apparatus**

6. State and explain advantages of hydrogen cooling as applied to turbo alternator.

**hydrogen cooling as applied to turbo alternator**