MR
INSTITUTE OF
TECHNOLOGY

USN | | | | | | | | | |

Internal Test2 – May 2020

Sub:	Electrical Machine Design							Code:	18EE55
Date:	20/05/2021	Duration:	90 mins	Max Marks:	50	Sem:	VI	Branch:	EEE
Note: Answer any FIVE full questions with neat diagram wherever necessary.									

		Marks	OBE CO	OBE RBT
1.	What are the desirable properties of insulating materials? Explain the classification of insulating materials?	[10]	CO2	L2
2.	Explain the limitations in design of electrical machines.	[10]	CO2	L2
3.	Derive the output equation of three phase transformer.	[10]	CO2	L3
4	Define specific and electrical magnetic loading.	[10]	CO3	L2
5.	Find the main dimensions of a core and window for a 500k VA, 6600/400v,50Hz, single phase, core type oil immersed ,self-cooled distribution transformer .Assume the flux density as 1.2wb/m^2 and current density of 2.75 A/mm^2 window space factor Kw=0.32,volt/turn is 16.8 volts. Use cruciform core section .Height of window is 3 times its width.	[10]	CO2	L3
6.	What are the desirable properties of magnetic materials? Explain in brief magnetic materials and its classification? Give a brief comparison between copper and aluminum wires .	[5+5] [10]	CO2	L3
7.	(a)Write brief note on CRGO used in electrical machines. (b) What are the desirable properties of conduction materials.?	[10]	CO3	L4
8.	Determine the dimensions of core and yoke for a 200KVA, 50Hz, 1-phase core type transformer. A cruciform core is used with distance between the adjacent limbs equal to 1.6 times the width of core laminations. Assume voltage per turn =14V, maximum flux density =1.1wb/sq.m; window space factor =0.32, current density =3A/mm^2; and stacking factor =0.9. The net iron area is 0.56d^2, where d is the diameter of the circumscribing circle. Also the width of the largest core stamping is 0.85d. Assume CRGO steel.	[10]	CO3	L4

All the Best Hard Work Never Fails***
ANSWER

Solution to question paper 1

Q1 AND Q2

1.a What are the desirable properties of insulating materials ? Explain the classification of insulating materials. (08 Marks)

Ans: Desirable properties of insulating materials

An ideal insulating material should have the following properties:

1. High dielectric strength, sustained at elevated temperatures.
2. High resistivity or specific resistance.
3. Low dielectric losses and low dielectric loss angle.
4. No attraction for moisture.
5. Good thermal conductivity
6. High degree of thermal stability i.e., it should not deteriorate at high temperatures.
7. Sufficient mechanical strength to withstand vibration and bending.
8. Solid insulating materials should have high melting or softening point.
9. Liquid materials should not evaporate or volatize.
10. Should be able to withstand moisture, chemical attack, heat and other conditions of service.

The insulating materials are classified as follows as per I.S 1271 and 1281 (I.S 1271 - 1958)

Sl.No.	Type	Maximum temperature	Examples
1	Class Y	90°C	Paper, cotton, silk, wood, fibre cellulose and similar organic materials, neither impregnated not immersed in oil. These materials have a tendency to absorb moisture and deteriorate rapidly; These are seldom used in electrical machines.
2	Class A	105°C	All materials belonging to Class Y when impreganted with natural resins, cellulose, esters etc. or immersed in a liquid dielectric; Enamelled wire, varinshed paper, laminated
3.	Class E	120°C	Enamelled wire insulations on a base of polyvinyl formal epoxy and polyurethane resins. Moulding powder plastics on phenolic formaldehyde etc.
4.	Class B	130°C	Mica, glass fibre, asbestos and similar inorganic impregnator or glued together with varnishes or compounds having ordinary heat resistance.
			Mica, glass fibre, asbestos and similar inorganic impregnated or glued together with more thermally resistant
5	Class F	155°C	Varnishes or compounds such as epoxide, polyurethane, etc.
6	Class H	180°C	Mica, asbestos, fiber glass when impregnated with silicones containing no orgainc fibrous materials.
7.	Class C	>180°C	Ceramics, quartz, asbestos, glass and mica which are neither impregnated no bound with orgainc substances. They are not directly involved in machine design

Q2

1. b. Explain the limitations in design of electrical machines. (08 Marks)

Ans: Apart from the availability of suitable materials, facilities available for manufacture of required machine parts and facilities required for transportation, the following considerations impose limitation on design.

1. **Saturation :** Electromagnetic machines use ferro - magnetic materials. The maximum allowable flux density to be used is determined by the saturation level of the ferro - magnetic material used. A high value of flux density results in increased excitation resulting in higher cost for the field system.

2. **Temperature rise :** The operating life of a machine depends upon the type of insulating materials used an the life of the insulating material in turn depends upon temperature rise of the machine. If an insulating material is operated beyond the maximum allowable temperature, its life is drastically reduced.

3. **Insulation :** The insulating used in the machine should be able to withstand the electrical, mechanical, and thermal stresses which are produced in the machine. Therefore, while designing the insulation, due consideration must be given to the capability of the insulation to withstand large mechanical stresses that are produced under short circuit conditions. The type of insulation is decided by the maximum operating temperature of the machine parts where it is put. The size of

insulation is decided by the maximum voltage stress and the mechanical stresses produces.

4. **Efficiency :** The efficiency should be as high as possible to reduce the operating costs. In order to design a highly efficient machine, the magnetic loading used should be small and this requires the use of large amount of material. Therefore, the capital cost of a machine designed for high efficiency is high while its running cost is low.

5. **Mechanical parts:** The size of the shaft should be such that it does not give rise to excessive unbalanced magnetic pull when deflected. In large machines, the size of the shaft is decided by considering the critical speed which depends on the deflection of the shaft. Bearing of rotating machines are subjected to the action of rotor weight, external loads, inertia forces due to unbalanced rotors and forces on account of unbalanced magnetic pull. The type of bearings to be used is decided by considering the above mentioned forces and also the type of construction whether the machine is horizontally or vertically mounted.

6. **Commutation :** The commutation conditions limit the maximum output that can be taken from a machine.

7. **Power factor :** Poor Power factor results in larger values of current for the power and, therefore, larger conductor sizes have to be used. The size and cost of an induction motor can be reduced by using a high value of flux density in air gap but these results in saturation in iron the parts of machine and consequently a poor power factor. Thus the value of flux density depends upon the power factor and hence power factor becomes a limiting factor.

8. **Consumer's specifications:** The specifications as laid down in the consumer's order have to be met and the design evolved should be such that it satisfies all the specifications and also the economic constraints imposed on the manufacture.

9. **Standard specifications :** These specification are the biggest strain on the design because both the manufactures as well as the consumer cannot get away from them without satisfying them.

Q3

Q3

Derive the output equation of a 3 phase core type transformer and also deduce an expression for EMF per turn. (10 Marks)

Ans: OUTPUT EQUATION:

In the case of 3–ϕ transformer, there are two windows. Each window contains the 1° and 2° windings of two phases (window 1 – R & Y; window 2 – Y & B) i.e. Each window contains two primary and two secondary windings.

Total cu area in each window,

$A_C = 2\, a_p T_p + 2 a_s T_s$

$$= 2 \times \frac{I_p T_p}{\delta} + 2 \times \frac{I_s}{\delta} T_s$$

$$= \frac{2}{\delta}\left[I_p T_p + I_s T_s\right]$$

$$A_c = \frac{4AT}{\delta} \quad (1)$$

As $I_p T_p = I_s T_s = AT$ if we neglect magnetizing mmf

Also, we have $k_w = \frac{A_c}{A_w}$

$$Ac = A_w K_w \quad (2)$$

Comparing eqns (1) & (2),

$$\frac{4AT}{\delta} = A_w K_w$$

$$AT = \frac{\delta A_w K_w}{4}$$

KVA rating of a 3-ϕ transformer,

$$Q = 3V_p I_p \times 10^{-3} = 3\,E_p I_p \times 10^{-3}$$

$$= 3E_t T_p I_p \times 10^{-3} = 3E_t \times AT \times 10^{-3}$$

$$= 3 \times 4.44 + \phi_m \times \frac{\delta A_w K_w}{4} \times 10^{-3}$$

$$=$$

$$= 3.33\, f\, B_m\, A_i\, \delta\, A_w\, k_w \times 10^{3}$$

$$\boxed{Q = 3.33 f\, B_m S K_w A_w A_i \times 10^{-3} \text{KVA}}$$

EMF per turn:

Consider the output of one phase i, KVA/phase = Q

The KVA rating per phase of a 3-ϕ transformer is,

$$Q = V_p I_p \times 10^{-3} = E_p I_p \times 10^{-3} = E_t\, T_p I_p \times 10^{-3}$$

$$= 4.44 f\, \phi_m\, T_p I_p \times 10^{-3}$$

The ratio $\phi m/AT$ is a constant for a transformer of a given type.

Let $\frac{\phi_m}{AT} = r$ where r is a constant

$$\therefore Q = 4.44 f\, \phi_m\, AT \times 10^{-3}$$

$$= 2 \times \frac{I_p T_p}{\delta} + 2 \times \frac{I_s}{\delta} T_s$$

$$= \frac{2}{\delta}\left[I_p T_p + I_s T_s\right]$$

$$A_c = \frac{4AT}{\delta} \quad (1)$$

As $I_p T_p = I_s T_s = AT$ if we neglect magnetizing mmf

Also, we have $k_w = \frac{A_c}{A_w}$

$Ac = A_w K_w$ (2)

Comparing eqns (1) & (2),

$$\frac{4AT}{\delta} = A_w K_w$$

$$AT = \frac{\delta A_w K_w}{4}$$

KVA rating of a 3-ϕ transformer,

$$Q = 3V_p I_p \times 10^{-3} = 3\, E_p I_p \times 10^{-3}$$

$$= 3E_t T_p I_p \times 10^{-3} = 3E_t \times AT \times 10^{-3}$$

$$= \; = 3 \times 4.44 + \phi_m \times \frac{\delta A_w K_w}{4} \times 10^{-3}$$

$$= 3.33\, f\, B_m\, A_i\, \delta\, A_w\, k_w \times 10^{-3}$$

$$\boxed{Q = 3.33 f\, B_m S K_w A_w A_i \times 10^{-3} \text{KVA}}$$

EMF per turn:

Consider the output of one phase i, KVA/phase = Q

The KVA rating per phase of a 3-ϕ transformer is,

$$Q = V_p I_p \times 10^{-3} = E_p I_p \times 10^{-3} = E_t\, T_p I_p \times 10^{-3}$$

$$= 4.44f\, \phi_m\, T_p I_p \times 10^{-3}$$

The ratio ϕm/AT is a constant for a transformer of a given type.

Let $\frac{\phi_m}{AT} = r$ where r is a constant

$$\therefore Q = 4.44f\, \phi_m\, AT \times 10^{-3}$$

It is defined as the electric loading per unit length (circum
periphery.

$$q = \frac{I_a/_A \times Z}{\pi D} = \frac{I_a Z}{A\pi D} \text{amp} - \text{conductos per metre.}$$

The term $I_a Z/A$ represents the total ampere - conductors o
the electric loading.

7. a. Derive the output equation of D.C. machine

Q6,

Using the same stepped cross section for the yoke as that of core,

Depth of yoke, $D_Y = a = 0.727$ m

Height of yoke, $H_Y = a = 0.272$ m

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

$$= 0.26 + (2 \times 0.272)$$

$$H = 0.804 \text{ m}$$

Overall length of frame, $W = D + a$

$$= 0.435 + 0.272$$

$$W = 0.707 \text{ m}$$

4. a. Compute the active and reactive components of no load current of 50 Hz, 1ϕ core type transformer with the following particulars:

Mean length of magnetic path = 300 cm

Gross cross sectional area = 150 cm^2

Maximum flux density = 1.5 Tesla

Specific core loss = 2.5 watts/kg

Ampere turns/cm at 1.15 Tesla = 7.0

Specific gravity of core material = 7.5 gm/cm^3

The effect of joints is equivalent to an air gap of 1 mm in the ma...

that of each of the side limbs.

3. b. Define iron space factor. (02 Marks)

Ans: Iron space factor (k_i) is defined as the ratio of net core area and gross core area

$$K_i = \frac{\text{Net core area}}{\text{Gross core area}}$$

$$= \frac{A_i}{A_{gi}}$$

3. c. Determine the dimensions of core and yoke for a 200 kVA, 50 Hz, 1 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/m², window space factor = 0.32, current density - 3 A/mm² and stacking factor = 0.9.
The net iron area is 0.56 d², where d is the diameter of circumscribing circle. Also the width of the largest stamping is 0.85 d. Assume CRGO steel. (12 Marks)

Ans: Voltage per turn, $E_t = 4.44 f B_m A_i$

$$A_i = \frac{E_t}{4.44 f B_m}$$

$$= \frac{14}{4.44 \times 50 \times 1.1}$$

$$A_i = 0.057\,\text{m}^2$$

Given net iron area, $A_i = 0.56 d^2$

$$i,\ 0.057 = 0.56\,d^2$$

$$d = 0.32\text{m}$$

For cruciform core, $a = 0.85d = 0.85 \times 0.32$

$$a = 0.272\text{m}$$

Given, $D = 1.6\,a = 1.6 \times 0.272$

$$D = 0.435\text{m}$$

Width of the window, $W_w = D - d$

$$= 0.435 - 0.32$$

$$= 0.115\text{m}$$

We know, $Q = 2.22 f B_m K_w A_w A_i \delta \times 10^{-3}$

$$200 = 2.22 \times 50 \times 1.1 \times 0.32 \times A_w \times 0.057 \times 3 \times 10^6 \times 10^{-3}$$

$$\Rightarrow A_w = 0.0298\,\text{m}^2$$

$$\text{Also, } A_w = H_w K_w \Rightarrow H_w = \frac{A_w}{W_w} = \frac{0.0298}{0.115}$$

$$H_w = 0.26\text{m}$$