B.Tech.

Third Semester Examination,

Electrical Machine-I (EE-207-F)

Note : Attempt any five questions.

Q. 1. (a) Give the concept of single phase transformer (ideal). Describe its performance with the help of e.m.f. equations, its phasor diagram at no load and under load.

Ans. It is possible to transform three phase power by means of only two single phase transformers. There are 2 methods of doing so, normely

(i) Open - delta connection method

(ii) T connection method.

Both of these methods result in slightly unbalanced output voltage under load because of the unsynumerical relations. This is not serious in commercial transformers, as their regulations is seldom poorer than 2 or 3%.

Such as arrangement is employed when :

(i) The three phase load is comparatively small, so that the installation does not warrant a three transformer bank.

(ii) One of the transformers in a B - B bank fails, so that service may be maintained until tne faulty T_x is repaired or a new one is substituted.

(iii) It is anticipated that the future load will increase to warrant the closing of the open Δ at some later date.

Q. 1. (b) Obtain the equivalent circuit of single phase 4kVA, 200/400 V, 50 Hz transformer from the following results :

O.C. Test : 200 V, 0.7 A 70 W on L.V. side

S.C. Test : 15 V, 10 A 80 W on H. V. side

Ans.

$$V_P = \frac{V_L}{\sqrt{3}} = \frac{400}{\sqrt{3}}$$

$$= 231\text{V}$$

$$V_R = 231 \angle D^oV, V_y = 231 \angle -120^oV \;\&\; V_B = 231 \angle 120^oV$$

$$I_R = \frac{hW \times 1000}{V_P \cos\phi}$$

$$= \frac{20 \times 1000}{231 \times 1 \cdot 0} = 43.3 \text{ A Ans.}$$

It may be represented as 43.30 $< \angle 0^o$ or

$(43 \cdot 3 + j0)A$

$$\because \qquad I_y = \frac{8 \times 1000}{231 \times 1}$$

$= 34 \cdot 64A$ **Ans.**

Q. 2. (a) Derive an expression for computing the per unit voltage regulation of a transformer both for lagging and leading power factor.

Ans.

$$\% \text{ regulation} = \frac{\text{terminal voltage on no load} - \text{on load}}{\text{TV of no load}} \times 100$$

$$= \frac{\text{voltage drop in transformer at load}}{\text{no load rated voltage (secondary)}} \times 100$$

$$= \frac{I_2 R_{02} \cos \phi + I_2 X_{02} \sin \phi}{\text{No load rated voltage}} \times 100$$

$$\% \text{ Reg} = \frac{I_2 R_2 \cos \phi - I_2 X_{02} \sin \phi}{\text{No load voltage}} \times 100$$

Q.2. (b) What is an auto transformer ? How does it transfer electrical energy from one circuit to another ? State its merits and demerits over the winding transformer.

Ans. The operating principle and general combination of an auto transformer is same as that of conventional 2 winding transformer.

Here, $V_1 I_1 \cos \theta = V_2 D_2 \cos \phi_2$

$\cos \theta_1 = \cos \phi_2$

Hence $V_1 I_1 = V_2 I_2$

$$\frac{V_2}{V_1} = \frac{I_1}{I_2} = \frac{N_2}{N_1} = K = \text{ Transformation ratio}$$

Power in winding $AC = E_{AC} I_1 = (V_1 - V_2) I_1$ volt amperes

Power $T_x = V_2 (D_2 - I_1)$

$$= V_2 I_2 \left(1 - \frac{I_1}{I_2}\right) = V_2 I_2 (1 - K)$$

$$\frac{I_1}{I_2} = K$$

$$1 - K = 1 - \frac{V_2}{V_1} = \frac{V_1 - V_2}{V_1}$$

$$= \frac{\text{High voltage} - \text{low voltage}}{\text{High voltage}}$$

Comparison

(i) Conductor material requirements

(ii) Core size

(iii) Cost

(iv) Losses and efficiency

(v) Leakage and Impedance, voltage regulation.

Q. 3. (a) Give conditions for satisfactory parallel operation of three phase transformer. Two transformer each of 800 kVA are connected in parallel. One has a resistance and reactance of 1% and

4% respectively and the other has 1.5% and 6% respectively. Calculate the load shared by each transformer and the corresponding p.f. when the total load shared by two transformer is 1000 kVA at 0.8 p.f. lagging.

Ans. Load in kW, P (Total) = 100 kW

$$\cos\phi = 0.8 \text{ (lag)}$$

$$\phi = \cos^{(-1)}(0.8)$$

$$= -36\cdot 87^\circ$$

Total load in kVA,

$$S = \frac{P}{\cos\phi} = \frac{100}{0\cdot 8} = 125$$

Hence, total shared load

$$= 125\angle -36\cdot 87^\circ \text{ kVA}$$

$$Z_A = (0\cdot 5 + j3) = 3.04\angle 80.54^\circ\Omega$$

$$Z_B = (0\cdot 6 + j10) = 10\cdot 02\angle 86.57^\circ\Omega$$

$$Z_A + Z_B = 13.046\angle 85.16^\circ\Omega$$

$$S_A = \frac{SZ_B}{Z_A + Z_B}$$

$$= \frac{125\angle -36\cdot 57^\circ \times 10.02\angle 86.57^\circ}{13\cdot 046\angle 85.16^\circ} \text{kVA}$$

$$= 96\angle -35^\circ .46\text{kVA}$$

$$S_B = \frac{SZ_A}{Z_A + Z_B}$$

$$= \frac{125\angle -36\cdot 87^\circ \times 3\cdot 04\angle 80\cdot 54^\circ}{13\cdot 046\angle 85\cdot 16^\circ} \text{kVA}$$

$$= 29\cdot 128\angle -41\cdot 91^\circ\text{kVA}$$

Q. 3. (b) Explain the scott connection for phase conversion in transformer. Also give application for it.

Ans. Scott Connection : Here, the measuring circuit is isolated from the power circuit. The fact that the meters in the secondary circuit of an instrument transformer are isolated electrically from the primary side is of very great importance in high voltage systems.

Large alternators usually operate at voltages between 11kV to 20kV while transmission voltages as high as 750kV are being used.

Therefore, in all electrical system it is necessary to have a measure of currents and voltage, both for metering purposes and for the operation of protective relays & other equipment. It is impossible to bring the high voltage lines directly to the switchboard to be connected to instruments as even for voltages upto a few thousand volts it would be difficult to insulate the equipment to provide safety for the operating personnel.

Q. 4. (a) Describe various three phase transformer connections and discuss their various groups.

Ans. (i) Three phase core type transformer.

(ii) Three phase shell type transformer.

Three phase T_x **connections.**

- Star
- Delta

Groups :

Group 1 : Zero phase displacement $(V_y\ 0\ pd\ 0\ D_2\ 0)$

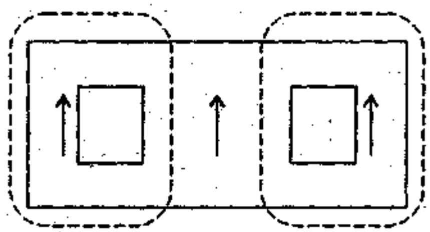
Group 2 : 180° phase displacement $(Y_y 6\ pd\ 6\ D_2 6)$

Group 3 : 30° lag phase displacement $(Py\ 1\ yd\ 1\ y = 1)$

Group 4 : 30° lead phase displacement $(Py\ 11, yd\ 11, y = 11)$

Q. 4. (b) Explain with suitable diagram how harmonics are introduced in transformer, even when the supply voltage be purely sinusoidal. If the magnetic circuit of the transformer is unsaturated, how will the harmonics be affected.

Ans. The use of high flux densities in the cores of power transformers, imposed by the requirements of an economical design and the reduction in size, result in high saturation level and the departure from rectinearly of the flux current relation or B-H (or BAT) curve. It has been noted that due to saturation effects, a sinusoidal flux and emf necessitate a pronounced third and less pronounced higher order harmonic components in the magnetising current.



Third Harmonics Flux paths

Q. 5. Derive an expression for the e.m.f. generated in a d.c. machine. A 10 kW, 6 pole d.c. generator develops an e.m.f. of 200 V at 1500 r.p.m. The armature has a lap connected winding. The average flux density is over a pole pitch is 0.9 Tesla. The length and diameter of armature are 0.25 M and 0.2 M respectively. Calculate :

(i) the flux per pole

(ii) the total number of active conductor in the armature and

(iii) the torque developed by the machine, when the armature supplies a current of 50 A.

Ans. Supply voltage per phase $= V = \frac{1100}{\sqrt{3}} = 6350$

Induced emf per phase, $E = \frac{1200}{\sqrt{3}}$

$= 692.8\text{V}$

Since power input $= \sqrt{3} V_L I_c \cos\phi$

$$= \sqrt{3} V_L I \cos\phi$$

$$I \cos\phi = \frac{\text{power input}}{\sqrt{3} V_L}$$

$$= \frac{90 \times 1000}{\sqrt{3} \times 1100}$$

$$= 47.24\text{A}$$

$$X_S = 4\Omega$$

$$\text{I} = E_R / Z_S$$

$$\text{I} = \frac{191 \cdot 58}{4} = 47.9\text{A}$$

$$\cos\phi = \frac{I \cos\phi}{\text{I}}$$

$$= \frac{47.24}{47.9}$$

$$= 0.986 \text{ (lead)}\textbf{Ans.}$$

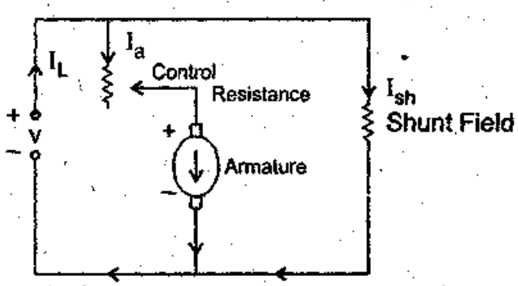
Q. 6. (a) What is meant by armature reaction ? How does it affects the main field flux ? Define GNP and MNP.

Ans. In a dc machine, the armature mmf act on the magnetic circuit of the machine in such a way as to distort the air gap flux and to change its magnitude. In an alternator the phase displacement or phase ϕ between current I and the emf F can be within the limits $-\pi/2$ to $+\pi/2$

Armature is a rotating part of a dc machine and is build up in a cylindrical or drum shape. Its purpose is to rotate the conductors in the uniform magnetic field.

Q. 6. (b) Why a register is required in series with the armature of a d.c. motor at the time of starting ? Describe a suitable startor for starting a d.c shunt motor.

Ans.



Motor starters are generally manufactured in–convenient sizes for use as auxiliaries with dc shunt and compound motors.

Their primary function is to limit the current in the armature circuit during the starting/accelerating period.

Since speed, $N \propto V - \frac{I_a R}{\theta}$

$$R = V - \frac{KN}{I_a}$$

$$I_1 = \frac{V}{R_1}$$

$$I_2 = V - \frac{E_b}{R_1}$$

$$I_2 = V - \frac{KN_1}{R_1}$$

$$I_2 = V - \frac{KN_1}{R_2}$$

So,
$$I_2 = V - \frac{KN_2}{R_2}$$

$$I_1 = V - \frac{KN_2}{R_3}$$

$$\frac{R_1}{R_2} = \frac{R_2}{R_3} = \frac{I_1}{I_2} = \gamma \text{ say}$$

or
$$\left(\frac{R_1}{R_2}\right)\left(\frac{R_2}{R_3}\right)\left(\frac{R_3}{R_4}\right)\left(\frac{R_4}{R_6}\right)\ldots\ldots\frac{R_{n-1}}{R_n} \times \frac{R_n}{R_a} = \gamma^n$$

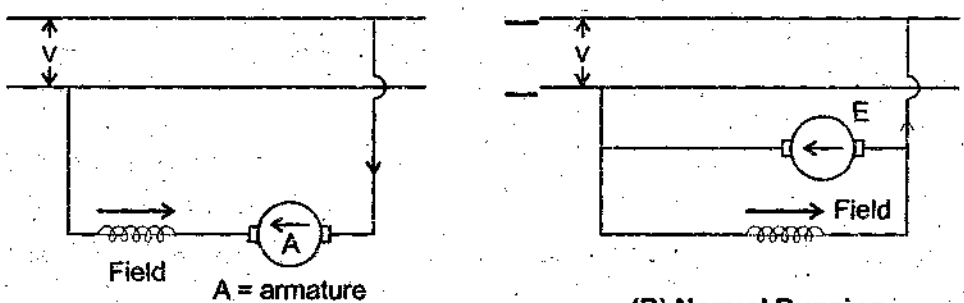
or
$$\frac{R_1}{R_a} = \gamma^n$$

or
$$\gamma = \sqrt[n]{\frac{R_1}{R_a}}$$

Q. 7. (a) Why is electric braking of electric motors superior to mechanical braking ? How is dynamic braking of d.c. shunt motor done ?

Ans. Electric Braking with dc motors

(i) Plugging or counter current braking.



(A) Normal Running DC motors (series)

(B) Normal Running DC Shunt motor

Electric braking torque, $K_1\phi I = K_1\phi\frac{E}{R}$

Since Braking amount, $I = \frac{E}{R}$, where E is the induced emf & R is total resistance in the motor circuit

Again

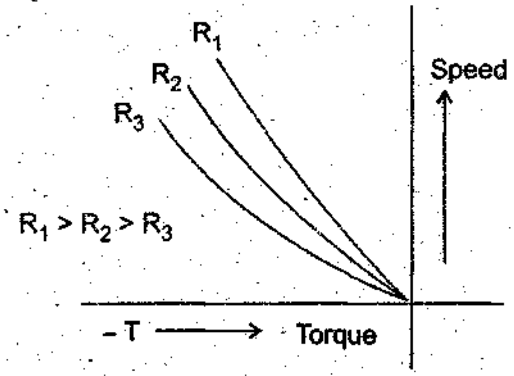
$$E \propto \phi N$$

$$\varepsilon = K_2\phi N$$

$$\frac{K_1\phi}{R} \propto K_2\ \phi N = K_3\phi^2 N$$

Q. 7. (b) Draw the speed-torque characteristics of d.c. shunt series, and compound motor and compare them, which characteristic is more suitable for traction purpose and why ?

Ans.



Q. 8. Write short notes on any two of the following :

(a) Armature voltage control of d.c. shunt motor

(b) Sumpner's back to back test

(c) Tap changing transformer

Ans. (a) Armature Voltage Control of d.c. Shunt Motor : In a dc machine, the armature mmf act on the magnetic circuit of the machine in such a way as to distort the air gap flux and to change its magnitude. In an alternator the phase displacement or phase ϕ between current I and the emf E can be within the limit $-\pi/2$ to $+\pi/2$

Armature is a rotating part of a dc machine and is build up in a cylindrical or drum shape. Its purpose is to rotate the conductors in the uniform magnetic field.

(b) Sumpner's Back to Back Test : Though the efficiency or regulation of the T_x can be determined from open circuit & short circuit tests accurately but for determination of temperature rise, it is necessary that the T_x be put on full load for a number of hours. T_x of smaller output can be loaded artificially by means of water loads or lamp loads but it may be very difficult to arrange suitable loads for loading T_x if large rating. Further there is tremendous wastage of electrical energy.

In Sumpner's, test, the 2 T_x are loaded fully, in similar way as 2 dc machines in a regenerative test, and the power requirement from the supply is that necessary for supplying the iron or copper losses of both T_x.