B.Tech.

Third Semester Examination

Electrical Machines-I (EE-207-F)

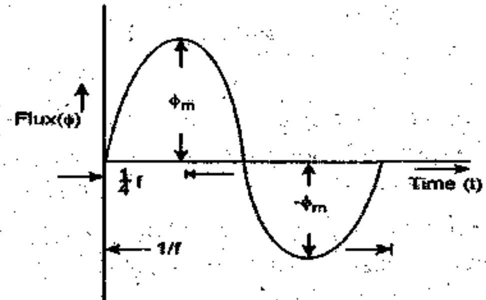
Note : Attempt any five questions. All questions carry equal marks.

Q. 1. (a) Derive an expression for the induced e.m.f. of a transformer. A 3000/200 V, 50 Hz, single phase transformer is built on a case having an effective cross-sectional area of 150 cm^2 & has 80 turns in low voltage winding. Calculate :

(i) The value of the maximum flux density in case and

(ii) The no. of turns in high voltage winding. **12**

Ans.



Average rate of change of flux $\frac{d\phi}{dt} = \frac{\phi_{max}}{1/4f} = 4f\phi_{max}$. since average emf induced per turn in volts is equal to average rate of charge of flux.

So average emf induced per turn $= 4f\phi_{max}$.

Since flux ϕ varies sinusoidally so emf induced will be sinusoidally

$\therefore$ R.M.S. value of emf induced $= 1.11 \times 4f\phi_{max}$

$\therefore$ R.M.S value of emf induced in primary

$$= 4.44\, f\phi_{max} \times N_1 \text{ (volts)}$$

Maximum value of flux $= \frac{200}{4.44 \times 50 \times 80} = 0.01126$ wb

$$D_{max} = \frac{\phi_{max}}{a} = \frac{0.01126}{150 \times 10^{-4}} = 0.75T$$

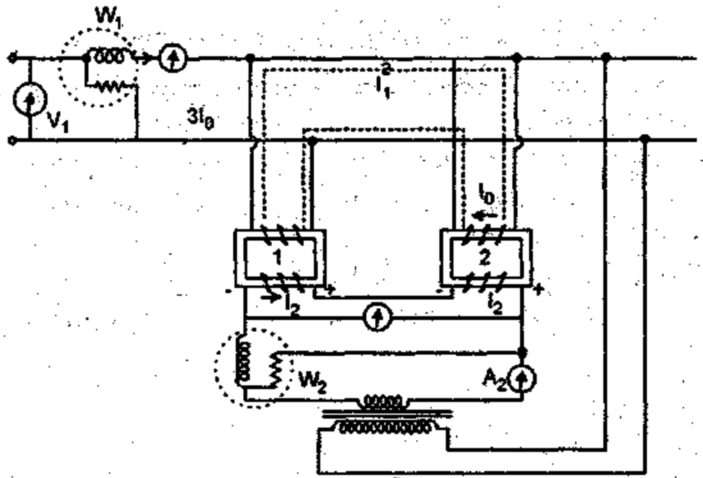
No. of turns in high voltage winding

$$= \frac{3000}{200} \times 80 = 1200 \text{ Ans.}$$

Q. 1. (b) Describe the back to back test for determining the regulation & efficiency of a pair of similar transformers giving the circuit diagram. What are the limitations of this test ? **8**

Ans. In Sumpner test the two transformers are loaded fully in similar way as two D.C. machine in a regenerative test, and the power required from the supply is the necessary for supplying the iron and copper losses for both transformers. For this test two similar transformers are required.

The primary winding of the two transformer are connected in parallel across the single phase supply with a voltmeter V_1 ammeter A_1 and and wattmeter W_1 in the circuit. The supply voltage V_1 must



be equal to the rated voltage of primary winding. The secondary winding of transformer are then connected together and voltage is measured between the other remaining two terminals by a voltmeter V_2 of double range. If the voltage measured is double that of secondary voltage of an transformer it shows that two transformer are not connected in opposition. By interchanging the two connection. The two transformer will opposite direction and voltage will give zero reading.

Now the two transformer are loaded fully by applying a computative low voltage from the regulating transformer to secondary circuit. The variation in this voltage will cause the change in the circulating current through the secondary winding this voltage is adjusted to such a value that ammeter A_2 shows full load secondary current. The secondary current will cause a current to circulate in the two primaries having a path. The arrows indicate instaneous direction of current in primaries due to secondary current since the secondaries are connected in opposition so direction of current in two primaries are in opposition. Hence the reading of wattmeter W_1 is not affected through the primaries and secondaries of two transformer carry full load current. Thus, wattmeter W_2 gives the full load copper losses of transformer.

Q. 2. (a) The efficiency of a 20 KVA, 2590/250 V, single phase transformer at u.p.t is 98% at rated load & also at half rated load. Determine

(i) Transformer case loss

(ii) Full load Cu loss

(iii) P.U. value of the equivalent resistance of the transformer. **10**

Ans. $P = 20 \text{ KVA} \times 1.0 = 20 \times 1000$ Watt

$$\eta = 0.98$$

$$\therefore \quad P_i + P_c = 408.163 \text{ Watt}$$

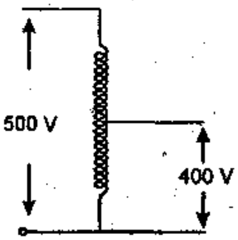
$$P_i + 1/4\, P_c = 204.082$$

$$\therefore \quad P_c = 272.1 \text{ Watt}$$

$P_i = 136.05$ Watt

Q. 2. (b) A 400/100 V, 5 KVA, two winding transformer is to be as an autotransformer to supply power at 400 V from 500 V source. Draw the connection diagram and determine the KVA output of the autotransformer. **10**

Ans.



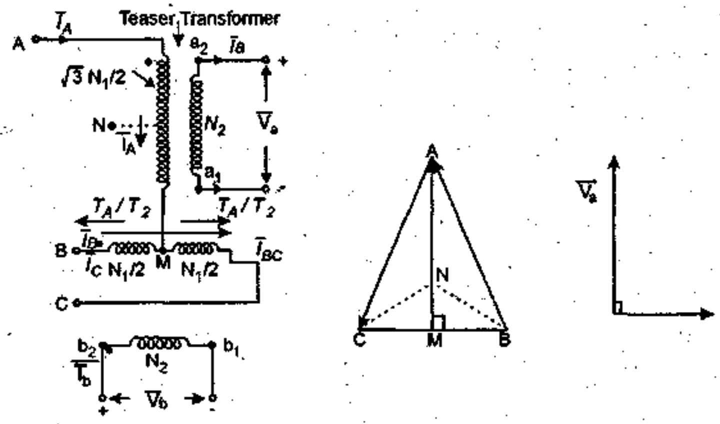
$$K = \frac{400}{500} = 0.8$$

The rated output $= \dfrac{100}{1 - 0.8} = 25$ KVA

Q. 3. (a) Explain with the help of connection and phasor diagrams, how Scott connections are used to obtain 2 phase supply from 3 phase supply mains. **10**

Ans. Scott Connection : Phase conversion from 3 phase to two phase is needed in special cases such as supplying 2 phase electric arc furnance.

The concept of 3/2 phase conversion follows from the voltage phasor diagram of balance 3ϕ supply. If the point M midway on V_BC could be located then V_{AM} leads V_{BC} by 90°. A two phase supply could thus be obtained by means of transformer are concern across AM called the teaser transformer and the other connected across the line B and C since $V_{AM} = \left(\sqrt{3}/2\right) V_{BC}$ the transformer primaries must have $\sqrt{3}N_1/2$ and N_1 turns this would mean equal voltage and turn in each transformer balance 2ϕ supply then could easily obtained by having both secondary with equal number of turns N_2. The point M is located midway on primary of transformer connection across the line B and C.



(a) (b) (c)

Fig. Scott Connection

Q. 3. (b) What are the conditions for satisfactory parallel operation of single phase transformer? Deduce expression for the load shared by two transformer in parallel when no load voltages of these transformers are not equal. **10**

Ans. Conditions for Parallel Operation :

(i) Polarities of transformer are same.

(ii) Voltage rating of primaries and secondaries are equal.

(iii) Per unit impedances of transformer are the same in magnitude.

(vi) Phase displacement are same.

(v) Phase sequence are same.

Load Sharing :

$$E_A = I_A Z_A + (I_A + I_B) Z_L$$

$$E_B = I_B Z_B + (I_A + I_B) Z_L$$

$$E_A - E_B = I_A Z_A - I_B Z_B$$

$$E_B = I_B Z_B + \frac{(E_A - E_B) + I_L Z_B}{Z_A} \times Z_L + I_B Z_L$$

$$I_B \left(Z_B + Z_L + \frac{Z_B}{Z_A} Z_L \right) = \frac{E_B Z_A - (E_A - E_B) Z_L}{Z_A}$$

$$I_B = \frac{E_B Z_A - (E_A - E_B) Z_L}{Z_A Z_B - Z_L (Z_A + Z_B)}$$

$$I_C = \frac{E_A - E_B}{Z_A + Z_B}$$

Q. 4. (a) What are the distinguishing features of Y-Y & Δ -Y 3 phase connections? Compare their advantages & disadvantages. **10**

Ans. Star-Star Connection :

Advantages : (i) Number of turns per phase and amount of insulation is minimum.

(ii) No phase displacement between primary and secondary voltage.

(iii) With the star point on both side it is possible to provide neutral point.

Disadvantages : (i) If the load of secondary side of transfomer is unbalanced the phase voltage of the load side changes unless the load star point is earthed.

(ii) The primary of the transformer draw a magnetizing current which has third and fifth harmonic.

Delta Star Connection :

(i) The sequence is required where supply voltage is to be step down.

(ii) In this scheme of connection the line voltage ratio is $\sqrt{3}$ times of transformer turn ratio and secondary line voltage have a phase shift of $\pm 30°$ with respect to primary line voltage

(iii) The neutral of the secondary is grounded to provide 3 phase-4 wire system and this scheme of connection is widely used in distribution system.

(iv) Star delta or delta star transformer cannot operated in parallel with star-star or delta-star even voltage ratio are matched.

Q. 4. (b) What is inrush phenomenon in transformers ? Discuss it qualitatively. **10**

Ans. When the primary side of the transformer is switched on to normal voltage with secondary open circuited a transient rush of current take place. This rush depend upon the point in cycle at when the voltage more is switched ON the value and direction of residual core flux, the shape of the saturation curve and normal flux density used. The worst condition occurs when the applied voltage has zero value at instant of switching.

$$\phi = \phi_{max} \sin(\omega t + \alpha) + \phi_{re} - \phi_{max} \sin \alpha)$$

If the transformer is switched on at the instant that the applied voltage passes through a peak value i.e., when $\alpha = 0$ a flux corresponding to steady state operation is immediately established in the transformer and also does the magnetising current. Such condition are those of normal no load operation and there is no transient

The worst condition for connection are $\alpha = -\frac{\pi}{2}$ i.e., when switch is closed at the instant the applied voltage passes through a zero value

$$\phi = -\phi_{max} \cos n\, \omega t + \phi_{res} + \phi_{max}$$

If flux attain nearly double of the normal flux. This reffer to as doubling effect.

Q. 5. (a) Derive the torque equation of a d.c. motor. **10**

Ans. Let T_e is the electromagnetic torque developed in Newton-meter by the motor running at n rps.

Power developed = Work done per second

$= WT_e = T_e \times 2\pi$ N watts

Electrical equivalent of mechanical power developed by armature

$= E_b I_a$ watts

$$\therefore \quad T_e \times 2\pi n = E_b I_a$$

$$T_e = \frac{E_b I_a}{2\pi n} = 0.159 \frac{E_b I_a}{n} \text{ N-m}$$

$$T_e = \frac{E_b I_a}{2\pi \frac{N}{60}} = 9.55 \frac{E_b I_a}{N}$$

$$E_b = \frac{P\phi ZN}{60A}$$

$$\therefore \quad T_e = 9.55 \times \phi \times \frac{Z \times N \times P}{60\ A}$$

$$= 0.159 \frac{P\phi Z I_a}{A}$$

Q. 5. (b) Discuss different methods of speed control. **10**

Ans. Speed Control of D.C. Shunt Motor : The following are the ways by which the speed of D.C. Shunt Motor can be controlled :

(i) Field Rheostat Control

(ii) Reluctance control

(iii) Fixed voltage control

Methods : (i) Armature resistance control

(ii) Shunted armature control

(iii) Armature voltage control

(iv) Ward Leonard method of speed control.

Speed Control of D.C. Series Motor :

(i) Armature resistance control

(ii) Shunted armature control

(iii) Armature terminal voltage control

Q. 6. (a) Explain the principles of plugging and rheostatic breaking of a d.c. motor. 10

Ans. Plugging or Counter Current Breaking : In a D.C. motor a reverse torque is obtained by reversing the current either in the armature or in the field. Polarity reversal of the field winding is rarely used because it results in larger breaking time due to relative large inductive of the field winding in comparison that can be obtained by polarity reversal of armature winding.

Rheostatic Breaking with Shunt Motor : The armature of D.C. Shunt Motor is disconnected from the supply and connected across the breaking resistance keeping the field connected to the supply.

Rheostatic Breaking with D.C. Series Motor : In case of series wound direct motor when it is disconnected from supply and is connected across a breaking resistance. It is essential that the connection of field winding are changed over.

Q. 6. (b) Define commutation & explain the process of commutation in d.c. generator. 10

Ans. Commutation : The commutation process the change from generated alternating current to an externally available direct current. The transfer of current from rotating armature to the stationary brushes involves a continuously moving contact.

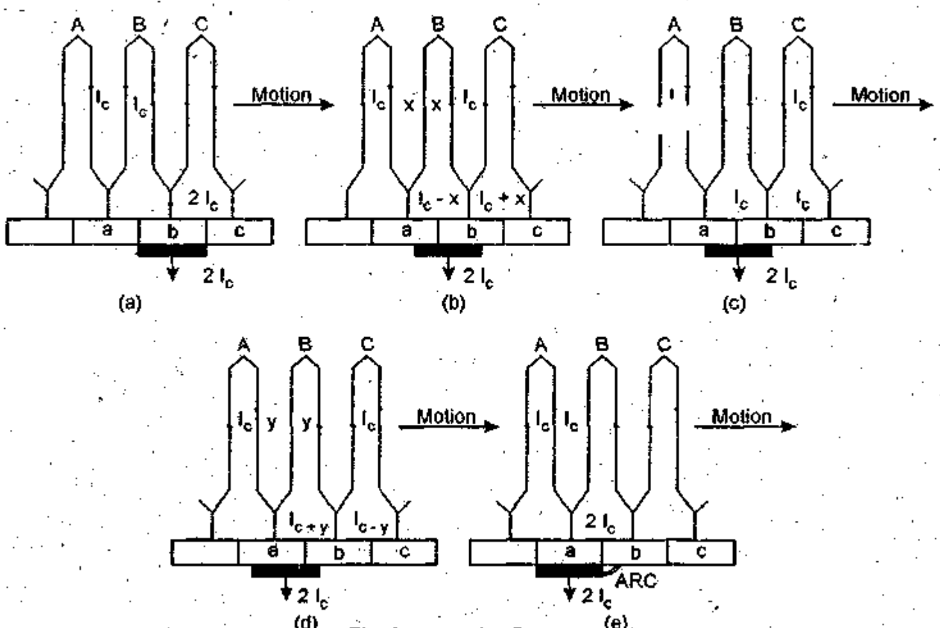


Fig. Commutation Process

In order to have a physical concept of commutation. Let us consider that the machine has a ring winding, for simplicity it is assumed that the width of commutator bar and the thickness of the insulation between the commutator bars is negligible. Let the current per conductor be of I_c amperes and the armature is moving from left to right and concentrate an coil B.

In fig. the brush is contact with only bar b of the commutator. All the current from the armature path which is to the right of brush pass through coil C. Commutator bar b conduct the combine current 2 I_c of the two paths the brush. The brush is just starting to be in contact with bar a now three are two paths to the brush for armature current carring from the armature path through commutator bars a and b. As the area of the contact with bar a increases, the current flowing to the brush via bar a increases and current via bar b decreases. The total current collected by the brush remain unchanged i.e., 2 I_c. If the current distribution between bars a and b were determined by the area of contact only. The current through the coil would decrease linearly, when the brush contact area are equal an bar a and b each bar deliver a current I_c to the brush and coil B carries no current. The brush contact area on bar b start to decrease with further rotation of armature and current deriverd by direction. When the brush break contact with bar b and a is totally on bar a the short circuit of coil B is removed and coil B carries a current of I_c ampere in counter clockwise direction. Then during the period of short circuit which is also known as period of commutation, the current in th short circuited coil should be removed to full value.

Q. 7. What is armature reaction ? Describe the effects of armature reaction on the operation of d.c. machines. How armature reaction is minimized ? 20

Ans. Armature Reaction : The effect of magnetic field set up by armature current on the distribution of flux under the main pole of DC machine is known as the armature reaction.

Effect of Armature Reaction on D.C. Machine :

(i) The cross magnetising effect of armature reaction distort the filed in air gap. There are two principle effects of the distortion of field namely (i) the creation of magnetic field in inter polar region (ii) weakened field strength in air gap.

(ii) The Demagnetisation effect of the armature reaction reduces the total flux per pole from its no load value to magnetising saturation and reduction in flux depend upon the degree of magnetic saturation.

(iii) The effect of armature reaction on the main field flux are opposite sign for a generator and a motor because of the same direction of armature current under main pole the direction of rotation of armature for motor is opposite to that of generator.

Remedies for Field Distortion :

(i) By flattning of pole.

(ii) By making the trailling horn of the pole piece longer than the advancing horn and cutting further from the surface.

(iii) The air gap length may be increased.

(iv) By reducing the cross sectional of pole piece.

(v) By providing interpoll between the main pole and compensating winding.

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

(a) 4 points starter,

(b) Tap changing transformer,

(c) Characteristics of d.c. motor,

(d) Equivalent circuit diagram of single phase transformer.

Ans. (a) 4 Points Starter : A four point starter with its internal winding connected to the lay shunt compound wound motor is shown in fig. It is obvious that when arm touches the stud No 1 line current divide in three part :

(i) One part pass through the shunt field winding.

(ii) Second part pass through starting resistance, armature and series field.

(iii) The third part through no voltage release coil and protective resistance.

Since in the arrangement "no volt release coil" circuit is independent of shunt field circuit it is not be affected by the charge of current in shunt field circuit. It means that the electromagnetic pull exerted by holding coil will always be sufficient and will prevent the spiral spring from restoring the arm to the "off" position no matter how the field rheostate is adjusted.

The possibility of accidently opening the field circuit is quite remote; hence there is the greater acceptance of four point starter over three point starter.

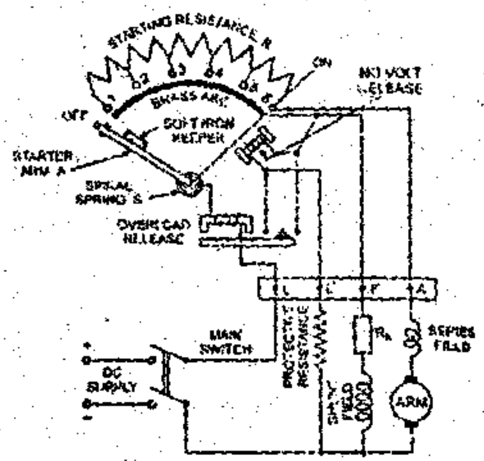
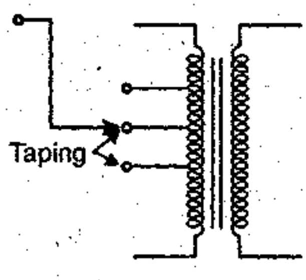


Fig. Four Point Starter

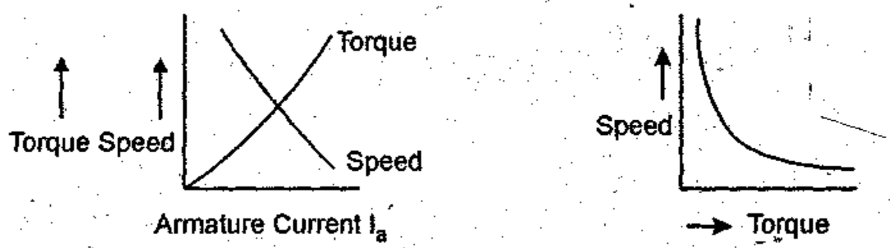


Transformer Taping

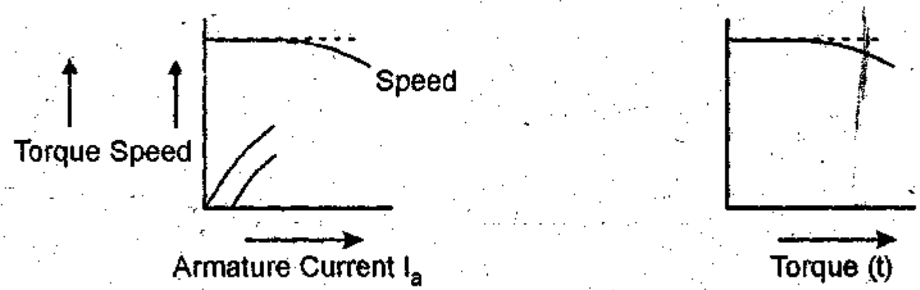
(b) Tap Changing Transformer : The principle of regulating the secondary voltage is based on changing the number of turns on the primary or secondary i.e., changing the ratio of transfer. Decrease in primary turns causes the increases in emf per turn and so in secondary output voltage. The secondary output voltage can also be increase by increasing the secondary turns and keeping the primary turns fixed. In other words the decrease in primary turns has the same effect as increase in secondary turns. The tapping can be of either side of transformer but it is prefer to have at H.V. Side.

(c) Characteristic of d.c. Motor :

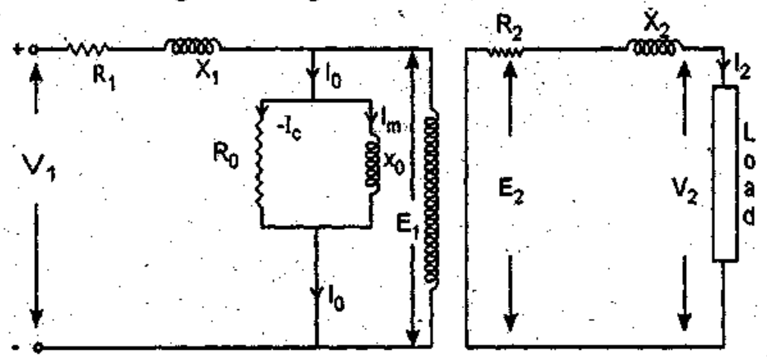
Series Motor :



Shunt Wound Motor :



(d) Equivalent Circuit Diagram of Single Phase Transformer :



Equivalent circuit is simply a circuit repres- entation of the equations describing the performance of the device

R_1 = Primary winding resistance

R_2 = Secondary winding resistance

X_1 = Primary winding reactance

X_2 = Secondary winding reactions

From S.C. Test : $R_{eq} = \frac{W_s}{I_s^2}$

$$Z_{eq} = \frac{V_s}{I_s}$$

$$X_{eq} = \sqrt{Z_{eq}^2 - R_{eq}^2}$$

From O.C. Test : $R_0 = \frac{V_1}{I_e} = \frac{V_1^2}{P_0}$

$$X_0 = \frac{V_1}{I_m} = \frac{V_1}{\sqrt{I_0^2 - I_c^2}}$$