Previous Year Questions with Answers

IV - Sem/ELECT/2019(S)(New)

(Theory - 1)

Full Marks : 80 **Time : 3 Hours**

Answer any **five** questions including **Q.Nos. 1 & 2**

Figures in the right-hand margin indicate marks.

1. Answer *all* the questions in brief : [2 × 10

(a) What is the function of pole shoe in a dc machine ?

(b) Why transformer rating is done in kVA ?

(c) State the working principle of DC motor.

(d) Define All Day Efficiency of Transformer.

(e) State two uses of Auto-Transformer.

(f) What type of speed control is obtained by flux control method and armature voltage control method ?

(g) State and condition for maximum efficiency in a transformer.

(h) Difference between core-type and shell-type transformer.

(i) State the name of vector groups for 180° phase displacement in three-phase transformers.

(j) Define commutator pitch.

2. Answer the following : [5 × 6

(a) Derive the condition for maximum power developed in a dc motor.

(b) Derive the condition for maximum efficiency in a dc generator.

(c) An 8-pole dc shunt generator with 778 wave connected armature conductors and running at 500 rpm supplies a load of 12.5Ω resistance at terminal voltage of 250 V. The armature resistance is 0.24Ω and field resistance is 250Ω . Find the armature current induced emf and flux per pole.

(d) Derive the emf equation of DC Generator.

(e) A 20kVA, 440/220V, 1-ϕ, 50 Hz transformer has iron loss of 324 W. The copper loss is found to be 100 W when delivering half full-load current. Determine:

(i) Efficiency when delivering full-load current at 0.8 pf lagging.

(ii) Percent of full-load kVA when the efficiency will be maximum.

(f) Compare the amount of copper used in between auto-transformer and two-winding transformer of same rating.

3. The total iron loss in a 460V, 50Hz single-phase transformer is 2400W. When a 230V, 25Hz supply is applied, the total iron loss is 800W. Calculate the hysteresis loss and eddy current loss at normal voltage and frequency of 460 V. [10

4. A 230 V dc shunt motor runs at 800 rpm and takes armature current of 50A. Find the resistance to be added to the field circuit to increase the speed to 1000 rpm at armature current of 80A. Assume flux proportional to field current. $R_a = 0.15\Omega$ and $R_f = 250\Omega$. [10

5. A 20 kVA, 1-ϕ, 50Hz, 2200/200V transformer gave the following results :

OC Test : 2200V applied to primary, Power = 220W.

SC Test : Power required to circulate full-load current in SC secondary 240W.

Calculate the efficiency at full-load and half-load at pf 0.8 lagging. [10

6. Explain short-circuit test of 1-ϕ transformer.[10

7. Explain about the process of communication in DC machines. [10

ANSWERS TO 2019(S)

1.(a) What is the function of pole shoe in a dc machine ?

Ans. The function of pole-shoe in a DC machine is to -

(i) support the field coils

(ii) increase the C.S. area of the magnetic circuit and reduces its reluctance.

(b) Why transformer rating is done in kVA ?

Ans. Transformer rating is in kVA due to following reasons :

(i) The losses i.e., iron loss depends upon voltage and copper loss depends upon current and thus the total loss depend upon voltage and current i.e., voltampere and the power factor (PF) of a transformer is independent of load.

(ii) Another point is that during manufacturing of a transformer, the manufacturer does not know the type of load to be used by the user and thus load PF has no impact on power rating and therefore the rating mentioned by the concern is VA a kVA.

(c) State the working principle of DC motor.

Ans. It is a rotating electrical m/c that converts d.c. power into mechanical power. It's operation is based on the principle that when a current carrying conductor is placed in a magnetic field, the conductor experiences a mechanical force.

(d) Define All Day Efficiency of Transformer.

Ans. The all day efficiency of transformer is the ratio of kwh o/p in 24 hours to the kwh i/p in 24 hours

(e) State two uses of Auto-Transformer.

Ans. Two uses of Auto-transformer is :

(i) To start induction motors, synchronous motors.

(ii) For the variable supply.

(f) What type of speed control is obtained by flux control method and armature voltage control method ?

Ans. By using flux control method the speed can be changed above the rated speed, but in case of armature voltage control method the speed can be reduced to rated speed of the D.C motor.

(g) State and condition for maximum efficiency in a transformer.

Ans. Condition for maximum efficiency in a transformer is that the iron loss is equal to the variable loss (copper loss).

(h) Difference between core-type and shell-type transformer.

Ans. Difference between core type and shell-type Transformer.

(i) In a core type transformer, the core is surrounded by a considerable part of the windings. But in shell-type transformer, the windings are sorrounded by a considerable part of the core.

(ii) In a core type transformer there are two magnetic circuits but in shell type there is one magnetic circuit.

(i) State the name of vector groups for 180° phase displacement in three-phase transformers.

Ans. The name of the vector groups for 180° phase displacement in three phase transformers is Yy6, Dd6, Dz6.

(j) Define commutator pitch.

Ans. Commutator Pitch : It is the number of commutator segments spanned by each coil of the armature winding.

For simple lap winding : $Y_C = 1$

For simple wave winding : $Y_C = 2$ pole pitches.

2. (a) Derive the condition for maximum power developed in a dc motor.

Ans. We know that in a d.c. motor, $V = E_b + I_a R_a$.

Multiplying both the ends by 'I_a'

$\therefore V I_a = E_b I_a + I_a^2 R_a$ ...(i)

where, VI_a = Electrical power supplied to armature.

$E_b I_a$ = Power developed by armature.

$I_a^2 R_a$ = Armature copper loss.

$\therefore$ We can take $p_m = E_b I_a$.

From equation (i), $p_m = VI_a - I_a^2 R_a$

For maximum power $\frac{dp_m}{dI_a} = 0$.

$$\Rightarrow \frac{d}{dI_a}(E_b I_a) = \frac{d}{dI_a}\left(VI_a - I_a^2 R_a\right) = 0$$

$$\Rightarrow E_b = V - 2 I_a R_a = 0$$

$$\therefore V - 2 I_a R_a = 0$$

$$\Rightarrow V = 2 I_a R_a$$

or, $\boxed{I_a R_a = \frac{V}{2}}$

$\therefore$ Putting the value of $I_a R_a$ equals to V.

i.e. $E_b = V^2 - I_a R_a = V - \frac{V}{2}$

$\Rightarrow \boxed{E_b = \frac{V}{2}}$

which is the condition for maximum power developed in a d.c. motor.

(b) Derive the condition for maximum efficiency in a dc generator.

Ans. Condition for maximum efficiency in a DC Generator:

Generator output = $V.I_L$

where V = Load voltage

I_L = Load current

Generator i/p = output + losses

Total losses = Variable losses + Constant losses

$= I_a^2R_a + W_c$

Generator i/p $= VI_L + I_a^2R_a + W_c$

∴ The shunt field current 'I_{sh}' is generally small as compared to 'I_L', and $\boxed{I_a = I_L}$ therefore can be neglected.

∴ General i/p $= VI_L + I_a^2R_a + W_c$

$$\therefore \eta = \frac{\text{Output}}{\text{Input}} = \frac{VI_L}{VI_L + I_a^2R_a + W_C}$$

$$= \frac{(VI_L/VI_L)}{\left(\frac{VI_L + I_a^2R_a + W_C}{V.I_L}\right)} = \frac{1}{\left(1 + \frac{I_a^2R_a}{VI_L} + \frac{W_c}{VI_L}\right)}$$

$$= \frac{1}{1 + \left(\frac{I_a^2R_a}{VI_L}\right) + \frac{W_c}{VI_L}}$$

$$= \frac{1}{1 + \left(\frac{I_aR_a}{V} + \frac{W_c}{V.I_L}\right)} \quad ...(i)$$

The efficiency will be maximum when the denominator of equation (i) is minimum

$$\frac{d}{dI_L}\left(\frac{I_aR_a}{V} + \frac{W_c}{VI_L}\right) = 0$$

$$\Rightarrow \frac{d}{dI_L}\left(\frac{I_LR_a}{V} + \frac{W_c}{VI_L}\right) = 0 \quad (\because I_L = I_a)$$

$$\Rightarrow \frac{R_a}{V} - \frac{W_c}{V.I_L^2} = 0$$

$$\Rightarrow \frac{W_c}{V.I_L^2} = \frac{R_a}{V}$$

$$\Rightarrow \boxed{W_c = I_L^2R_a = I_a^2R_a}$$

i.e., $\boxed{\text{Variable loss} = \text{Constant loss}}$.

(c) An 8-pole dc shunt generator with 778 wave connected armature conductors and running at 500 rpm supplies a load of 12.5Ω resistance at terminal voltage of 250 V. The armature resistance is 0.24Ω and field resistance is 250Ω. Find the armature current induced emf and flux per pole.

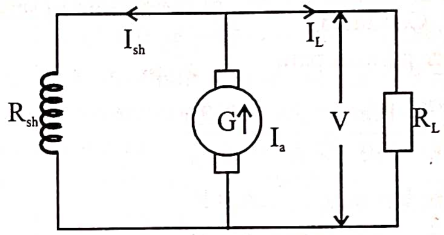
Ans. Given data:

$P = 8, Z = 778, N = 500$ rpm,

$R_L = 12.5\ \Omega, V = 250$ volt,

$R_a = 2.24\ \Omega, R_{sh}\ 250\ \Omega,$

$A = Z$ (Wave connected)



$$I_L = \frac{V}{R_L} = \frac{250}{12.5} = 20\text{ A.}$$

$$I_{sh} = \frac{V}{R_{sh}} = \frac{250}{250} = 1\text{A.}$$

$\therefore\ I_a = I_L + I_{sh} = 20 + 1 = 21\text{A.}$

$\therefore\ E_g = V + I_aR_a = 250 + 21 \times 0.24$

$= 250 + 5.04 = 255.04$ V.

As per Emf equation, $E_g = \dfrac{P\phi zN}{60A}$

$$\Rightarrow \phi = \frac{E_g \times 60A}{p.z.N} = \frac{255.04 \times 60 \times 2}{8 \times 778 \times 500} = 0.00983\text{ Wb. (Ans)}$$

(d) Derive the emf equation of DC Generator.

Ans. Let ϕ = flux/pole in wb

Z = total no. of armature conductors

A = No. of parallel path

N = Speed of arm. in r.p.m.

E_g = Generated emf

Flux cut by one conductor in one revolution of the armature.

$d\phi = P\phi$ weber

Time taken to complete one rev.

$$dt = \frac{60}{N} \text{ sec.}$$

$$\text{E.m.f. generated/conductor} = \frac{d\phi}{dt} = \frac{P\phi}{\left(\frac{60}{N}\right)}$$

$$= \frac{P\phi N}{60} \text{ volts.}$$

Emf of generated E_g = emf per parallel path

$$= \frac{\text{Emf}}{\text{Conductor}} \times \text{No. of conductors in series per parallel path}$$

$$E_g = \frac{P\phi n}{60} \times \frac{Z}{A} = \frac{P\phi Zn}{60A}$$

For lap wdg $A = P$

wave wdg $A = 2$

$$\therefore \text{ For lap wdg, } E_g = \frac{\phi Zn}{60}$$

$$\therefore \text{ For wave wdg, } E_g = \frac{p\phi Zn}{120}$$

(e) A 20kVA, 440/220V, 1-ϕ, 50 Hz transformer has iron loss of 324 W. The copper loss is found to be 100 W when delivering half full-load current. Determine:

(i) Efficiency when delivering full-load current at 0.8 pf lagging.

(ii) Percent of full-load kVA when the efficiency will be maximum.

Ans. Given data:

Rating of transformer = 20 kVA = 20 × 10^3 VA

Ratio of voltage = 440/220.

$$\therefore\ k = \frac{220}{440} = \frac{1}{2} = 0.5$$

f = 50 Hz, W_0 = Iron loss = 324 W

At $\frac{1}{2}$ of F.L. i.e. $x = \frac{1}{2}$

Copper loss = $E_{C_{\frac{1}{2}}}$ = 100 W.

(i) $W_{C_{FL}}$ = At F.L. cu.loss = 100 × 4 = 400 W

$\therefore$ Total F.L. losses = $W_0 + W_{C_{FL}}$

$= 324 + 400 = 724$ W = 0.724 kW

F.L. output at 0.8 PF = 20 kVA × PF

$= 20 \times 0.8 = 16$ kW.

% FL efficiency (η_{FL}) at 0.8 PF

$$= \frac{\text{Output}}{\text{Input}} \times 100$$

$$= \frac{16}{16 + 0.724} \times 100 = 95.67\%. \text{ (Ans).}$$

$$\text{(ii)}\quad \frac{\text{kVA for max '}\eta\text{'}}{\text{F.L. kVA}} = \sqrt{\frac{W_0}{E_{C_{FL}}}}$$

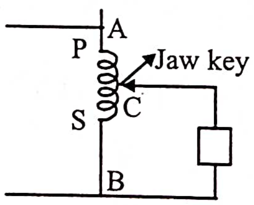
$$= \sqrt{\frac{324}{400}} = 0.9$$

kVA for maximum 'η' = 0.9 × FL kVA

$\therefore$ Efficiency will be maximum at 90% of F.L. kVA. (Ans)

(f) Compare the amount of copper used in between auto-transformer and two-winding transformer of same rating.

Ans. In an auto transformer there is a single winding in which there is a jaw key which can be moved to cut the single winding to both primary and secondary winding.



AC = Primary winding

BC = Secondary winding

but in a two winding Transformer primary and secondary windings are isolated electrically but coupled magnetically with magnetic core.

Wt. of cu. in auto Transformer

$(W_a) \propto N.I.$

$(N_1 - N_2)I_1 + N_2(I_2 - I_1)$

Wt. of Cu. in an ordinary

(W_0) two wdg. transformer $\propto (N_1I_1 + N_2I_2)$

$$\therefore \frac{W_a}{W_0} = \frac{N_1I_1 - N_2I_1 + N_2I_2 - N_2I_1}{N_1I_1 + N_2I_2}$$

$$\text{Or, } \frac{W_a}{W_0} = \frac{N_1I_1 + N_2I_2 - 2N_2I_1}{N_1I_1 + N_2I_2}$$

$$= \frac{\dfrac{N_1I_1 + N_2I_2 - 2N_2I_1}{N_1I_1}}{\dfrac{N_1I_1 + N_2I_2}{N_1I_1}} = \frac{1 + \dfrac{N_2}{N_1} \times \dfrac{I_2}{I_1} - 2\dfrac{N_2}{N_1}.\dfrac{I_1}{I_1}}{1 + \dfrac{N_2}{N_1}.\dfrac{I_2}{I_1}}$$

$$\frac{W_a}{W_0} = \frac{1+1-2k}{1+1} = (1-k)$$

Saving of Cu. by using auto transformer = $W_a - W_a$

$= W_0 - (1-k)W_0$

Saving of Cu. = $W_0(1 - 1 + K) = KW_0$

Thus the comparision between auto-transformer and two-winding transformer regarding amount of copper winding used is well derived.

3. **The total iron loss in a 460V, 50Hz single-phase transformer is 2400W. When a 230V, 25Hz supply is applied, the total iron loss is 800W. Calculate the hysteresis loss and eddy current loss at normal voltage and frequency of 460 V.**

Ans. Given data:

W_{0_1} = 2400 W at supply voltage of V_1 = 460 V and frequency = 50 Hz.

Now W_{0_2} = 800w, when supply voltage is 230V and f = 25 Hz.

W_h = ?, W_e = ? (at normal voltage and frequency)

In a transformer, $\phi_m \propto \frac{V_1}{f_1}$. Since in the second case, voltage as well frequency are halved, therefore $\frac{V_1}{f_1}$ will remain same. Thus ϕ_m will remain same in both the cases.

(i) Total iron loss $P_i = af + bf^2 = w_h + w_c$.

$$\therefore \frac{P_i}{f} = a + bf$$

For Case-1 : $\frac{2400}{50} = a + 50b$ ...(i)

For Case-2 : $\frac{800}{25} = a + 25b$ ...(ii)

Equating equation (i) and (ii)

$a + 50b = 48$

$a + 25b = 32$

$25b = 16 \Rightarrow b = \frac{16}{25} = 0.64$

$\therefore a = 16$

Hysteresis loss (W_h) at 50 Hz

$= af = 16 \times 50 = 800$ W.

Eddy current loss (W_e) at 50 Hz

$= bf^2 = 0.64 \times 50^2 = 1600$ w. (Ans)

4. **A 230 V dc shunt motor runs at 800 rpm and takes armature current of 50A. Find the resistance to be added to the field circuit to increase the speed to 1000 rpm at armature current of 80A. Assume flux proportional to field current. $R_a = 0.15\Omega$ and $R_f = 250\Omega$.**

Ans. Given data :

Case-1 : V = 230 volt, R_{sh} = 250 W

N_1 = 800 rpm, I_{a_1} = 50A

$$I_{sh_1} = \frac{V}{R_{sh}} = \frac{230}{250}$$

$\boxed{\phi_1 \propto I_{sh_1}}$

$\therefore \boxed{E_{b_1} \propto \phi_1 N_1}$

$\therefore E_{b_1} = V - I_{a_1}R_a = 230 - 50 \times 0.15$

$= 230 - 7.5 = 222.5$ V.

Case-2 : N_2 = 1000 rpm

Hence it is the flux control method $(\because N_2 > N_1)$

$E_{b_2} = V - I_{a_2}R_a = 230 - 80 \times 0.15$

$= 230 - 12 = 218$V.

$\phi_2 \propto I_{sh_2}$

$$\therefore I_{sh_2} = \frac{V}{R_{sh} + R} = \frac{230}{250 + R}$$

As $E_b \propto \phi N$

$$\therefore \frac{E_{b_2}}{E_{b_1}} = \frac{\phi_2 N_2}{\phi_1 N_1}$$

$$\Rightarrow \frac{218}{222.5} = \frac{\left(\frac{230}{250+R}\right)\times 1000}{\left(\frac{230}{250}\right)\times 800}$$

$$\Rightarrow \frac{218}{222.5} = \frac{230}{250+R} \times \frac{250}{230} \times \frac{1000}{800}$$

$$\Rightarrow 250 + R = \frac{250 \times 1000 \times 222.5}{218 \times 800} = 318.95$$

$$\Rightarrow R = 318.95 - 250 = 69.95\Omega. \text{(Ans)}$$

5. A 20 kVA, 1-ϕ, 50Hz, 2200/200V transformer gave the following results :

OC Test : 2200V applied to primary, Power = 220W.

SC Test : Power required to circulate full-load current in SC secondary 240W.

Calculate the efficiency at full-load and half-load at pf 0.8 lagging.

Ans. According to question:

At FL, 0.8 PF lagging :

Output = kVA cos ϕ = 20 × 0.8 = 16 kW

= 16 × 10^3W.

W_0 = Iron loss = 220 W

W_C = Copper loss = 240 W.

Total losses = 220 +240= 460 W.

Input = Output + total losses.

= 16000 + 460 = 16460 W

$$\therefore \text{F.L. efficiency}(\eta_{FL}) = \frac{\text{output}}{\text{input}} \times 100$$

$$= \frac{16000}{16460} \times 100 = 97.21\%.$$

At half FL, 0.8 PF lagging :

$$\text{Copper losses} = W_{C_{\frac{1}{2}}} = \left(\frac{1}{2}\right)^2 \times 240 = 60\text{W}.$$

Iron losses = W_0 = same = 220 W

Total losses = 60 + 220 = 280 W

$$\text{Output at this load} = \frac{20\text{ kVA}}{2} \times \cos\phi$$

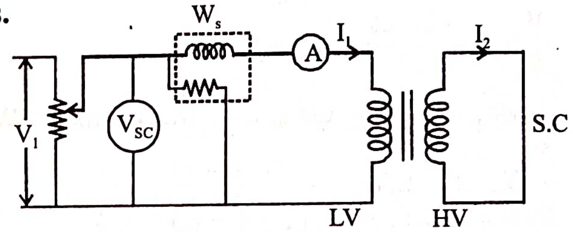
= 10 × 0.8 = 8 kw = 8000 W

$\therefore$ Input = 8000 + 280 = 8280 W

$$\therefore '\eta' = \frac{8000}{8280} \times 100 = 96.63\%. \text{ (Ans)}$$

6. Explain short-circuit test of 1-ϕ transformer.

Ans.



This test is performed to determine R_{01}, X_{01} and f.l. Cu. losses of the transformer. Usually this test is performed at H.V. side and l.V. side is short circuited (S.C.). Variable low voltage is applied at the i/p by using a variac.

i.e. 2 – 4% of rated voltge is applied at the i/p

V_{SC} = volt meter reading of this voltage.

The watt meter will read f.l. Cu. losses of the transformer wdg.

W_S = wattmeter reading

I_1 = f.l. primry current

$$\therefore W_S = P_C = I_1^2 R_1 + I_1^2 R_2{}^1 = I_1^2 (R_1 + R_2{}^1) = I_1^2 R_{01}$$

$R_2{}^1 \rightarrow$ is the resistance ref. to pri.

$$\therefore R_{01} = \frac{P_C}{I_1^2}$$

$$\text{Similarly } Z_{01} = \frac{V_{SC}}{I_1} = \text{impedance of the coil.}$$

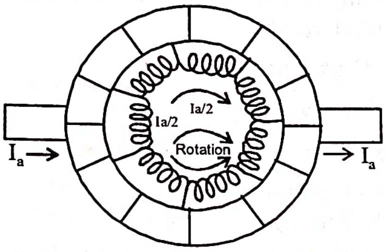
$$\therefore X_{01} = \sqrt{Z_{01}^2 - R_{01}^2} = \text{leakage reactance of the wdg.}$$

S.C. power factor (PF) = cos ϕ_S

$$= \frac{P_C}{V_{SC} I_1} \text{ can be also determined.}$$

7. **Explain about the process of communication in DC machines.**

Ans. The reversal of current in a coil as the coil passes the brush axis is called *Commutation.* When commutation takes place, the coil under going commutation is short circuited by the brush. Let us consider a z-pole lap wound d.c. generator. There are two parallel paths (A = p = 2) between the brushes. Therefore, each coil of the wdg. Carries one half $\left(I_a/2\right)$ of the total current (I_a) entering or leaving the armature. It is being represented in figure.



Note that the currents in the coils connected to a brush are either all towards the brush (+ve brush) or all directed away from the brush (–ve brush).

Therefore, current in a coil will reverse as the coil passes a brush. This reversal of current as the coil passes a brush is called *commutation*.

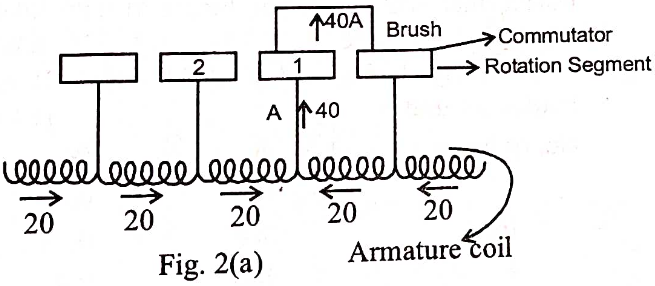


Fig. 2(a)

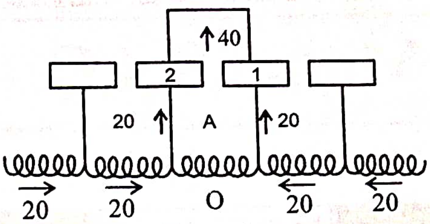


Fig. 2(b)

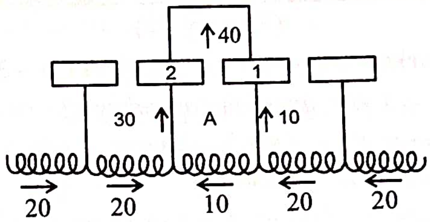


Fig. 2(c)

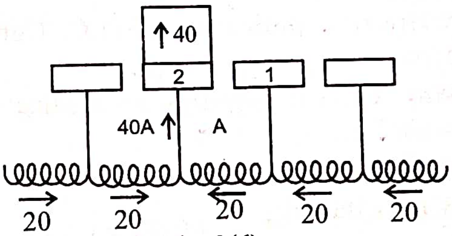


Fig. 2(d)

In figure 2 (a) the brush is getting 40A from coil-A.

In figure 2 (b) the brush is getting a current of 40A. i.e. it gets 20A from-A and 20A from-adjacent coil. In figure 2 (c) it gets 30A through segment-2 & 10A through-1. Lastly in figure 2(d) the brush is getting a current of 40A from segment-2. Thus the coil-A has under gone *communation*. Each coil under goes commutation in this way as it passes the brush axis.

MODEL - 1

(Theory - 1)

Full Marks - 80 **Time - 3 Hours**

*Answer any **five** questions including Q. No. 1 & 2.*

The figures in the right-hand margin indicate marks.

1. Answer *all* questions : [$2 \times 10 = 20$

(a) State the different types of losses which occurs in transformer.

(b) Write the application of D.C. Compound Motor.

(c) Why starter is necessary for starting of D.C. motor ?

(d) What is voltage regulation in 1ϕ transformer ?

(e) What is Burden ?

(f) Define 'Ratio Error' in current transformer.

(g) What is all day efficiency ?

(h) What is critical resistance of a D.C. shunt generator ?

(i) Show the phasor representation of a pure resistive load.

(j) What is the essential difference between lap and wave windings ?

2. Answer any *six* from the following : [$5 \times 6 = 30$

(a) Derive the torque equation of D.C. motor.

(b) Explain the commutation process in D.C. Generator.

(c) Derive the condition for maximum efficiency of a transformer.

(d) A 4 pole, 220 V shunt motor has 540 lap-wound conductor. It takes 32 A from the supply mains and develops output power of 5.595 kW. The field winding takes 1 A. The armature resistance is 0.09 Ω and the flux per pole is 30 mWb.

Calculate :

(i) the speed and

(ii) the torque developed in N-M.

(e) Derive the e.m.f. equation of DC Generator.

(f) A 30 kVA, 2400/120 V, 50 Hz transformer has a high voltage winding resistance of 0.1 Ω and a leakage reactance of 0.22 Ω. The low voltage winding resistance is 0.035 Ω and the leakage reactance is 0.012 Ω. Find the equivalent winding resistance, reactance and impedance referred to the

(i) High voltage side

(ii) Low voltage side.

Answer any *three* from the following : [$3 \times 10 = 30$

3. A shunt generator has F.L. current of 196 A at 220 V. The stray losses are 720 W and the shunt field coil resistance is 55 Ω. If it has a F.L. efficiency of 88%. Find the armature resistance. Also find the load current corresponding to maximum efficiency. [10

4. Explain all day efficiency of a transformer. Find the all day efficiency of 500 kVA distribution transformer whose copper loss and iron loss at full load are 4.5 kW and 3.5 kW respectively during a day of 24 hours. It is loaded as under [10

No. of hours	Loading in kW	P.F.
6	400	0.8
10	300	0.75
4	100	0.8

5. Explain the working principle of current transformer. [10

6. An autotransformer supplies a load of 5 kW at 110 volt at unity power factor. If the applied primary voltage is 220 volt, calculate the power transferred to the load (i) inductively (ii) conductively. [10

ANSWER TO MODEL - 1

1.(a) State the different types of losses which occurs in transformer.

Ans. Different types of losses occurs in a transformer are :

(i) Core loss or iron loss.

(ii) Copper loss

Core loss is of two types i.e. eddy current and hysteresis loss. Copper loss is the variable loss.

(b) Write the application of D.C. Compound Motor.

Ans. Applications of D.C. Compound Motor: Differential compounded d.c. motors are rarely used but cumulative compounded d.c. motors are used where a fairly constant speed is required with irregular loads or suddenly applied heavy loads i.e., the industrial uses are :

(i) Presses
(ii) Shearing machines.
(iii) Punching machines.
(iv) Reciprocating machines
(v) Ice mills etc.

(c) Why starter is necessary for starting of D.C. motor ?

Ans. At the time of starting

$E_b = 0$ but $E_b = V - I_a R_a$

i.e. $0 = V - I_a R_a$

or $\boxed{I_a = \frac{V}{R_a}}$

as R_a is small say 0.1 Ω

$V = 220$ V (dc)

$$\therefore I_a = \frac{220}{0.1} = 2200 \text{ A}$$

∴ At starting the current is too high & this high current of 2200A will damage most of the parts such as armature, commutator etc. and in order to reduce this current starters are needed in dc motors.

(d) What is voltage regulation in 1ϕ transformer ?

Ans. The voltage regulation (V.R) of a transformer is the arithmetic difference between the no-load secondary voltage and secondary voltage on load expressed as % of no-load voltage.

$$\text{Mathematically : } \%\text{V.R.} = \frac{{}_0V_2 - V_2}{{}_0V_2} \times 100$$

where ${}_0V_2$ = No-load secondary voltage

V_2 = load secondary voltage

For leading PF of the load, V.R. is -ve but +ve for other loads.

(e) What is Burden ?

Ans. Burden : The rated *burden* is the volt-ampere loading which is permissible without errors exceeding the limits for the particular class of accuracy.

Total secondary burden

$$= \frac{(\text{Sec. wdg. induced voltage})^2}{\left(\begin{array}{l}\text{Impedance of the sec. wdg} \\ \text{ckt. including impedance of sec. wdg}\end{array}\right)}$$

(f) Define 'Ratio Error' in current transformer.

Ans. Ratio error in C.T. : Ratio error is defined as the difference of nominal ratio & actual ratio divided by actual ratio.

$$i.e., \text{Ratio error} = \frac{\text{Nominal ratio} - \text{actual ratio}}{\text{actual ratio}}$$

It is also expressed in percentage (%).

(g) What is all day efficiency ?

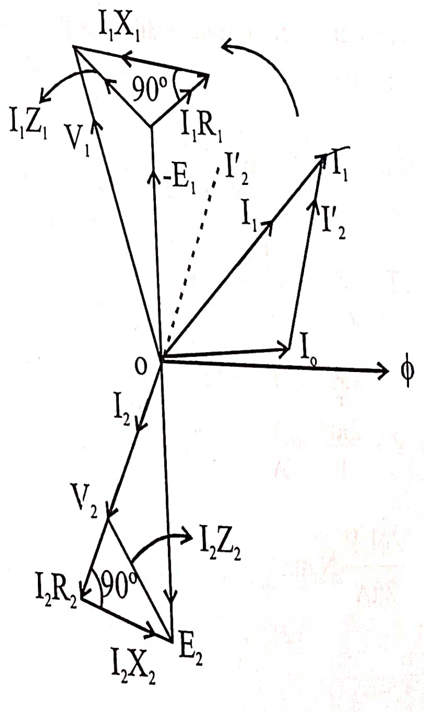
Ans. The all day efficiency of transformer is the ratio of kwh o/p in 24 hours to the kwh i/p in 24 hours

(h) What is critical resistance of a D.C. shunt generator ?

Ans. Critical resistance in a D.C. shunt generator is the max. field resistance (for a given speed) with which the shunt generator would just excite. The critical field resistance should be always more than the field. CKT resistance so that the d.c. generator will build up.

(i) Show the phasor representation of a pure resistive load.

Ans.



(j) What is the essential difference between lap and wave windings ?

Ans. In a lap wdg, the commutator pitch is 1 where as for a wave wdg. it is about twice the pole pitch.

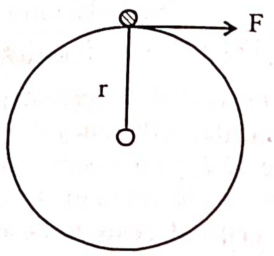
2.(a) Derive the torque equation of D.C. motor.

Ans. Let T_a = armature torque of a dc motor.

Consider the armature rotating with a speed of N rpm & the force experienced on each conductor = F = Bil newton.

Torque developed in a DC motor

Torque is the turning moment of a force about an axis and is measured by the product of force (F) and radius (r) at right angle to which the force acts as



$T = F \times r$

In a dc motor, each conductor is acted upon by a Circumferential force (F) at a distance (r)

∴ Each conductor exerts a torque tending to rotate the armature.

F = Bil Newton.

Torque in each conductor = Bil × r

Total armature torque = Bil × r × Z

= z Bil r

Now $i = \frac{I_a}{A}$, $B = \frac{\phi}{a}$

$$\therefore T_a = Z \times \frac{\phi}{a} \times \frac{I_a}{A} \times \ell \times r$$

$$= Z \times \frac{\frac{\phi}{\frac{2\pi r\ell}{P}}}{} \times \frac{\frac{I}{a}}{A} \times \ell \times r$$

$$= \frac{Z\phi I_a P}{2\pi A} \text{ N.m}$$

$$\therefore \boxed{T_a = \frac{1}{2\pi}\phi z I_a\left(\frac{P}{A}\right)} \text{ N.m}$$

Where I_a = armature current

ϕ = flux/pole, z = Armature conductors

A = No. of paralled path.

where N = rps.

Similarly $\boxed{E_b = \frac{p\phi zN}{60A}}$

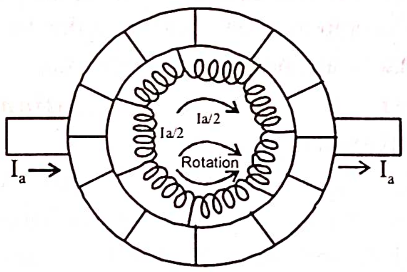
$$\Rightarrow \frac{P\phi z}{A} = \frac{60 \times E_b}{N}$$

$$\therefore T_a = 0.159 \times \left(\frac{60 \times E_b}{N}\right) \times I_a$$

$$= 9.55 \frac{E_b I_a}{N} \text{ N.m.}$$

(b) Explain the commutation process in D.C. Generator.

Ans. The reversal of current in a coil as the coil passes the brush axis is called *Commutation.* When commutation takes place, the coil under going commutation is short circuited by the brush. Let us consider a z-pole lap wound d.c. generator. There are two parallel paths (A = p = 2) between the brushes. Therefore, each coil of the wdg. Carries one half $\left(I_a/2\right)$ of the total current (I_a) entering or leaving the armature. It is being represented in figure.



Note that the currents in the coils connected to a brush are either all towards the brush (+ve brush) or all directed away from the brush (–ve brush).

Therefore, current in a coil will reverse as the coil passes a brush. This reversal of current as the coil passes a brush is called *commutation.*

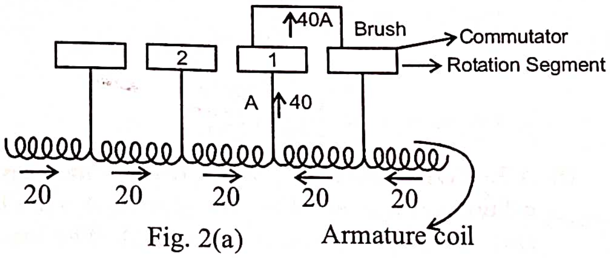


Fig. 2(a)

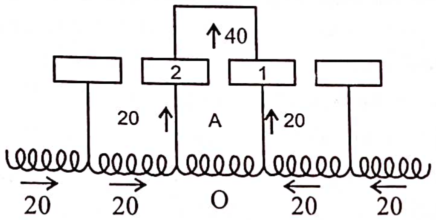


Fig. 2(b)

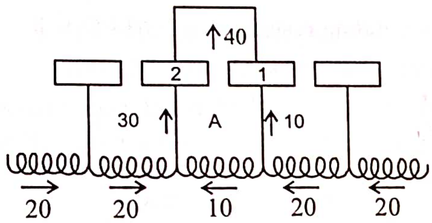


Fig. 2(c)

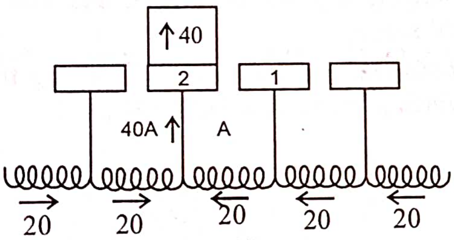


Fig. 2(d)

In figure 2 (a) the brush is getting 40A from coil-A.

In figure 2 (b) the brush is getting a current of 40A. i.e. it gets 20A from-A and 20A from-adjacent coil. In figure 2 (c) it gets 30A through segment-2 & 10A through-1. Lastly in figure 2(d) the brush is getting a current of 40A from segment-2. Thus the coil-A has under gone *communation*. Each coil under goes commutation in this way as it passes the brush axis.

(c) Derive the condition for maximum efficiency of a transformer.

Ans. Efficiency of a transformer (Full load)

$$= \frac{\text{Full load VA} \times \text{PF}}{(\text{Full load VA}) \times \text{PF} + P_i + P_C}$$

$$= \frac{V_2 I_2 \cos\phi_2}{V_2 I_2 \cos\phi_2 + P_i + I_2^2 R_{02}}$$

$$= \frac{V_2 \cos\phi_2}{V_2 \cos\phi_2 + \frac{P_i}{R_2} + I_2 R_{02}}$$

Condition for maximum efficiency is that

$$\frac{d}{dI_2}(\text{denominator}) = 0 \quad (V_2 \rightarrow \text{const})$$

$$\therefore \frac{d}{dI_2}\left(V_2 \cos\phi_2 + \frac{P_i}{I_2} + I_2 R_{02}\right) = 0$$

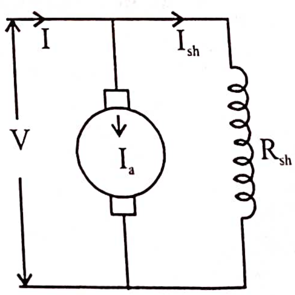
$$\text{or, } 0 - \frac{P_i}{I_2^2} + R_{02} = 0$$

$$\text{or, } P_2 = I_2^2 R_{02}$$

$\Rightarrow$ Iron loss = Cu. loss

(d) A 4 pole, 220 V shunt motor has 540 lap-wound conductor. It takes 32 A from the supply mains and develops output power of 5.595 kW. The field winding takes 1 A. The armature resistance is 0.09 Ω and the flux per pole is 30 mWb.
Calculate :
(i) the speed and
(ii) the torque developed in N-M.

Ans. Given data,
$P = 4$, $V = 220$ volt, $z = 540$, $I = 32$ A,
$P_{o/p} = 5.595$ kw, $I_{sh} = 1$A, $R_a = 0.09\ \Omega$,
$\phi = 30$ mwb $= 30 \times 10^{-3}$ wb,
$A = P = 4$ (lap winding).



(i) $I_a = I - I_{sh} = 32 - 1 = 31$ A

$E_b = V - I_a R_a$

$= 220 - 31 \times 0.09 = 220 - 2.71 = 217.29$V.

According to formula,

$$E_b = \frac{P\phi ZN}{60A} \Rightarrow N = \frac{E_b \times 60A}{P\phi Z}$$

$$= \frac{217.29 \times 60 \times 4}{4 \times 30 \times 10^{-3} \times 540} = 804.77 \text{ rpm.}$$

(ii) Torque developed in N.m. = ?

$$T = 9.55 \times \frac{P_{(o/p)}}{N} = 9.55 \times \frac{5.595 \times 10^3}{804.777}$$

$$= 66.39 \text{ N.m.} \quad (\text{Ans})$$

(e) Derive the e.m.f. equation of DC Generator.

Ans. Let ϕ = flux/pole in wb

Z = total no. of armature conductors

A = No. of parallel path

N = Speed of arm. in r.p.m.

E_g = Generated emf

Flux cut by one conductor in one revolution of the armature.

$d\phi = P\phi$ weber

Time taken to complete one rev.

$$dt = \frac{60}{N} \text{ sec.}$$

$$\text{E.m.f. generated/conductor} = \frac{d\phi}{dt} = \frac{P\phi}{\left(\frac{60}{N}\right)}$$

$$= \frac{P\phi N}{60} \text{ volts.}$$

Emf of generated E_g = emf per parallel path

$$= \frac{\text{Emf}}{\text{Conductor}} \times \text{No. of conductors in series}$$

per parallel path

$$E_g = \frac{P\phi n}{60} \times \frac{Z}{A} = \frac{P\phi Zn}{60A}$$

For lap wdg $\quad A = P$

wave wdg $\quad A = 2$

$$\therefore \text{For lap wdg, } E_g = \frac{\phi Zn}{60}$$

$$\therefore \text{For wave wdg, } E_g = \frac{p\phi Zn}{120}$$

(f) A 30 kVA, 2400/120 V, 50 Hz transformer has a high voltage winding resistance of 0.1 Ω and a leakage reactance of 0.22 Ω. The low voltage winding resistance is 0.035 Ω and the leakage reactance is 0.012 Ω. Find the equivalent winding resistance, reactance and impedance referred to the

(i) High voltage side

(ii) Low voltage side.

Ans. Rating of the transformer = 30 kVA.

Voltage ratio = 2400/120 V, f = 50 Hz

HV winding resistance = 0.1 Ω = R_1

L leakage reactance = 0.22 Ω = X_1

LV winding resistance = 0.035 Ω = R_2

Leakage reactance = 0.012 Ω = X_2

(i) Therefore equivalent resistance, reactance and impedance reference to HV side will be found as follows :

$$\text{Here, } K = \frac{120}{2400} = \frac{1}{20} = 0.05$$

Here primary side is HV side and secondary is LV side.

Resistance reference to HV winding from LV winding i.e., ref to primay = R'_2.

$$= \frac{R_2}{K^2} = \frac{0.035}{\left(\frac{1}{20}\right)^2} = 400 \times 0.035 = 14\Omega$$

$$\therefore R_{01} = R_1 + R'_2 = 0.1 + 14 = 14.1\ \Omega$$

$$\therefore X_1^2 = \frac{X_2}{K^2} = \frac{0.012}{\left(\frac{1}{20}\right)^2} = 400 \times 0.012 \times 4.8\Omega.$$

$$\therefore X_{01} = X_1 + X'_2 = 0.22 + 4.8 = 5.02\ \Omega.$$

$$\therefore Z_{01} = \sqrt{R_{01}^2 + X_{01}^2} = \sqrt{14.1 + 5.02^2} = 16\Omega.$$

(ii) Reference to LV side i.e. secondary side

$$R_1^1 = R_1 \times k^2 = 0.1 \times \left(\frac{1}{20}\right)^2 = \frac{0.1}{400} = 0.00025\,\Omega$$

$$X_1^1 = X_1.k^2 = 0.22 \times \frac{1}{400} = 0.00055\,\Omega$$

$$\therefore R_{02} = R_2 + R_1^1 = 0.035 + 0.00025 = 0.03525\,\Omega$$

$$\therefore X_{02} = X_2 + X_1^1 = 0.012 + 0.00055 = 0.01255\,\Omega$$

$$\therefore Z_{02} = \sqrt{R_{02}^2 + X_{02}^2} = \sqrt{0.03525^2 + 0.01255^2} = -\Omega.$$

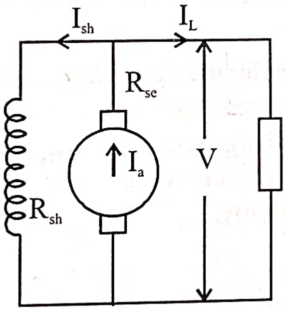
3. **A shunt generator has F.L. current of 196 A at 220 V. The stray losses are 720 W and the shunt field coil resistance is 55 Ω. If it has a F.L. efficiency of 88%. Find the armature resistance. Also find the load current corresponding to maximum efficiency.**

Ans. Given data,

I_{FL} = FL current = 196 A, V = 220 volt

Stray losses = 720W, R_{sh} = 55 Ω, η_{FL} = 0.88,

R_a = ?, I_L corresponding to η_{max}.



$$\therefore I_{sh} = \frac{V}{R_{sh}} = \frac{220}{55} = 4A$$

$\therefore I_a = I_{FL} + I_{sh}$ = 196 + 4 = 200 A.

Generator output power = $V.I_{FL}$

= 220 × 196 = 43120 W = 43.12 kW.

Power input = output power + total losses.

$$\therefore \eta = \frac{\text{Output power}}{\text{Input power}}$$

$$\Rightarrow 0.88 = \frac{43120}{\text{Output power} + \text{Total losses}}$$

$$= \frac{43{,}120}{43{,}120 + \text{Total losses}}$$

$\therefore$ 43,120 × 0.88 + 0.88 × total losses = 43,120

$$\Rightarrow \text{Total losses} = \frac{43{,}120(1-0.88)}{0.88} = 6468 \text{ watt.}$$

Total losses = (constant losses) + (variable losses)

= (shunt feild losses + stray losses) + (armature cu.losses) = (I^2_{sh} R_{sh} + 720) + (I^2_a R_a)

$\Rightarrow$ I^2_a R_a = Total losses – I^2_{sh} R_{sh} – 720

= 6468 – 4^2 × 55 – 720 = 4868

$$\therefore R_a = \frac{4868}{I_a^2} = \frac{4868}{200^2} = 0.1217\,\Omega. \text{ (Ans)}$$

Under maximum 'η' condition,

constant losses = variable losses.

i.e., shunt field cu.losses + stray losses = I^2_a R_a.

i.e., I^2_{sh} R_{sh} + 720 = I^2_a × 0.1217

$\therefore$ 4^2 × 55 + 720 = I^2_a × 0.1217

$$\therefore I_a^2 = \frac{16 \times 55 + 720}{0.1217} = 13{,}147$$

$$\therefore I_a = \sqrt{13{,}147} = 114.5A$$

$\therefore$ Load current (I_L) = $I_a - I_{sh}$ = 114.5 – 4 = 110.5A.

$\therefore$ Load current corresponding to maximum 'η' = 110.5 A.

4. **Explain all day efficiency of a transformer. Find the all day efficiency of 500 kVA distribution transformer whose copper loss and iron loss at full load are 4.5 kW and 3.5 kW respectively during a day of 24 hours. It is loaded as under**

No. of hours	Loading in kW	P.F.
6	400	0.8
10	300	0.75
4	100	0.8

Ans. The all day efficiency of transformer is the ratio of kwh o/p in 24 hours to the kwh i/p in 24 hours

Rating of transformer = 500 kVA.

(i) When time = 6 hours, PF = 0.8

$\therefore$ Output load = 500 kVA × 0.8 = 400 kW

$\therefore$ It is the full load condition i.e.,

$$x = \text{fraction of load} = \frac{400 \text{ kw}}{400 \text{ kw}} = 1$$

W_0 = iron loss at full load = 4.5 kW

W_{cu} = FL cu. loss i.e., at (400 kw) = $x^2 W_c$

$= 1^2 \times 3.5 = 3.5$ kw

$\therefore$ Total loss = $W_0 + W_{cu} = 4.5 + 3.5 = 8$ kW

(ii) W_0 = 4.5 5 kw (same), PF = 0.75

FL o/p = 500 kVA × 0.75 = 375 kw

$$x = \frac{300 \text{ kw}}{300 \text{ kw}} = 0.8$$

$\therefore W_{cu} = x^2 w_c = 0.8^2 \times 3.5 = 2.24$ kw.

$\therefore$ Total loss = 4.5 + 2.24 = 6.75 kw.

(iii) When load 100 kw, PF = 0.8

$x = \frac{100}{400} = 0.25$, o/p (FL) = 500 kVA × 0.8 = 400 kW.

$W_0 = 4.5$ kw

$\therefore W_{cu} = x^2 w_c = 0.25^2 \times 3.5 = 0.21875$ kw

$= 0.22$ kw (say).

$\therefore$ Total loss = 4.5 + 0.21875 = 4.5 + 0.22 kw

= 4.72 kW.

Total losses in 24 hours.

= (8 × 6 + 6.74 × 10 + 4.72 × 4)

= (48 + 67.4 + 18.88) = 134.28 kwh.

Output at 0.8 PF :

$\therefore$ In 24 hours = 400 kw × 6 = 2400 kwh.

Outout at 0.75 PF :

i.e., In 24 hours = 300 kw × 10 = 3000 kwh

Output at 0.8 PF at 100 kw and o/p = 100 kw × 4 = 400 kwh.

$\therefore$ Total o/p = 2400 + 3000 + 400 = 5800 kwh (in 24 hours).

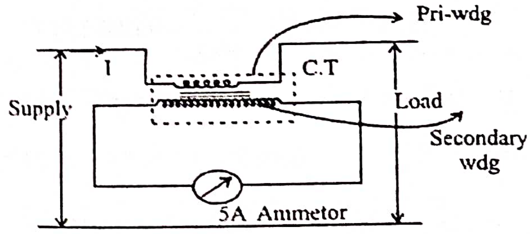
$$\therefore \text{All day '}\eta\text{'} = \frac{\text{Output in 24 hours.}}{\text{Output in 24 hours + Total losses in 24 hours}}$$

$$\therefore \eta_{\text{all day}} = \frac{5800}{5800 + 134.28} \times 100$$

$$= \frac{5800}{5931.58} \times 100 = 97.7\%. \quad \text{(Ans)}$$

5. Explain the working principle of current transformer.

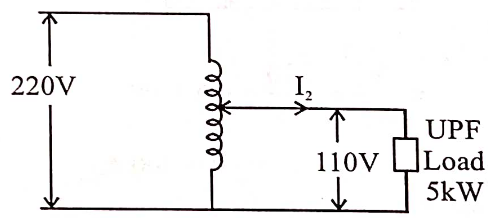
Ans. Working principle



The principle of C.T. is connected to the main supply and load when under normal operating conditions the secondary wdg. of the C.T. is connected to its burden and the sec. is closed under fault conditions when there is a severe current in the i/p, the pri. wdg. will receive that amount of current and C.T. has ratio of say 100 : 1, 100 : 5 etc thus the current will be now steped down to that ratio. The sec. wdg. is connected across an ammeter of low range i.e., say 5A. Hence the large amount of current is now substantially reduced to safe value of thus the load side is protected. Again the sec. side of C.T. is never open circuited. In this way it acts as a measuring instrument.

6. An autotransformer supplies a load of 5 kW at 110 volt at unity power factor. If the applied primary voltage is 220 volt, calculate the power transferred to the load (i) inductively (ii) conductively.

Ans.



Here $K = \frac{110}{220} = 0.5$

Load paper in VA

$= V_2 I_2 \cos\phi_2$

$$\therefore \text{Load power in VA} = \frac{5000\text{w}}{\cos\phi_2}$$

$$= \frac{5000w}{1}$$
$= 5000$ VA
$= 5$ KVA.

$\therefore$ I_2 = Secondary current $= \frac{5000VA}{V_2}$

$$= \frac{5000}{110}$$

$$= \frac{500}{11} A.$$

$\therefore$ Primary Current $= I_1 = K.\ I_2 = 0.5 \times \frac{500}{11}$

$$= \frac{250}{11} A .$$

$\therefore$ Power input $= V_1 I_1 = 220 \times \frac{250}{11}$

$= 5000$ VA.

$\therefore$ Power transferred inductively
$= (1 - k) \times$ input
$= (1 - 0.5) \times 5$ KVA $= 2.5$ KVA.

$\therefore$ Power transferred conductively
$= 5$ KVA $- 2.5$ KVA
$= 2.5$ KVA. **(Ans)**

MODEL - 2

(Theory - 1)

Full Marks - 80 **Time - 3 Hours**

*Answer any **five** questions including Q. No. 1 & 2.*
The figures in the right-hand margin indicate marks.

1. Answer *all* questions : [$2 \times 10 = 20$

(a) What is back emf in a d.c. motor ?

(b) What is all day efficiency ?

(c) Why transformer rating is in kVA ?

(d) What is commutation ?

(e) Why starter is necessary for starting of D.C. motor ?

(f) A 50 kw, 440 V, Shunt generator having an armature circuit resistance including inter-pole wdg. of 0.15Ω at normal working temp. was run as a shunt motor on no-load at rated voltage and speed. The total current drawn by the motor was 5A including shunt field current of 1.5 A. Calculate the efficiency of the shunt generator at $\frac{3}{4}$ the f.l.

(g) What is the difference between a power and distribution transformer ?

(h) What purpose is served by the pole shoe in a dc m/c

(i) The greatest percentage of heat loss in a dc m/c is due to what ?

(j) Which of the DC shunt motor speed control method gives the new speed above rated speed.

2. Answer any six from the following : [$5 \times 6 = 30$

(a) State use of C.T. and P.T.

(b) A 120 volt, d.c. shunt motor has an armature resistance of 0.2 Ω and a field resistance of 60 Ω. The full-load line current is 60 A and full-load speed is 1500 r.p.m. If the brush contact drop is 3 V, find the speed of the motor at half-load.

(c) A 50 kVA, 6360/240 V, 50 Hz two winding transformer gave the following test results for measurements on h.v. side.

O.C. Test : 6360 V, 1 A, 2000 W

S.C. Test : 180 V, 6.6 A, 1000 W

Find : (i) Parameters as referred to high voltage side, (ii) Regulation and efficiency at full-load 0.8 p.f. lagging.

(d) Derive the emf equation of a transformer.

(e) What is critical speed of a d.c. shunt generator ? Also explain the condition for voltage development.

(f) Why cooling of transformer is necessary and how it can be cooled ?

Answer any *three* from the following : [$3 \times 10 = 30$

3. Two 1100/400 V, single-phase transformers have total equivalent impedances of $(0.2 + j\,0.5)$ Ω and $(0.3 + j0\,.6)$ referred to the secondary side. They are connected in parallel and supply a load of 50 kW at a power factor of 0.85 lagging. Find (i) the magnitudes of their secondary currents (ii) the power delivered by each transformer. [10

4. A dc shunt generator delivers full load current of 200 A at 240 V. The shunt field resistance is 60 Ω and full load 'η' is 90%. the rotational losses are 800 w. Find. [10

(i) Armature resistance

(ii) Current at which max^{m} efficiency occurs ?

5. A 400 kVA transformer has an iron loss of 2kw and the maximum efficiency at 0.8 pf occurs when the load is 240 kw. Calculate [10

(i) The maximum efficiency at unity PF

(ii) The efficiency on f.I. at 0.71 PF lagging.

6. Design the resistance sections of a seven-stud starter for 36.775 kW, 400 V d.c. shunt motor. Full-load efficiency is 92% and total cu-losses are 5%. of the input. Shunt field resistance is 200 Ω. The lower limit of the current through the armature is to be the full-load value. [10

ANSWER TO MODEL - 2

1.(a) What is back emf in a d.c. motor ?

Ans. It is also called as counter emf which acts in the opposite direction to applied voltage. It is always less than the applied voltage (v). It helps for the armature current (I_a) to flow against 'v'.

$$\therefore E_b = V - I_a R_a$$

and $\therefore E_b = \dfrac{P\phi zN}{60A}$

(b) What is all day efficiency ?

Ans. The all day efficiency of transformer is the ratio of kwh o/p in 24 hours to the kwh i/p in 24 hours

(c) Why transformer rating is in kVA ?

Ans. Transformer rating is in kVA due to following reasons :

(i) The losses i.e., iron loss depends upon voltage and copper loss depends upon current and thus the total loss depend upon voltage and current i.e., voltampere and the power factor (PF) of a transformer is independent of load.

(ii) Another point is that during manufacturing of a transformer, the manufacturer does not know the type of load to be used by the user and thus load PF has no impact on power rating and therefore the rating mentioned by the concern is VA a kVA.

(d) What is commutation ?

Ans. Commutation : Commutation is a phenomenon in a d.c. machine in which there is reversal of current in a coil as the coil passes the brush axis. Due to commutation i.e., when it takes place, the coil undergoing commutation is short-circuited by the brush.

(e) Why starter is necessary for starting of D.C. motor ?

Ans. At the time of starting

$E_b = 0$ but $E_b = V - I_a R_a$

i.e. $0 = V - I_a R_a$

or $\boxed{I_a = \dfrac{V}{R_a}}$

as R_a is small say 0.1 Ω

$V = 220$ V (dc)

$$\therefore I_a = \frac{220}{0.1} = 2200 \text{ A}$$

∴ At starting the current is too high & this high current of 2200A will damage most of the parts such as armature, commutator etc. and in order to reduce this current starters are needed in dc motors.

(f) A 50 kw, 440 V, Shunt generator having an armature circuit resistance including inter-pole wdg. of 0.15Ω at normal working temp. was run as a shunt motor on no-load at rated voltage and speed. The total current drawn by the motor was 5A including shunt field current of 1.5 A. Calculate the efficiency of the shunt generator at $\frac{3}{4}$ the f.l.

Ans. No-load Conditions :

No-load i/p power $= VI_0 = 440 \times 5 = 2200$ w

No-load armature $= I_{a_0} = 5 - 1.5 = 3.5$

No-load arm. Cu. loss $= I_{a_0}^2 R_a = (3.5)^2 \times 0.15 = 2$w

$\frac{3}{4}$th f.l. Conditions

F.l. o/p current of generator $= \dfrac{50 \times 10^3}{440} = 113.6$A.

Generator o/p current at $\frac{3}{4}$ th f.l $= \frac{3}{4} \times 113.5$

$= 85.2$ A.

Armature current $= I_a = 85.2 + 1.5 = 86.7$ A

Arm. Cu. loss $= I_a^2 R_a = (86.7)^2 \times 0.15 = 1127.5$ watt

Total losses = Constant losses + Arm. Cu. loss
$= 2198 + 1127.5 = 3225.5$ w

Generator $^{o}\!/_{p}$ at $\frac{3}{4}$th f.l $= \frac{3}{4} \times 50 = 37.5$ kw

Efficiency of the generator at $\frac{3}{4}$ the f.l.

$$= \frac{^{o}\!/_{p}}{^{o}\!/_{p} + \text{losses}} = \frac{37.5\times10^3}{37.5\times10^3 + 3225.5} \times 100$$

$= 91.85\%$ **Ans**

(g) What is the difference between a power and distribution transformer ?

Ans. Distribution transformers are always operated with variable load in 24 hours and it has more losses but in a power transformer the losses are minimum with load constant. Power transformers are used in generation, substations, etc. & they have high efficiency.

(h) What purpose is served by the pole shoe in a dc m/c

Ans. The pole shoe serves the following purpose

(i) They spread out the flux in the air gaps.

(ii) They support the field coils.

(iii) Reluctance of magnetic path is reduced.

(i) The greatest percentage of heat loss in a dc m/c is due to what ?

Ans. Cu. loss because the value of I_a is very large.

(j) Which of the DC shunt motor speed control method gives the new speed above rated speed.

Ans. Field contral or Flux control method.

2.(a) State use of C.T. and P.T.

Ans. Uses of CT:

(i) CTs are used both for the measurements and protection purposes.

(ii) For metering purposes s/s., CTS are installed to measure the electrical energy in a H.T. system.

(iii) In s/s CTS are installed to protect the structure, appliances, transformers against faults.

(iv) In protection of alternators, transformers, transmission lines differential current balance protection will be used by taking the help of CTs.

(v) In measurement of very high current CTs can be used and the high value current is reduced according to CT ratio.

Uses of P.T :

(i) Potential transformers are used for both protection and measurement purposes,

(ii) In substations eitehr in EHT, H.T., P.T.S are used. These will protect the system from over voltages.

(iii) In order to measure vary high voltages, the P.T.S can have reduction ratio and this ratio will convinient for the measurement of such high voltages.

(b) A 120 volt, d.c. shunt motor has an armature resistance of 0.2 Ω and a field resistance of 60 Ω. The full-load line current is 60 A and full-load speed is 1500 r.p.m. If the brush contact drop is 3 V, find the speed of the motor at half-load.

Ans. Given data,

$R_a = 0.2\ \Omega$, $R_{sh} = 60\ \Omega$, $V = 120$ Volt.

$I_{fl} = 60$ A, $N_{fl} = 1500$ rpm, $V_b = 3$V.

Speed at half load = ?

At full-load :

$$I_{sh} = \frac{V}{R_{sh}} = \frac{120}{60} = 2A.$$

$$I_{a_f} = I_{f_l} - I_{sh} = 60 - 2 = 58 \text{ A.}$$

$$E_{b_f} = V - I_{a_f} R_a - V_b$$
$$= 120 - 58 \times 0.2 - 3 = 105.4 \text{ V.}$$

At half load :

I_{sh} = same as that of full load = 2 A.

$T_a \propto \phi I_a$.

In a dc shunt motor ϕ-constant.

$$\therefore \boxed{T_a \propto 'I_a'}$$

$T_{a_f} = 2T_{a_{hf}}$ ('hf' stands for half load)

$$\therefore I_{a_f} = 2 I_{a_{hf}}$$

$$\therefore I_{a_{hf}} = \frac{I_{a_f}}{2} = \frac{58}{2} = 29A.$$

$$\therefore IE_{a_{hf}} = V - I_{a_{hf}} R_a - V_b$$
$$= 120 - 29 \times 0.2 - 3 = 111.2 \text{ V.}$$

According to speed relation,

$$\boxed{N \propto E_b}$$

$$\therefore \frac{N_{hf}}{N_f} = \frac{E_{b_{hf}}}{E_{b_f}}$$

$$\Rightarrow N_{hf} = \frac{E_{b_{hf}}}{E_{b_f}} \times N_f = \frac{111.2}{105.4} \times 1500 = 1582.54 \text{ rpm.}$$

(c) A 50 kVA, 6360/240 V, 50 Hz two winding transformer gave the following test results for measurements on h.v. side.

O.C. Test : 6360 V, 1 A, 2000 W

S.C. Test : 180 V, 6.6 A, 1000 W

Find : (i) Parameters as referred to high voltage side, (ii) Regulation and efficiency at full-load 0.8 p.f. lagging.

Ans. Given data,

O.C. Test : 6360 V, 1A, 2000 W.

SC. Test : 180 V, 6.6 A, 1000 W.

(i) Here H.V. side is primary and it must be referred.

From O.C. Test :

$W_0 = 2000$ W, $I_0 = 1$A, $V_1 = 6360$ V.

$$\therefore W_0 = V_1 I_0 \cos\phi_0 \Rightarrow \cos\phi_0 = \frac{W_0}{V_1.I_0}$$

$$\text{or, } \cos\phi_0 = \frac{2000}{6360 \times 1} = 0.314$$

$\therefore I_w = I_0 \cos\phi_0 = 1 \times 0.314 = 0.314$ A.

$I_m = I_0 \sin\phi_0 = 1 \times 0.949 = 0.949$ A.

$$\therefore R_0 = \frac{V_1}{I_w} = \frac{6360}{0.314} = 20254.77\,\Omega.$$

$$\therefore X_0 = \frac{V_1}{I_m} = \frac{6360}{0.914} = 6958.42\,\Omega.$$

From S.C. Test : $V_{sc} = 180$ V, $I_{sc} = 6.6$ A, $W_{sc} = 1000$ W.

$\therefore V_{sc} . I_{sc} . \cos\phi_s = W_{sc}$.

or $\cos\phi_s = 0.84$

$$Z_{01} = \frac{V_{sc}}{I_{sc}} = \frac{180}{6.6} = 27.27\,\Omega$$

$$R_{01} = \frac{W_{sc}}{I_{sc}^2} = 22.95\,\Omega$$

$$X_{01} = \sqrt{Z_{02}^2 - R_{02}^2} = 14.72\,\Omega.$$

$$I_1 = \text{FL current} = \frac{50,000}{6360} = 7.86 \text{ A.}$$

$\therefore$ F_L v.d. in primary with PF = 0.8 (lag)

$= I_1 (R_{01}\cos\phi_2 + X_{01}\sin\phi_2)$

$= 7.86\,(22.95 \times 0.8 + 14.72 \times 0.6)$

$= 213.73$ V.

Voltage to be applied on the HV side

$= 6380 + 213.73 = 6573.73$ V.

$$\therefore \text{FL regulation} = \frac{213.73}{6360} \times 100 = 3.36\%.$$

Efficiency : $W_0 = 2000$ w, $W_{cu} = 1000$w at FL.

$\therefore$ Total losses at FL = 3000 W

output = 50,000 × cos ϕ_2

= 50,000 × 0.8 = 40,000 W.

Input = 40,000 + 3000 = 43000 W.

$$\therefore \%\eta = \frac{\text{Output}}{\text{Input}} \times 100 = \frac{40,000}{43,000} \times 100 = 93\%.$$

(d) Derive the emf equation of a transformer.

Ans. Emf. equation of 1ϕ transformer

Consider that an alternating voltage (V_1) of frequency (f) is applied to the primary

The sinusoidal flux (ϕ) produced by the primary Can be represented by

$\phi = \phi_m \sin\omega t$

The instantaneous e.m.f. (e_1) induced in the primary is

$$e_1 = -N_1 \frac{d\phi}{dt} = -N_1 \frac{d}{dt}(\phi_m \sin\omega t)$$

$$= -\omega N_1 \phi_m \cos\omega t = -2\pi N_1 \phi_m \cos\omega t$$

$$= 2\pi f N_1 \phi_m \sin(\omega t - 90°)$$

It is clear from the above eqn. that maximum value of induced emf in the primary is

$$E_{m1} = 2\pi f N_1 \phi_m$$

The r.m.s. value of E_1 of the primary e.m.f. is

$$E_1 = \frac{E_{m1}}{\sqrt{2}} = \frac{2\pi f N_1 \phi_m}{\sqrt{2}} = 4.44 f N_1 \phi_m$$

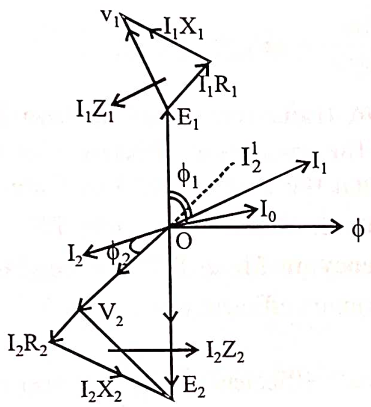
Similarly $\therefore e \propto -\frac{d\phi}{dt}$

$e = -N\ 4.44\ f\phi_m$

or, $\boxed{e = -N\frac{d\phi}{dt}}$ $\therefore E_2 = 4.44\ f\ \phi_m N_2$

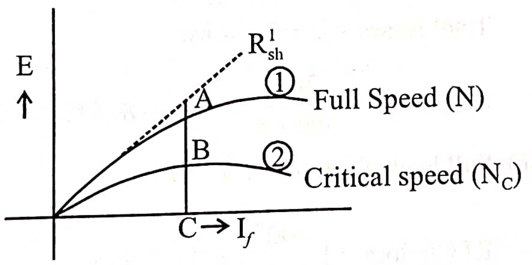
(ii) Draw phasor diagram of transformer having resistive-inductive load.

Ans. Phasor diagram having resistive & inductive load of a transformer :



(e) What is critical speed of a d.c. shunt generator ? Also explain the condition for voltage development.

Ans.



The critical speed of a DC shunt generator is the minimum speed below which it fails to excite clearly, it is the speed for which the given shunt field resistance represents the critical resistance. Crve (2) corresponds to critical speed because the shunt field resistance (R_{Sh}) line is tangential to it. If the generator runs at full speed (N), the new O.C.C. moves upward and the $R_{Sh}{}^1$ line represents critical resistance for this speed

$\therefore$ Speed α Critical resistance

In order to find critical speed, take any convininent point 'C' on excitation axis and erect a perpendicular so as to cut R_{Sh} and $R_{Sh}{}^1$ lines at points B and a respectively. Then,

$$\frac{BC}{AC} = \frac{N_C}{N}$$

$$\Rightarrow N_C = N \times \frac{BC}{AC}$$

The condition for voltage build up are that :-

(a) There must be some residueal magnetism in generator poles.

(b) The connection of the field winding should be such that the field current strengthens the residual magnetism.

(c) Resistance of the field circuit must be less than critical resistanc. The speed of the generator should be higher than critical speed.

(f) Why cooling of transformer is necessary and how it can be cooled ?

Ans. In transformers losses are produced due to heat and these losses are iron losses in the core and I^2R losses in the windings. To prevent undue temp. rise this heat is removed by cooling.

(i) In small transformers (below 50 kVA), natural air colling is employed i.e. the heat produced is carried out by the surroundin air.

(ii) Medium size power or distribution transformers are generally cooled by housing then in he tanks filled with oil. The oil serves a double purpose carrying the heat from the windings to the surface of the tank and insulating the pri. & sec.

(iii) For large transformers, extrenal radiators are added to increase the cooling surface of the oil filled tank. The oil circulates around the transformer & moves through the radiators where the heat is released to surrounding air. Some time colling fans blow air over the radiators to acceleratae the cooling process.

3. Two 1100/400 V, single-phase transformers have total equivalent impedances of (0.2 + j 0.5) Ω and (0.3 + j0 .6) referred to the secondary side. They are connected in parallel and supply a load of 50 kW at a power

factor of 0.85 lagging. Find (i) the magnitudes of their secondary currents (ii) the power delivered by each transformer.

Ans. $Z_1 = (0.2 + j0.5)\ \Omega$

$Z_2 = (0.3 + j0.6)\ \Omega$ ref. to sec.

$$\text{Total load kVA} = \frac{50}{0.85} = 58.82 \text{ kVA}$$

$$S = 58.82 \angle -36^0 \text{ kVA}$$

$$S_1 = S \text{ x } \frac{Z_2}{Z_1 + Z_2} = 58.82 \angle -36^0 \text{ x } \frac{Z_2}{Z_1 + Z_2}$$

$$S_1 = 58.82 \angle -36^0 \text{ x } \frac{(0.3 + j0.6)}{0.2 + j0.5 + 0.3 + j0.6}$$

$$= 58.82 \angle -36^0 \text{ x } \frac{(0.3 + j0.6)}{(0.5 + j1.1)} \text{ kVA} \quad \text{—(i)}$$

$$S_2 = 58.82 \angle -36 \text{ x } \frac{Z_2}{Z_1 + Z_2} \quad \text{——(ii)}$$

$$= 58.82 \angle -36 \text{ x } \frac{0.2 + j5}{(0.5 + j1.1)} \text{ kVA} \quad \text{(Ans)}$$

Convert the rectangular to polar form to find S_1 and S_2.

$$\text{Sec current} = \frac{S}{V_2} = \frac{58.82 \times 10^3}{400} = 147 \text{ A.}$$

4. **A dc shunt generator delivers full load current of 200 A at 240 V. The shunt field resistance is 60 Ω and full load 'η' is 90%. the rotational losses are 800 w. Find.**

(i) Armature resistance

(ii) Current at which max^m efficiency occurs ?

Ans. $V = 240$ v, $I_L = 200$ A

$$\text{Generator } \%_p = VI_L = 240 \text{ x } 200 = 48000 \text{ w}$$

$$\text{Generator } i/_p = \frac{48000\text{w}}{\eta} = \frac{48000}{0.9} = 53333 \text{ w}$$

Total losses = 53333 – 48000 = 5333 w

$$\text{Shunt field current } (I_{Sh}) = \frac{240}{40} = 4\text{A}$$

$I_a = I_L + I_{Sh} = 4 + 200 = 204$ A.

Shunt. Cu. loss = $I_{Sh}^2 R_{Sh} = 4^2 \times 60 = 960$ w

Const. losses = Rotational losses + Shunt Cu. loss

Arm. Cu. loss = Total losses – Colst. losses

= 5333 – 1760 = 3573 w.

i.e. $I_a^2 R_a = 3573$

$$\text{or, } R_a = \frac{3573}{I_a^2} = \frac{3573}{204^2} = 0.0858\ \Omega$$

(ii) For max^m. efficiency the condition is

Variable loss = Const. losses

or, $I_L^2 R_a = 1760$

$$\therefore I_L = \sqrt{\frac{1760}{0.0858}} = 143.22 \text{ A(Ans)}$$

5. **A 400 kVA transformer has an iron loss of 2kw and the maximum efficiency at 0.8 pf occurs when the load is 240 kw. Calculate**

(i) The maximum efficiency at unity PF

(ii) The efficiency on f.I. at 0.71 PF lagging.

Ans. Maximum efficiency at unity P.F

$$\text{(i) kVA for max}^m\text{. effieciency} = \frac{240}{0.8} = 300 \text{ kVA}$$

At max^m. η Cu. loss = iron loss

Cu. loss at 300 kVA base load = 2 kw

$$\%_p = 300 \text{ x } 1 = 300 \text{ kw}$$

Total losses = 2 + 2 = 4 kw.

$$\text{Max}^m \text{ '}\eta\text{'} = \frac{300}{300 + 4} \times 100 = 98.6\%$$

(ii) Full load efficiency at 0.71 PF

$$\text{F.I Cu. loss} = \left(\frac{400}{300}\right)^2 \times 2 = 3.55 \text{ k}$$

iron loss = 2 kw

Total f.I. losses = 3.55 + 2 = 5.55 kw

$$\text{F.I } \%_p = 400 \text{ x } 0.71 \text{ kw.}$$

$$\therefore \text{F.I efficiency} = \frac{400 \times 0.71}{400 \times 0.71 + 5.55} \times 100 = 98\%$$

6. Design the resistance sections of a seven-stud starter for 36.775 kW, 400 V d.c. shunt motor. Full-load efficiency is 92% and total cu-losses are 5%. of the input. Shunt field resistance is 200 Ω. The lower limit of the current through the armature is to be the full-load value.

Ans. $\eta = 0.92$, o/p power = 36.775 kw, $R_{Sh} = 200\Omega$

$$\text{I/P power} = \frac{\text{O/P Power}}{\eta} = \frac{36.775}{0.92} = 39.97 \text{ kW}$$

$$\text{I/P Current } (I_L) = \frac{\text{I/P Power}}{400}$$

$$= \frac{39.97 \times 1000}{400} = 99.93 \text{ A}$$

$$I_{Sh} = \frac{400}{200} = 2\text{A}.$$

$$I_a = I_L - I_{Sh} = 99.93 - 2 = 97.93 \text{ A}$$

$$\text{Total Cu-loss} = 5\% \text{ of i/p} = 39.97 \times \frac{5}{100} = 1.99 \text{ kW}$$

$$\text{shunt Field loss} = I_{Sh}^2 R_{Sh} = 2^2 \times 200 = 800 \text{ W}$$

$$\text{Arm. Cu-loss} = 1.99 \times 10^3 - 800$$
$$= 1990 - 800 = 1190 \text{ W}$$

$$\therefore \text{Arm. resistance } (R_a) = \frac{1190}{I_a^2}$$

$$= \frac{1190}{97.93^2} = 0.124\ \Omega$$

Minimum Current = I_a (acc. to question)

$\therefore$ Minimum curvent = 97.93A = I

$$\text{Maximum current} = \frac{400}{R_1}$$

R_1 = Total resistance of armature ckt. on stud For a seven stud starter i.e. for (6 – sections)

$$\therefore \left(\frac{I}{I_m}\right)^2 = \frac{R_a}{R_1}$$

$$\text{Or, } \left(\frac{97.93}{\frac{400}{R_1}}\right)^6 = \frac{R_a}{R_1} = \frac{0.124}{R_1}$$

$$\text{or, } \left(\frac{97.93 \times R_1}{400}\right)^6 = \frac{0.124}{R_1}$$

$$\text{or, } (97.93 \times R_1)^6 \times R_1 = 0.124$$

$\therefore$ Thus R_1 will be found

$$\therefore R_1^6 \times R_1 = \frac{(0.124)^6}{(97.93)^6} \times (400)^6$$

$$R_1^7 = \left(\frac{400}{97.93}\right)^6 \times (0.124)^6$$

$$\Rightarrow R_1 = 2\Omega,$$

$$R_2 = kR_1$$

$$k = \frac{I}{I_m},\quad I_m = \frac{400}{2} = 200 \text{ A}$$

$$k = \frac{97.93}{200} = 0.489$$

$$R_2 = KR_1 = 0.489 \times 2 = 9.78 = 0.978\ \Omega$$
$$R_3 = KR_2 = 0.489 \times 0.978 = 0.233\ \Omega$$
$$R_5 = 0.489 \times R_4 = 0.489 \times 0.233 = 0.1139\ \Omega$$

Upto R_6 we will find

$$\therefore R_6 = 0.489 \times 0.1139 = 0.0557\ \Omega$$

$P = 4$, $V = 220$ V, $P_L = 10$ kw $= 10 \times 10^3$ w

$N = 1500$ rpm, $A = P = 4$

$Z = 512$, $R_{Sh} = 100\ \Omega$, $R_a = 0.1\ \Omega$

$\phi = ?$

$P_L = V \times I_L$ or, $10 \times 10^3 = 220 \times I_L$

$$\text{or, } I_L = \frac{10{,}000}{220} = 45.45 \text{ Amp.}$$

$$I_{Sh} = \frac{V}{R_{Sh}} = \frac{220}{100} = 2.2 \text{ Amp.}$$

$$I_a = I_{Sh} + I_L = 2.2 + 45.45 = 47.65 \text{ a}$$

$$E_g = V + I_a R_a = 220 + 45.65 \times 0.1$$
$$= 224.765 \text{ volt.}$$

$$E_g = \frac{P\phi ZW}{60A}$$

$$\text{or, } 224.765 = \frac{4 \times \phi \times 512 \times 1500}{60 \times 4}$$

$$\therefore \phi = \frac{224.765 \times 60}{512 \times 1500} = 0.0175 \text{ wb.}$$ **(Ans)**