BALASORE SCHOOL OF ENGINEERING

SUBJECT – ENERGY CONVERSION – I

THEORY-01
SUB.CODE.- EET-401
4TH SEM.

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ENERGY CONVERSION-1

CHAPTER-1 (D.C. Generator)

SHORT QUESTIONS

1. **What is the function of pole shoe in a D.C. machine?[2015(S)1(a)]**
   Ans: The function of pole shoe :(i)to expand the magnetic field into the air-gap in continuous manner. (ii) to support the field winding placed on the pole core.

2. **What is the critical resistance of a d.c. shunt generator ? [2015(S)2(a)][2017 (S) OLD 2(a)]**
   Ans : The resistance line which just touches the O.C.C. of the shunt generator is called critical resistance.
   It is the maximum field resistance at the given field at which the generator would just excite.

3. **What is the function of interpoles and how are interpole windings connected? [2015bp)1(a)]**
   Ans : Function of interpoles : to improve commutation and to neutralize cross magnetising armature reaction .It is connected in series with armature winding.

4. **What is eddy current loss ? How it can be minimized? [2015bp)3(i)]**
   Ans : When armature core rotates in the magnetic field ,voltage is induced .So current is flowing in the solid armature and armature starts heating. This is called eddy current loss.

5. **What is the critical resistance and critical speed of d.c. generator ? [2016(S)2(a)]**
   Ans : The resistance line which just touches the O.C.C. of the shunt generator is called critical resistance. The minimum speed at a given armature resistance below which it fails to excite is called critical speed.

6. **What is magnetic drag ?2014(s)1(a)**
   Ans : The electromagnetic force developed in dc generators due to generator action is called electromagnetic drag.

7. **What is dummy coils?2013(s)1(a)**
   Ans : Dummy coils are used in the wave winding .Because after winding armature conductors some coils may left blank which create mechanical imbalance.

8. **What is voltage regulation of D.C. generator?[2013(s)3(a)]**

Ans : The change in terminal voltage of a generator between full and no load (at constant speed) is called the voltage regulation, usually expressed as a percentage of the voltage at full-load.

% voltage regulation=$[(V_{NL}-V_{FL})/V_{FL}]*100$

V_{FL}=terminal voltage of dc generator at no load

V_{FL}=terminal voltage of dc generator at full load

9. **What is commutation? [2017(S) 6(a)]**

Ans : Current in a coil will reverse as the coil passes a brush. This reversal of current as the coil passes & brush is called commutation.

10. **What is resultant pitch? [2017(S) 7(a)]**

Ans : It is the distance between the beginning of one coil and the beginning of next coil to which it is connected.It is denoted by Y_R.

11. **What is the function of commutator? [2017(S) old 1 (a)]**

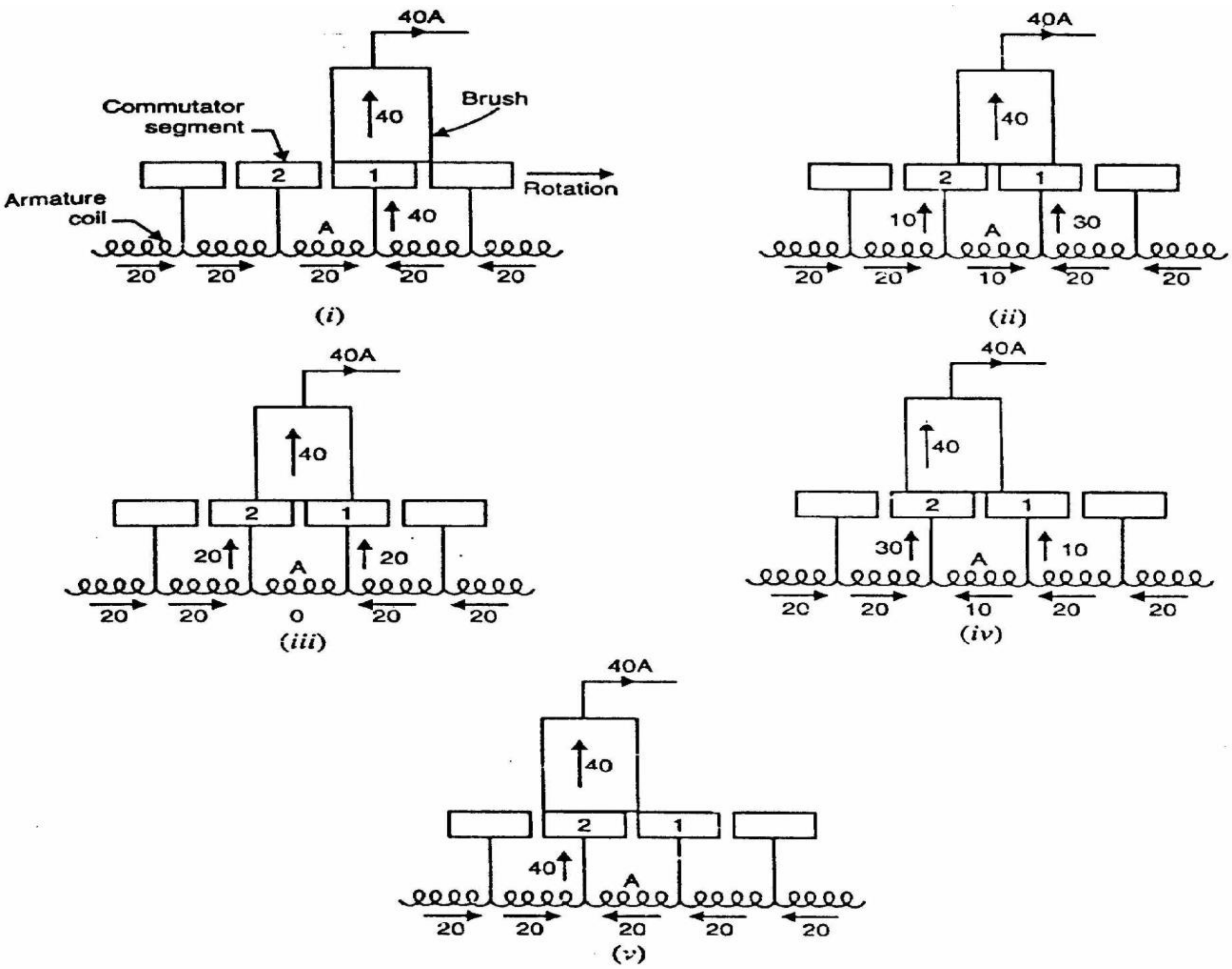
Ans: It is a mechanical device which has no. of segments which converts given A.C. to D.C. current.It is also called as mechanical rectifier.

MEDIUM QUESTIONS

1. **Explain the commutation process in d.c. motor. [2016(S)3(b)*2015(bp)7(iii)][2013(S)2014(s)3(c)][2017 (S) OLD 3(C)]***

Ans: Commutation : Current in a coil will reverse as the coil passes a brush. This reversal of current as the coil passes & brush is called commutation .

Commutation process : The reversal of current in a coil as the coil passes the brush axis is called Commutation. When commutation takes place, the coil undergoing commutation is short circuited by the brush. The brief period during which the coil remains short circuited is known as commutation period Tc. If the current reversal is completed by the end of commutation period, it is called ideal commutation. If the current reversal is not completed by that time, then sparking occurs between the brush and the commutator which results in progressive damage to both.



i) the brush is in contact with segment 1 of the commutator .The commutator segment 1 conducts a current of 40 A to the brush; 20 A from coil A and 20 A from the adjacent coil as shown. The coil A has yet to undergo commutation.

(ii) There are now two parallel paths into the brush as long as the short-circuit of coil A exists. The brush again conducts a current of 40 A; 30 A through segment 1 and 10 A through segment 2. Note that current in coil A (the coil undergoing commutation) is reduced from 20 A to 10 A.

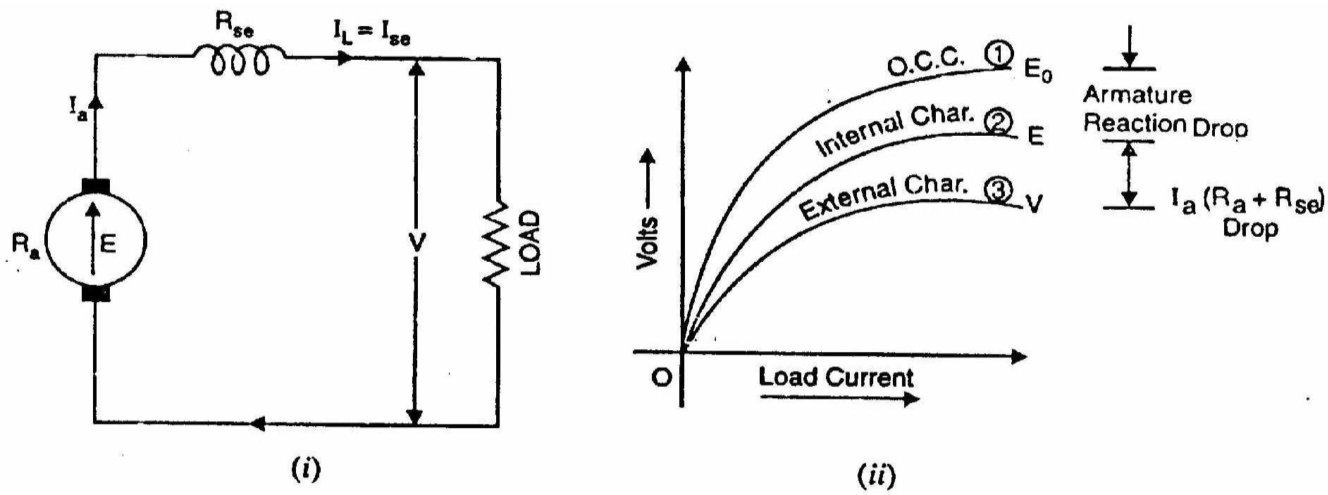
(iii) Fig. (iii) shows the instant when the brush is one-half on segment 2 and one-half on segment 1. The brush again conducts 40 A; 20 A through segment 1 and 20 A through segment 2. Current in coil A is zero

(iv) Fig. (iv) shows the instant when the brush is three-fourth on segment 2 and one-fourth on segment 1. The brush conducts a current of 40 A; 30 A through segment 2 and 10 A through segment 1. Note that current in coil A is 10 A but in the reverse direction to that before the start of commutation.

(v) Fig.(v)The brush again conducts 40 A; 20 A from coil A and 20 A from the adjacent coil to coil A. Note that now current in coil A is 20 A but in the reverse direction.

2.Draw the external characteristics of d.c. shunt and series generator and explain briefly. [2016(S)4(b)][2014(s)3(b)][2017(S) OLD 1(b)]

Ans: <u>External Characteristics of Series Generator</u>



Curve 3 shows the external characteristic of a series generator. It gives the relation between terminal voltage and load current I_L:.

E_B=V-I_L(Ra + Rse)

Therefore, external characteristic curve will lie below internal characteristic curve by an amount equal to ohmic drop [i.e., Ia(Ra + Rse)] in the machine .

Curve 2 shows the external characteristic of a shunt generator. It gives the relation between terminal voltage V and load current IL.( )a V = E – IaRa = E – I_L + Ish R

Therefore, external characteristic curve will lie below the internal characteristic curve by an amount equal to drop in the armature circuit [i.e., (I_L + Ish)Ra].

2. **State and explain the conditions for building up of voltage in the dc generator.**

   Ans : (i)There must be some residual magnetism in generator poles.

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

   (iii) The resistance of the field winding should be less than the critical resistance.

   (iv)The load resistance may be more than its critical value.

3. **Derive the emf equation of D.C. generators ?[2014(S)1(b)][2017(S)6(b)][2017(S)OLD 1(C)]**

   Ans : We know that Z=no. of conductors

   N= speed in rpm

   A=no of parallel paths

   P=no of poles

   Φ=flux per pole in weber

   F=frequency in Hz

   From electromagnetic induction principle we know that $e=N\frac{d}{dt}\Phi$

When a conductor rotates in the magnetic field dϕ=Pϕ : dt=$\frac{60}{N}$ s

For N=1 : e= N$\frac{d}{dt}$ϕ=$\frac{PN\varphi}{60}$ volt

No of conductors per parallel path=$\frac{Z}{A}$

Induced emf per parallel path=(Induced emf in a conductor) *(no of conductors per parallel path)

$$=\frac{PN\varphi}{60}*\frac{Z}{A}=\frac{P\varphi ZN}{60A} \text{ volt}$$

LONG QUESTIONS

1. Discuss in detail the armature reaction in d.c. machine and the methods to reduce its effects. [2015(S)7(c)][2017(S)5(b)][2017 (S) OLD 2(c)]

Ans: The action of armature flux on the main flux is known as armature reaction.

Explanation of Armature Reaction

With no current in armature conductors, the M.N.A. coincides with G.N.A. However, when current flows in armature conductors, the combined action of main flux and armature flux shifts the M.N.A. from G.N.A. In case of a generator, the M.N.A. is shifted in the direction of rotation of the machine. In order to achieve sparkles commutation, the brushes have to be moved along the new M.N.A. Under such a condition, the armature reaction produces the following two effects:

1. It demagnetizes or weakens the main flux.
2. It cross-magnetizes or distorts the main flux.

Let us discuss these effects of armature reaction by considering a 2-pole generator (though the following remarks also hold good for a multi polar generator).

(i) fig. (i) shows the flux due to main poles (main flux) when the armature conductors carry no current. The flux across the air gap is uniform. The m.m.f. producing the main flux is represented in magnitude and direction by the vector OFm in Fig. (i). Note that OFm is perpendicular to G.N.A. (ii) Fig. (2.3) (ii) shows the flux due to current flowing in armature conductors alone (main poles unexcited). The armature conductors to the left of G.N.A. carry current "in" (x) and those to the right carry current "out" (•). The direction of magnetic lines of force can be found by cork screw rule. It is clear that armature flux is directed downward parallel to the brush axis. The m.m.f. producing the armature flux is represented in magnitude and direction by the vector OFA in Fig. (2.3) (ii).Fig. (2.3) (iii) shows the flux due to the main poles and that due to current in armature conductors acting together. The resultant m.m.f. OF is the vector sum of OFm and OFA as shown in Fig. (2.3) (iii). Since M.N.A. is always perpendicular to the resultant m.m.f., the M.N.A. is shifted through an angle ?. Note that M.N.A. is shifted in the direction of rotation of the generator.

(iv) In order to achieve sparkles commutation, the brushes must lie along the M.N.A. Consequently, the brushes are shifted through an angle ??so as to lie along the new M.N.A. as shown in Fig. (iv). Due to brush shift, the m.m.f. FA of the armature is also rotated through the same angle ?. It is because some of the conductors which were earlier under N-pole now come under S-pole and vice-versa. The result is that armature m.m.f. FA will no longer be vertically downward but will be rotated in the direction of rotation through an angle ??as shown in Fig.

(iv). Now FA can be resolved into rectangular components Fc and Fd.

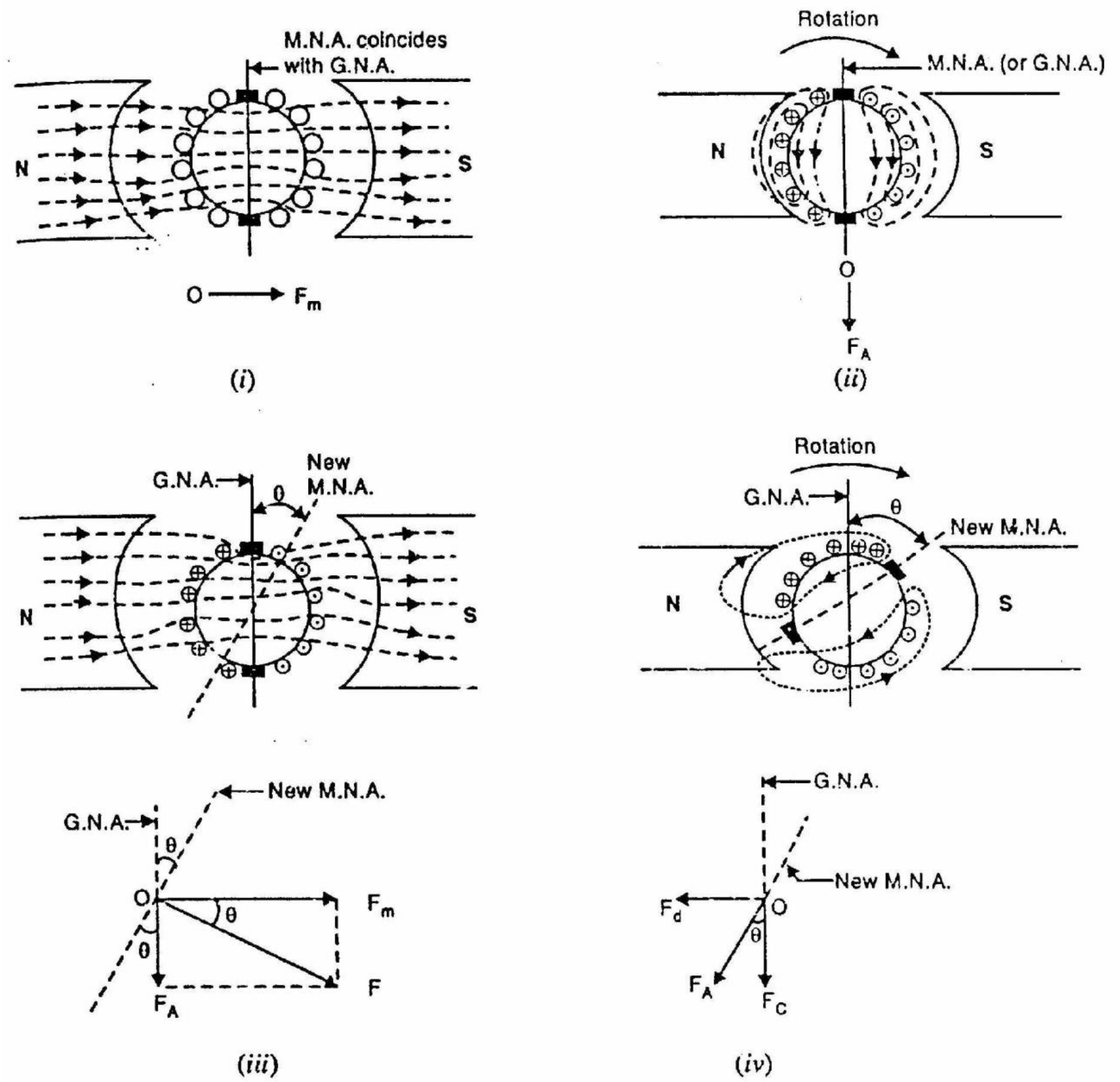


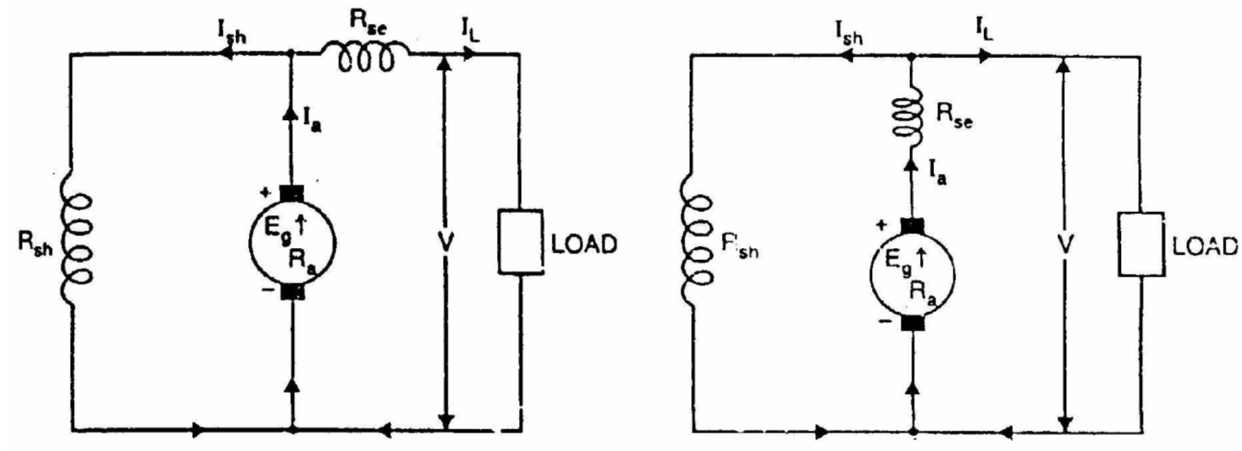
Fig.

(a) The component Fd is in direct opposition to the m.m.f. OFm due to main poles. It has a demagnetizing effect on the flux due to main poles. For this reason, it is called the demagnetizing or weakening component of armature reaction.
(b) The component Fc is at right angles to the m.m.f. OFm due to main poles. It distorts the main field. For this reason, it is called the cross magnetizing or distorting component of armature reaction.
It may be noted that with the increase of armature current, both demagnetizing and distorting effects will increase.

2. **A 20Kw compound generator works on full load with a terminal voltage of 220 V. The armature series and shunt field resistances are 0.1, 0.05 and 120 Ώ respectively. Calculate the generated emf, when the generator is connected short shunt. Also find power developed in the armature. [2015bp)4(iv)]**

Ans : Given data : P=20kW, V=220 V, R_a=0.1Ω , R_{sh} =120Ω,R_{se}= 0.05Ω

Short shunt



(i) (ii)

$I_l=\frac{20000}{220}$=90.9 A

Voltage across armature=220-(90.9*0.05)=220+4.545=224.545 V

I_{sh}=(224.545/120)=1.87 A

I_a=90.9+1.87=92.77 A

E_g=220+(90.9*0.05)+(92.77*0.1)=233.822 V

P=233.822*92.77=21691.67 W

3. **A 110 V shunt generator has a full load current of 100 A, shunt field resistance of 55Ω and constant losses of 500 W. If full no load efficiency is 88%, find armature resistance. Assume voltage to be constant at110 V, calculate the efficiency at half load and at 50 % overload. Find also load current. [2015bp)5(iii)][2017(S)6(c)]**

Ans : V=110 V, I_l=100 A, R_{sh}=55Ω, W_c=500W

4. **A 4 pole d.c. shunt generator with a shunt field resistance of 100 Ώ and an armature resistance of 1Ώ has 378 wave connected conductors in its armature. The flux per pole is 0.01 Wb. If a load resistance of 10 Ώ is connected across the armature terminals and the generator is driven at speed of 1000rpm.Calculate the power absorbed by the load.** ***2016(S)1(c)]***

ANS :

5. **A separately excited D.C. generator , when driven at 1500 r.p.m. ,supplied a load current of 200 A at 250 volt to a circuit of constant resistance. What will be the current and the voltage if the speed is reduced to 1250 rpm keeping the field current unaltered ?R_a=0.05Ω,B.D.=2V,negelect the effect of armature reaction.2014(s)1(c)**

Ans :

6. **A 20 kW compound generator works on full load with a terminal voltage of 230 V. The armature, series and shunt field resistances are 0.1Ω, 0.05Ω and 115Ω respectively. Calculate the generated emf when the generator is connected short shunt.[2013()S;1(c)][2017(S)5(c)]**

   Ans :

7. **(i) What is critical resistance and critical speed for shunt generator.**

(ii)Write condition for voltage build-up of a shunt generator.

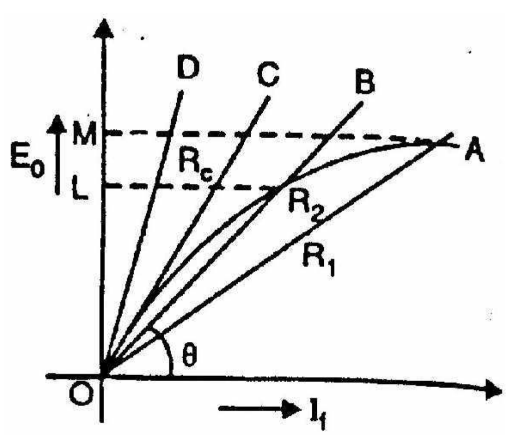
Ans : Critical Field Resistance for a Shunt Generator

We have seen above that voltage build up in a shunt generator depends upon field circuit resistance. If the field circuit resistance is R1 (line OA), then generator will build up a voltage OM as shown in the Fig. If the field circuit resistance is increased to R2 (tine OB), the generator will build up a voltage OL, slightly less than OM.

As the field circuit resistance is increased, the slope of resistance line also increases. When the field resistance line becomes tangent (line OC) to O.C.C., the generator would just excite. If the field circuit resistance is increased beyond this point (say line OD) , the generator will fail to excite. The field circuit resistance represented by line OC (tangent to O.C.C.) is called critical field resistance RC for the shunt generator. It may be defined as under:

The maximum field circuit resistance (for a given speed) with which the shunt generator would just excite is known as its critical field resistance.

It should be noted that shunt generator will build up voltage only if field circuit resistance is less than critical field resistance.



CHAPTER-2

(D.C. Motor)

SHORT QUESTIONS

1. **What happens if the direction of current at the terminals of a series motor is reversed? [2015(bp)2(i)]**
   Ans : As the direction of both magnetic field and the direction of armature current is reversed, so direction of rotation remains the same.

2. **What are the advantages of Swinburne's test for determining efficiency of d.c. motor? [2015(bp)4(i)]**
   Ans : Advantages of Swinburne's test :
   (i)The power required to carry out the test is small because it is a no-load test.
   (ii)The efficiency can be determined at any load because constant losses are known.
   (iii)This test is very convenient.

3. **What are the drawbacks in 3-point starter for which a 4-point starter was developed next? [2015(bp)5(i)]**
   Ans : In 3-point starter, no load release coil is in series with the field winding so speed control by flux control method is not possible. So 4-point starter was developed.

4. **Why starter is necessary for starting of d.c. motor? [2016(S)3(a)][2014(s)4(a)]**
   Ans : We know that $I_a=(V-E_b)/R_a$.At rest back emf is zero as speed is zero. So armature current increases far more than the rated value. So a resistor is connected in series with the armature to limit the armature current to 1.5 times its rated value.

5. **What is the function of NVC in the starter ? [2016(S)4(a)]**
   Ans : In case the power fails or the voltage dips below rated value no volt release coil demagnetizes and the handle comes back to OFF position. So motor can be started from OFF position again; the armature winding can be saved from burning.

6. **Why d.c. series motor is started with load ? [2016(S)5(a)]**
   Ans : D.C. series motor is started with load because it will rotate at speed more than its rated value if started with no-load. So commutator and brushes may get damaged.

7. **What is back emf ?[2013(s)5(a)]2014(s)2(a)[2017(S)2(a)]**
   Ans : When armature conductors rotates in the magnetic field of D.C. motor due to dc motor principle emf is induced in them due to generator action .The polarity of induced emf is opposite to that of supply voltage. This voltage is called back emf or counter emf.

$E_g = E_b = \frac{\varphi ZNP}{60A}$ volt.

8. **State the principle of D.C. motor. 2013(S)2(a)[2017 (S) OLD 4(a)]**
   Ans : If a current carrying conductor is placed in the magnetic field a mechanical force is produced on it. F_m=BiL Newton
9. **Why d.c. Series Motor should not be started at no load. [2017 (S) old 3 (a)]**

Ans : In series motor field winding is in series to armature winding. In any DC motorthe speed depends inversely on the flux and directly proportional to emf, N ~E/flux.Motor armature current is decided by the load.On no load the armature current drawn by the motor will very small.For d.c. series motor,Flux is Directly proportional to Armature current. and on no load as Ia is small hence flux produced is also very small.

According to speed equation,Speed is Inversely proportional to Flux i.e ($N \alpha 1/\Phi$)as Eb is almost constant. As from Speed Equation Speed is inversely proportional to flux and for no load or less load the flux produced is also less hence the rotor rotates at very high speed which can damage the motor mechanically.

10. **What is speed regulation? [2017 (S) old 5 (a)]**

    Ans : It is the ratio of difference in speed full load speed and no load speed to load speed.

    Speed regulation = $(N_{FL}-N_{NL}) / N_{NL}$

<u>MEDIUM QUESTIONS</u>

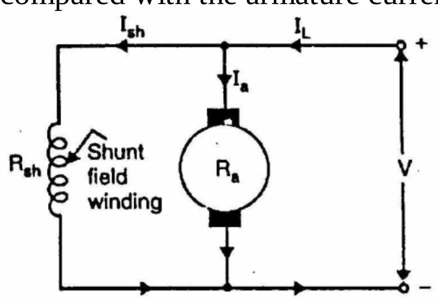
1. **A shunt wound dc machine has an armature resistance of .12Ώ and a field resistance of 100Ώ. The machines rated terminal voltage is 250 V. Find the ratio of speeds as a generator and motor if line current is 50 A in each case? 2015(S)1(c)]**
   Ans :

2. Make a classification of various types of D.C. motor and show their circuit diagram. 2015(S)2(b)]

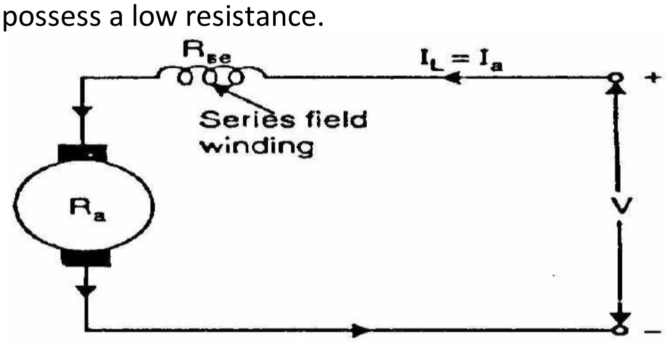
Ans: Types of D.C. Motors

Like generators, there are three types of d.c. motors characterized by the connections of field winding in relation to the armature viz.:

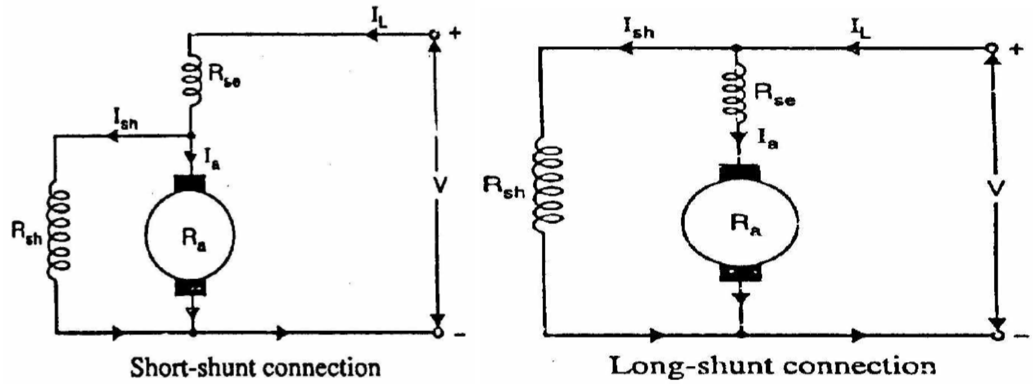
(i) **Shunt-wound motor** in which the field winding is connected in parallel with the armature. The current through the shunt field winding is not the same as the armature current. Shunt field windings are designed to produce the necessary m.m.f. by means of a relatively large number of turns of wire having high resistance. Therefore, shunt field current is relatively small compared with the armature current.



(ii) **Series-wound motor** in which the field winding is connected in series with the armature . Therefore, series field winding carries the armature current. Since the current passing through a series field winding is the same as the for the same m.m.f. Therefore, a series field winding has a relatively small number of turns of thick wire and, therefore armature current, series field windings must be designed with much fewer turns than shunt field windings, will possess a low resistance.



(iii) **Compound-wound motor** which has two field windings; one connected in parallel with the armature and the other in series with it. There are two types of compound motor connections (like generators). When the shunt field winding is directly connected across the armature terminals, it is called short-shunt connection. When the shunt winding is so connected that it shunts the series combination of armature and series field, it is called long-shunt connection. It is so connected that it shunts the series combination of armature and series field, it is called long-shunt connection .The compound machines (generators or motors) are always designed so that the flux produced by shunt field winding is considerably larger than the flux produced by the series field winding. Therefore, shunt field in compound machines is the basic dominant factor in the production of the magnetic field in the machine.



3. **Under what conditions is sparking produced at the brushes of a d.c. motor? How it can be rectified? 2015(bp)2(ii)] 2015(S)6(b)] 2015(bp)5(ii)]**

Ans: Sparking is produced in D.C. motor due to cross magnetising armature reaction and poor commutation.

It can be eliminated by using compensating winding and interpoles.

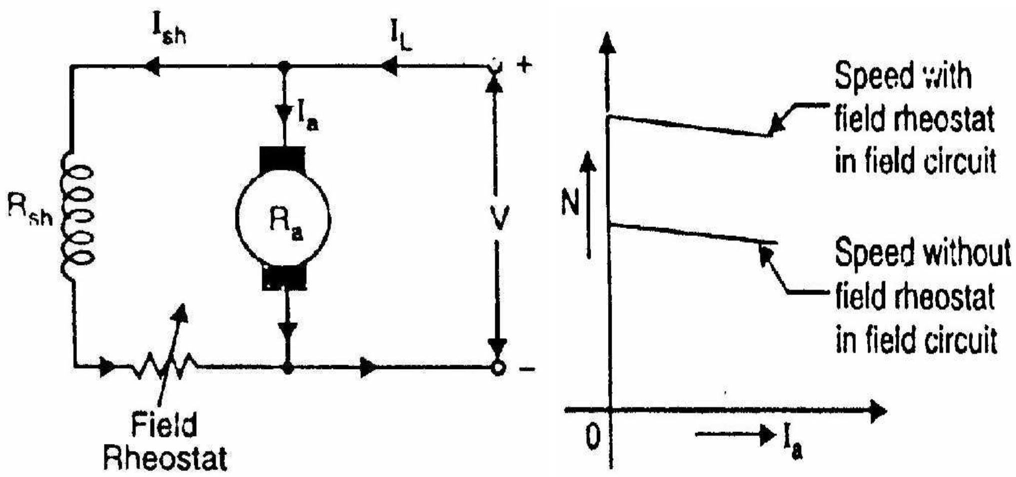
4. **Explain the field flux method of speed control of d.c. motor. [2016(S)2(b)][2017 (S) OLD 5(b)]**

Ans : Different speed control methods are :

(i) Flux control method
(ii) Armature control method
(iii) Voltage control method

Flux control method

It is based on the fact that by varying the flux , the motor speed (N) can be changed and hence the name flux control method. In this method, a variable resistance (known as shunt field rheostat) is placed in series with shunt field winding.



The shunt field rheostat reduces the shunt field current Ish and hence the flux .Therefore, we can only raise the speed of the motor above the normal speed. Generally, this method permits to increase the speed in the ratio 3:1. Wider speed ranges tend to produce instability and poor commutation.

Advantages

(i) This is an easy and convenient method.

(ii) It is an inexpensive method since very little power is wasted in the shunt field rheostat due to relatively small value of Ish.

(iii) The speed control exercised by this method is independent of load on the machine.

Disadvantages

(i) Only speeds higher than the normal speed can be obtained since the total field circuit resistance cannot be reduced below Rsh—the shunt field winding resistance.

(ii) There is a limit to the maximum speed obtainable by this method. It is because if the flux is too much weakened, commutation becomes poorer.

Note. The field of a shunt motor in operation should never be opened because its speed will increase to an extremely high value.

5. **Under what conditions is sparking produced at the brushes of a d.c. motor? How it can be rectified? 2015(bp)2(ii)]**

   Ans : (i) Due to poor commutation.

   (ii) Due to armature reaction.

   (iv) Armature reaction can be neutralized can be by using compensating winding.

   (v) Commutation can be improved by using interpoles.

6. **Derive the torque equation and speed equation of d.c. motor. *2016()(b)] [2014(S)2(b)]2013(S)2(b)[2017(S)7(C)][2017(S) OLD 4(c)]***

   Ans: Let in a d.c. motor

   r = average radius of armature in m

   l= effective length of each conductor in m

Z = total number of armature conductors
A = number of parallel paths
i = current in each conductor = Ia/A
B = average flux density in Wb/m2
ϕ= flux per pole in Wb
P = number of poles
Force on each conductor, F = B i l newtons
Torque due to one conductor=F*R N-m
Total armature torque=Z*F*r N-m
=Zbilr

$T_a=\frac{ZIlr\varphi}{2*A}$

As $a=\frac{2rl\pi}{P}$

$T_a=\frac{ZIP\varphi}{2A\pi}$ N-m

$T_a=0.159*Z\phi I\frac{P}{A}$ N-m

Since Z,P,A are fixed for a given machine,

$T_a \alpha \phi I$.

We know that emf equation is given by $E_g=\frac{ZNP\varphi}{60A}$

Speed Equation ,$N=(60A/ZP)(E_g/\phi)=K(V-I_aR_a)/\phi$

7. Explain determination of efficiency by Swinburne's test.[2013(s)5(b)][2017 (S) OLD 6(c)]

Ans : This test is applicable to those machines in which flux is practically constant .i.e. for shunt and compound machines.

The no-load current I_o and I_{sh} is measured by the ammeter. The no load armature current $I_{ao.}$

Let supply voltage = V, no-load input=VI_o watt.

Power input to armature=$V(I_o-I_{sh})$

Power input to shunt=VI_{sh}

No-load power input to armature supplies the following losses-(i) iron loss, (ii) friction loss,

(vi) windage loss (iv) armature copper loss,$(I_o-I_{sh})^2R_a=I_{ao}^2R_a$

(vii) Constant loss=$VI_o-(I_0-I_{sh}^2)R_a$

Knowing the constant loss of dc machine its efficiency at any other load can be determined as given below .Let I be the load current at which efficiency is required.

Then armature current $I_a=I-I_{sh}$ if the machine is motoring

$I_a=I+I_{sh}$ if the machine is generating

Efficiency if running as motor

Input=VI, armature copper loss=$I_a^2R_a=(I-I_{sh})^2R_a$

Constant loss= W_c as found above

Total losses=$(I-I_{sh})^2R_a+W_c$, $\eta_m=\frac{input-losses}{input}=\frac{VI-(I-Ish)2Ra-Wc}{VI}$

Efficiency when running as generator

Output=VI, armature copper loss=$(I+I_{sh})^2R_a$, constant loss=W_c

Total losses=$(I+I_{sh})^2R_a+W_c$, $\eta_g=\frac{output}{output+losses}=\frac{VI}{VI+(I+Ish)2+Wc}$

8. **Compare shunt and series motor.[2014(s)4(b)]**

Ans : SHUNT MOTOR

(i) Field coil is connected in parallel to armature.

(ii) Field coil is thin and carries very small current than that of armature.

(iii) Speed is nearly constant.

(iv) Not suitable for heavy load.

Uses are lathes , machine tools etc

SERIES MOTOR

(i) Field coil is connected in series with armature.

(ii) Field coil is thick and and carries armature current.

(iii) Speed is very high in no loads and decreases with increases with load.

(iv) Suitable for heavy load.

Uses are electric locomotives, cranes etc.

9. **Explain brake test to find efficiency of D.C. motor.[2014(s)5(a)]**

Ans : <u>Brake test</u>

In this method, a brake is applied to a water-cooled pulley mounted on the motor shaft as shown in Fig. One end of the rope is fixed to the floor via a spring balance S and a known mass is suspended at the other end. If the spring balance reading is S kg-Wt and the suspended mass has a weight of W kg-Wt,

Net pull on the rope = (W -S) kg-Wt = (W -S) *9.81 Newton

If r is the radius of the pulley in meters, then the shaft torque Tsh developed by the motor is :

Tsh=(W-S)*9.81*r N – m

If the speed of the pulley is N r.p.m., then,

Output power =$\frac{2\pi NTsh}{60}=\frac{2\pi N*(W-S)*9.81*r}{60}$ watts

Let V = Supply voltage in volts

I = Current taken by the motor in amperes

□□Input to motor = V I watts

□□fficiency=$\frac{2\pi N(W-S)*r*9.81}{60*VI}$

LONG QUESTIONS

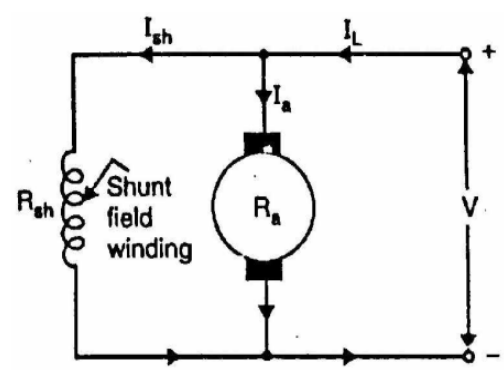
1. **A 230 V, dc shunt motor has a no-load has a no-load current of 4A and a no-load speed of 800 r.p.m. The field and armature resistance are 200 Ώ and 0.2Ώ respectively. The full-load current of the motor is 45 A. Find the full-load speed. Assume the armature reaction weakens the field by 2% at full-load and voltage drop in brush contact resistance is 2 V in each case. 2015(S)3(c)]**

2. **A d.c. shunt motor drives a centrifugal pump whose torque varies as the square of the speed. The motor is fed from a 220 V supply and takes 50 A when running at 1000 r.p.m. What resistance must be inserted in the armature circuit in order to reduce the speed to 800 rpm. The armature and field resistance of the motor are 0.1Ώ and 100Ώ respectively. *2015(bp)3(iii)]***

3. **Write short notes of a d.c. shunt motor.** ***2015(bp)7(i)]***

Ans: (i) Shunt-wound motor in which the field winding is connected in parallel with the armature . The current through the shunt field winding is not the same as the armature current.

(ii) Shunt field windings are designed to produce the necessary m.m.f. by means of a relatively large number of turns of wire having high resistance. Therefore, shunt field current is relatively small compared with the armature current.



(iv) Its speed is nearly constant.

(v) It is not suitable for heavy load condition.

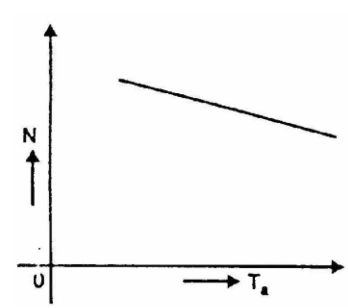
(vi) Uses are lathe,machine tools,blowers,centrifugal pumps etc.

4. **Draw and explain in brief speed vs. torque characteristics of different types of d.c. motor.**

2015(bp)6(iii)][2017(S) OLD 7(iii)]

Ans : <u>SHUNT MOTOR</u>

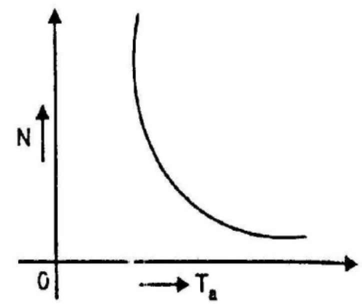
(i) Speed falls somewhat as the load torque increases.



(ii) There is slight change in the speed of a shunt motor from no-load to full load. Hence, it is essentially a constant-speed motor.

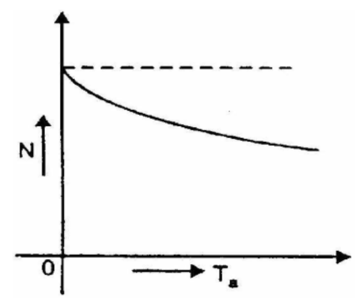
SERIES MOTOR

The N/Ta characteristic of a series motor is shown in above figure. It is clear that series motor develops high torque at low speed and vice-versa. It is because an increase in torque requires an increase in armature current, which is also the field current. The result is that flux is strengthened and hence the speed drops . Reverse happens should the torque be low.



CUMULATIVE COMPOUND MOTOR

Above figure shows N/Ta characteristic of a cumulative compound motor. For a given armature current, the torque of a cumulative compound motor is more than that of a shunt motor but less than that of a series motor.



5. A 4 pole, 240V, wave connected shunt motor gives 1119kW when running at 1000 rpm and drawing armature and field current of 50 A and 1A respectively. It has 540 conductors. Its resistance is 0.1Ώ. Assume a drop of 1 volt per brush, find

(i) Total torque
(ii) Useful flux per pole
(iii) Rotational losses
(iv) Efficiency. [2016(S)5(c)]

6. **A d.c. shunt machine has armature and field resistance of 0.025Ω and 80Ω respectively. When connected to constant 400 V bus-bars and driven as generator at 450 rpm, it delivers 120 kW. Calculate its speed when running as motor and absorbing 120 kW from the same bus-bars.[2013(s)2(c)]**

   Ans :

7. **The speed of a 37.3 kW series motor working on 500 V supply is 750 rpm at full load and 90 % efficiency. If the load torque is made 350 N-m and 5Ω resistance is connected in series with the machine, calculate the speed at which the machine will run.Assume the magnetic circuit to be unsaturated and armature and field resistance to be 0.5Ω.[2013(s)5(c)]**

8. Short notes on characteristics of shunt motor.2013(s)7(c)

9. A d.c. shunt motor fed from 220 V supply drives as the square of the speed and takes 45 A when running at 900 rpm. What resistance must be inserted in the armature circuit in order to reduce the speed to 700 r.p.m. The armature and field resistance of the motor are 0.1Ω and 110Ω respectively.[2014(s)2(c)]

10.A d.c. series motor, with unsaturated magnetic circuit and with negligible resistance, when running at certain speed on a given load takes 50 A at 500 V. If the load torque varies as the cube of the speed , find resistance which should be connected in series with the machine to reduce the speed by 25%.[2014(s)4(c)]

11.A d.c. shunt motor rated at 12.5 kW output runs at no-load at 1000 r.p.m. from 250 V supply consuming input current of $A. The armature resistance is 0.5Ω and shunt field resistance is 250Ω. Calculate the efficiency of the machine when delivering full-load output of 12.5kW while operating at 250 V.[2014(s)5(c)]

CHAPTER-3

(Transformers)

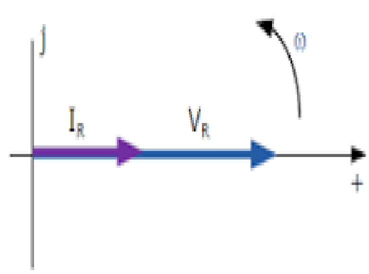
SHORT QUESTIONS

1. **Define what is voltage regulation of a transformer ? 2015(S)3(a)]** ***2016(S)1(a)]2013(S)3(a)[2017(S)2(a)]***

Ans: The voltage regulation of a transformer is the arithmetic difference (not phasor difference) between the no-load secondary voltage (0V2) and the secondary voltage V_2 on load expressed as percentage of no-load voltage i.e. %age voltage regulation =$(V_{O2}-V_2)/V_{O2}$
where V_{O2} = No-load secondary voltage = K V1
V_2 = Secondary voltage on load

2. **Show the phasor diagram of pure resistive load.**

Ans :



3. **Define all-day efficiency of transformer. 2015(S)6(a)] [2016(S)6(a)]2014(s)7(a)**

Ans : The ratio of output in kWh to the input in kWh of a transformer over a 24-hour

$$\eta_{all\text{-}day} = \frac{\text{KWh output in 24 hours}}{KWh\ input\ for\ 24\ hours}$$

It is calculated in distribution transformers.

4. Derive the condition of maximum of efficiency of transformer.[2013(s)4(a)]

Ans : $P_i = I^2R$ => Iron loss= copper loss

Where P_i=iron loss, I^2R= copper loss

5. **State at what load maximum efficiency occurs if iron loss and full load Cu loss given? [2014(s)6(a)]**

Ans : $I_{2max} = \sqrt{\frac{iron\ loss}{R02}}$

Where R_{02}=equivalent resistance with respect to secondary

I_{2max}=secondary current

6. **Why transformer rating is in KVA ? [2017 (S) 1(a)][2017(s)old 6(a)]**

Ans : Copper losses (I^2R)depends on Current which passing through transformer winding while Iron Losses or Core Losses or Insulation Losses depends on Voltage. That's why the Transformer Rating may be expressed in kVA, Not in kW.

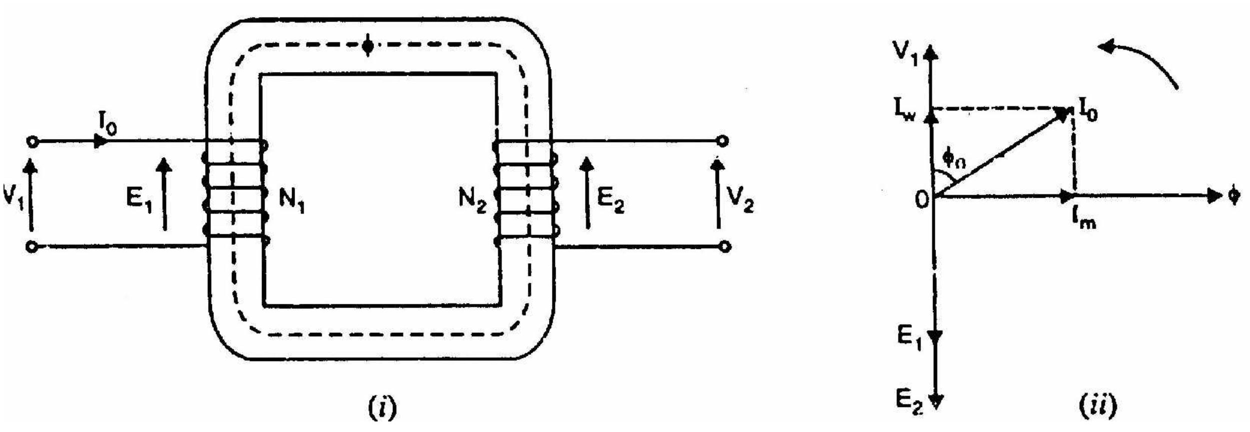
7. **State the different types of losses which occurs in transformer? [2017 (S) 3(a)]**

Ans : They include heat losses and eddy currents in the primary and secondary conductors of thetransformer. Heat losses, or I^2R losses, in the winding materials contribute the largest part of the load losses. They are created by resistance of the conductor to the flow of current or electrons.

MEDIUM QUESTIONS

1. **Draw the phasor diagram of a transformer on no-load and explain. 2015(S)4(b)][2017 (S) OLD 5(c)]**

Ans :



The primary will draw a small current I0 to supply (i) the iron losses and (ii) a very small amount of copper loss in the primary. Hence the primary no load current I0 is not 90° behind the applied voltage V1 but lags it by an angle ?0 < 90° as shown in the phasor diagram . No load input power, $W0 = V_1 I_0 \cos \phi_0$

(i) The component IW in phase with the applied voltage V1. This is known as active or working or iron loss component and supplies the iron loss and a very small primary copper loss.

$I_w = I_0 \cos \phi_0$

(ii) The component Im lagging behind V1 by 90° and is known as magnetizing component. It is this component which produces the mutual flux in the core.

$Im = I_0 \sin \phi_0$

It is emphasized here that no load primary copper loss is very small and may be neglected. Therefore, the no load primary input power is practically equal to the iron loss in the transformer i.e.,

No load input power, W_0 = Iron loss

2. Derive the condition of maximum efficiency of a transformer. 2015(S)7(b))

Ans : Output power=$V_2I_2\cos\phi_2$

If R_{02} is the total resistance as referred to secondary

Total Cu loss,$P_c=I_2^2R_{02}$; Total losses=P_i+P_c

Transformer efficiency $\eta= V_2I_2\cos\phi_2/(V_2I_2\cos\phi_2+P_i+I_2^2R_{02})$

Dividing I_2 in numerator and denominator

$\eta= V_2\cos\phi_2/(V_2\cos\phi_2+(P_i/I_2)+I_2R_{02})$

Dividing above expression w.r.t. zero ,we get

$\frac{d}{dI2}$(denominator)=0

$d/dI_2(V2\cos\phi2+(P_i/I_2)+I_2R_{02})=0$

$0-P_i/I_2^2+R_{02}=0$

$Pi=I_2^2R_{02}$

Iron loss=copper loss

Hence efficiency of a transformer will be maximum when copper losses are equal to constant or iron losses.

3. Derive the emf equation of 1-Φ transformer from 1st principle. 2015(bp)3(ii)] [2014(s)7(b)]2015(S)1(b)]2013(s)3(b)

Ans : Consider that an alternating voltage V1 of frequency f is applied to the primary . The sinusoidal flux produced by the primary can be

$\phi=\phi_m\cos\omega t$

The instantaneous e.m.f. e1 induced in the primary is

$E_1=-N1(d\phi/dt)=-N_1 d/dt(\phi_m\cos\omega t)$

$-\omega N_1 \varphi_m \cos\omega t = -2\pi f N_1 \varphi_m \cos\omega t$

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

It is clear from the above equation that maximum value of induced e.m.f. in the primary is $E_{m1} = 2\pi f N_1 \phi_m$

The r.m.s. value of primary, $E_1 = E_{m1}/\sqrt{2} = 2\pi f N_1 \phi_m/\sqrt{2}$

$E1 = 4.44\ f\phi_m\ N1$ volt

$E2 = 4.44\ f\ \phi_m N2$ volt

In an ideal transformer, E1 = V1 and E2 = V2.

3. State and explain the condition of parallel operation of 1-Φ transformer. 2015(bp)4(ii)] 2015(S)5(b)] [2017 (S) OLD 7(i)(ii)] 20ns : Conditions for satisfactory parallel operation

In order that the transformers work satisfactorily in parallel, the following conditions should be satisfied:

(i) Transformers should be properly connected with regard to their polarities.
(ii) The voltage ratings and voltage ratios of the transformers should be the same.
(iii) The per unit or percentage impedances of the transformers should be equal.
(iv) The reactance/resistance ratios of the transformers should be the same.

Condition (i)

Condition (i) is absolutely essential because wrong connections may result in dead short-circuit. It will be seen that round the loop formed by the secondary's , the two secondaries e.m.f.s E_A and E_B oppose and there will be no circulating current.

Condition (ii)

This condition is desirable for the satisfactory parallel operation of transformers .If this condition is not met, the secondary e.m.f.s will not be equal and there will be circulating current in the loop formed by the secondary . This will result in the unsatisfactory parallel operation of transformers. Let E_A and E_B be their no-load secondary voltages and Z_A and Z_B be their impedances referred to the secondary. Then at no-load, the circulating current in the loop formed by the secondary is

Circulating current , $I_C = (E_A - E_B)/(Z_A + Z_B)$

Even a small difference in the induced secondary voltages can cause a large circulating current in the secondary loop because impedances of the transformers are small. This secondary circulating current will cause current to be drawn from the supply by the primary of each transformer. These currents will cause copper losses in both primary and secondary. This creates heating with no useful output.

When load is connected to the system, this circulating current will tend to produce unequal loading conditions i.e., the transformers will not share the load according to their kVA ratings. It is because the circulating current will tend to make the terminal voltages of the same value for both transformers. Therefore, transformer with smaller voltage ratio will tend to carry more than its proper share of load. Thus, one transformer would tend to become overloaded than the other and the system could not be loaded to the summation of transformer ratings without overloading one transformer.

Condition (iii)

This condition is also desirable for proper parallel operation of transformers. If this condition is not met, the transformers will not share the load according to their kVA ratings. Sometimes this condition is not fulfilled by the design of the transformers. In that case, it can be corrected by inserting proper amount of resistance or reactance or both in series with either primary or secondary circuits of the transformers where the impedance is below the value required to fulfill condition (iii).

Condition (iv)

If the reactance/resistance ratios of the two transformers are not equal, the power factor of the load supplied by the transformers will not be equal. In other words, one transformer will be operating with a higher and the other with a lower power factor than that of the load. Condition (iii) is much more important than condition (iv). Considerable deviation from condition (iv) will result in only a small reduction in the satisfactory degree of operation.

For parallel operation of three phase transformers following two conditions are essential

Condition(iv)

Phase sequence must be same.

Codition(v)

Transformers must belong to the same group number.

Transformer1	Yy	Dd	Yy	Yd	Yd
Transformer2	Yy	Dd	Dd	Dy	Yz

12. Discuss the No-load test and short circuit test of a 1Φ transformer. [2016(S)5(b)][2017(S)1(b)]

Ans : **<u>OPEN-CIRCUIT TEST</u>**

This test is conducted to determine the iron losses (or core losses) and parameters R0 and X0 of the transformer. In this test, the rated voltage is applied to the primary (usually low-voltage winding) while the secondary is left open circuited.

The applied primary voltage V1 is measured by the voltmeter, the no load current I0 by ammeter and no-load input power W0 by wattmeter as shown

In fig. . As the normal rated voltage is applied to the primary, therefore, normal iron losses will occur in the transformer core. Hence wattmeter will record the iron losses and small copper loss in the primary. Since no-load current I0 is very small (usually 2-10 % of rated current). Cu losses in the primary under no-load condition are negligible as compared with iron losses.

Hence, wattmeter reading practically gives the iron losses in the transformer. It is reminded that iron losses are the same at all loads. Fig. (7.30 (ii)) shows the equivalent circuit of transformer on no-load.

Iron losses, Pi = Wattmeter reading = W_o

No load current = Ammeter reading = I_o

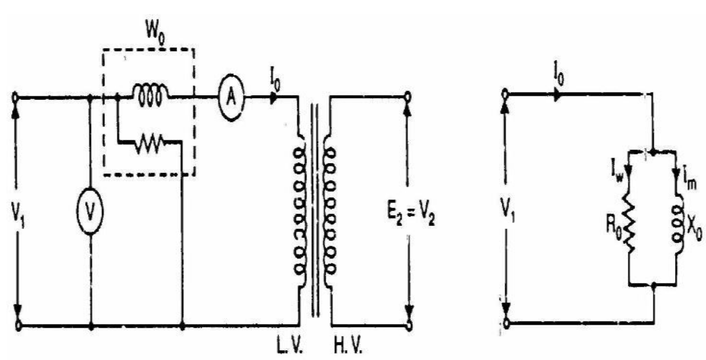
Applied voltage = Voltmeter reading = V_1

Input power, W_o = V1 $I_o \cos \phi_0$

⍰No - load p.f.,$\cos \phi_o=(W_oI_o)/V_1$

$I_m=I_o\sin\phi_o$

$I_w=I_o\cos\phi_o$



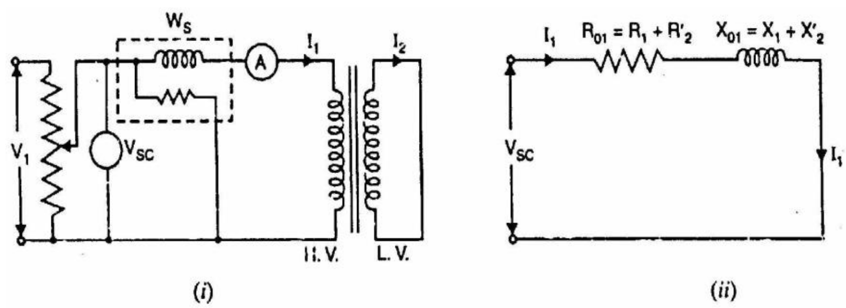
(i) (ii)

$R_o=(V_1/I_w)$ $X_o=(V_1/I_m)$

Open-circuit test enables us to determine iron losses and parameters R_0 and X_0 of the transformer.

SHORT CIRCUIT TEST

This test is conducted to determine R01 (or R02), X01 (or X02) and full-load copper losses of the transformer. In this test, the secondary (usually low-voltage winding) is short-circuited by a thick conductor and variable low voltage is applied to the primary as shown in figure given below in the transformer windings. Fig. shows the equivalent circuit of a transformer on short circuit as referred to primary:



Full load Cu loss, PC = Wattmeter reading = WS
Applied voltage = Voltmeter reading = VSC
F.L. primary current = Ammeter reading = I1

$P_c=I_1^2R_1+I_1^2R_2'=I_1^2R_{01}$

$R_{01}=(P_c/I_1^2)$

where R01 is the total resistance of transformer referred to primary.

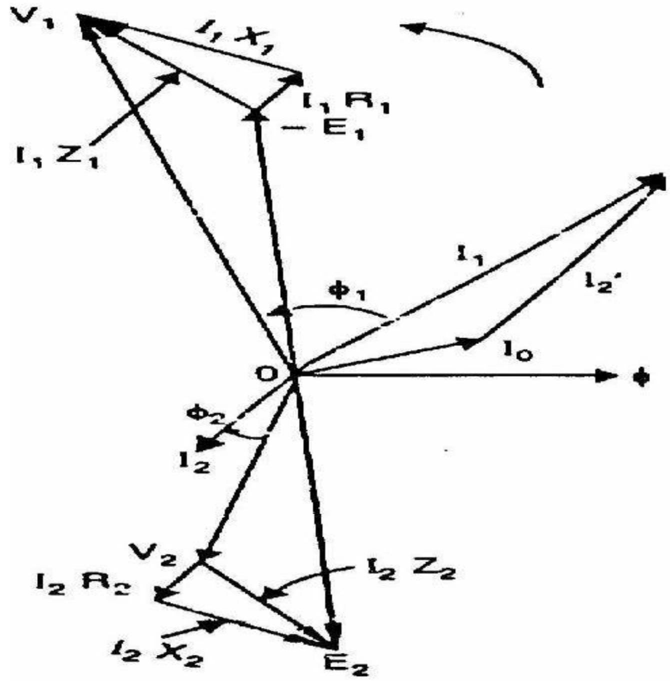
Total impedance referred to primary,$Z_{01}=(V_{sc}/I_{1})$

Total leakage reactance referred to primary,$X_{01}=$ $\sqrt{Z01^2+R01^2}$

Short-circuit p.f,$\cos\phi_2=P_c/(V_{sc}/I_1)$.

Thus short-circuit lest gives full-load Cu loss, R01 and X01.

13. Draw the phasor diagram of transformer having resistive-inductive load.[2013(s)]3(b)(ii)



14. **A 3000/200 V , 50 Hz, 1-ϕ transformer is built on a core having an effective cross sectional area of 150 cm^2 and has 80 turns in the low voltage winding. Calculate (i) the value of maximum flux density in the core,(ii) the no of turns in the high voltage winding. [2013 (s)4(b)]**

15. State the uses of auto transformer.[2014(s)6(b)]

Ans : (i) To obtain a neutral in a 3-wire ac distribution systems .The auto-transformer used in this manner is called balance coil.

(ii) Autotransformers used with a nos. of tappings used for starting induction motors and synchronous motors. These are known as auto starters.

(iii) A continuously variable autotransformer finds useful applications in electrical testing lab.

(iv) It is used as regulating transformers.

(v) Auto-transformers are used as boosters to raise the voltage in an ac feeders.

LONG QUESTIONS

16. A 220/110 V, single phase two winding transformer is fed from 220 V supply. The input at no-load is 400 VA and 150 watt. Find (a)no-load current and power factor,(b)magnetizing current and working component opf no-load current. 2015(S)2(c)]

17. 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, 1A, 2000W

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

Find (i) Parameters as referred to high voltage side.

(ii)Regulation and efficiency at full load 0.8 p.f. lagging*. 2015(S)5(c)]*

18. A 200kVA transformer has an efficiency of 98% at full load. If the maximum efficiency occurs at three quarters of full load, calculate the efficiency at half load. Assume negligible magnetizing current and power factor 0.8 at all loads. *2015(bp)1(iii)]*

19. A 5kVA distribution transformer has a full load efficiency of 95% at which copper loss is equal to the iron loss. The transformer is loaded for 24 hours as under :

No load for 10 hrs, one fourth full load for 7 hrs, half full load for 5 hrs and full load for 2 hrs.

Calculate the all day efficiency of the transformer. ***2015(bp)2(iii)]***

20. A 100kVA, 6600/250 V, 50 Hz transformer gave the following results :

O.C. Test : 900 W, normal voltage

S.C. Test : (Data on H.v. side) :12 A, 290 V, 860 W.

Calculate the efficiency and regulation at full load at 0.8 p.f. lagging.

21. Write short notes on equivalent circuit of transformer. 2015(bp)7(ii)]

22. The no-load current of a transformer is 15 A at power factor of 0.2(lag) when connected to 460 V, 50 Hz supply. If the primary ending has 550 turns, calculate

- ***(i) The magnetizing component of no-load current.***
- ***(ii) Iron loss.***
- ***(iii) The maximum value of flux in the core.*** **[2016(S)2(c)]**

23. A 600 kVA, 1Φ transformer has an efficiency of 92% both full load and half load at unity power factor .Determine its efficiency at 60% of full-load at 0.8 power factor. **[2016(S)3(c)]**

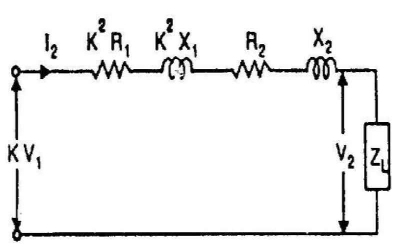
24. Draw **approximate and exact voltage drop of transformer using simplified phasor diagram.[2013(s)3(c)]2014(s)6(c)**

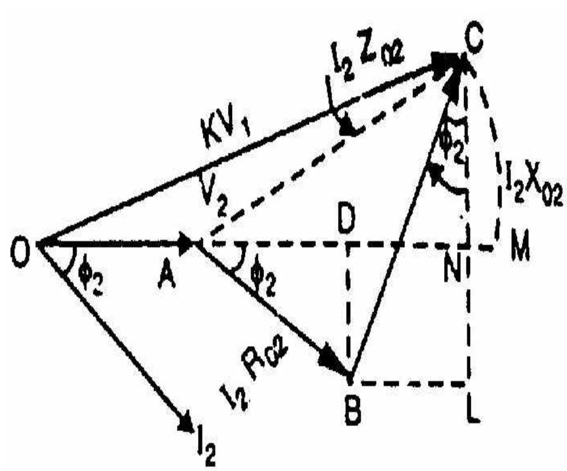
Ans: The approximate equivalent circuit of transformer referred to secondary is shown in figure. At no-load, the secondary voltage is K V1. When a load having a lagging p.f. cos ϕ2 is applied , the secondary carries a current I2 and voltage drops occur in (R2 + K2 R1) and (X2 + K2 X1). Consequently, the secondary voltage falls from K V1 to V2. Referring to Fig . , we have,

$V_2=KV_1-I_2[(R_2+K^2R_1)+j(X_2+K^2X_1)]$

$=KV_1-I_2(R_{02}+jX_{02})=$

Drop in secondary voltage$=KV_1-V_2=I_2Z_{02}$





Approximate voltage drop in secondary=AN=AD+DN

=AD+BL (□BL= DN)

$I_2R_{02}\cos\phi_2+I_2X_{02}\sin\phi_2$

For a load having a leading p.f. cos □2, we have,

Approximate voltage drop □□I2R02 cos□2 □□I2X02 sin □2

25. A 600 kVA, 1-ϕ transformer has an efficiency of 92% both at full load and half load t unity power factor. Determine its efficiency at 60 % of full load at 0.8 pf lag.[2013(S4(c))]

***26.*Short notes on maintenance schedule of power transformer.2013(s)7(d) 2015(bp)6(ii)]**

Ans :

Sl. No.	**ITEMS**	**PERIOD OF INSPECTION**
1	Oil level, temperature(if high)	*week*
2	*D*ehydrating breather, temperature(if low)	*month*
3	*Free air or oil seal breather, bushings*	*3 months*
4	Oil(crackle and dielectric tests),paint work ,external connection ,internal above oil level(non-conservator)	*year*
5	Complete examination including acidity test of oil and inspection of core and windinds	*2 or 3 years*

***27.* A 200kVA transformer has an efficiency of 98% at full load. If the maximum efficiency occurs at three quarters of full load, calculate (i)iron loss at full load,(ii)cu loss at full load (iii)efficiency at half load. Ignore magnetizing current and assume a pf of 0.8 at all loads.[2014(s)7(c)]**

CHAPTER-04

(AUTOTREANSFORMER)

SHORT QUESTIONS

1. State the uses of autotransformer. 2015(S)7(a)]

Ans : Applications of Autotransformers

(i) Autotransformers are used to compensate for voltage drops in transmission and distribution lines. When used for this purpose, they are known as booster transformers.

(ii) Autotransformers are used for reducing the voltage supplied to a.c. motors during the starting period.

(iii)Autotransformers are used for continuously variable supply.

MEDIUM QUESTIONS

1. What is an auto-transformer ? State its merits and demerits over the two winding transformer. 2015(bp)1(ii)]

Ans : An autotransformer has a single winding on an iron core and a part of winding is common to both the primary and secondary circuits.

Merits

(i) An autotransformer requires less Cu than a two-winding transformer of similar rating.

(ii) An autotransformer operates at a higher efficiency than a two-winding transformer of similar rating.

(iii) An autotransformer has better voltage regulation than a two-winding transformer of the same rating.

(iv) An autotransformer has smaller size than a two-winding transformer of the same rating.

(v) An autotransformer requires smaller exciting current than a two-winding transformer of the same rating.

It may be noted that these advantages of the autotransformer decrease as the ratio of transformation increases.

Demerits

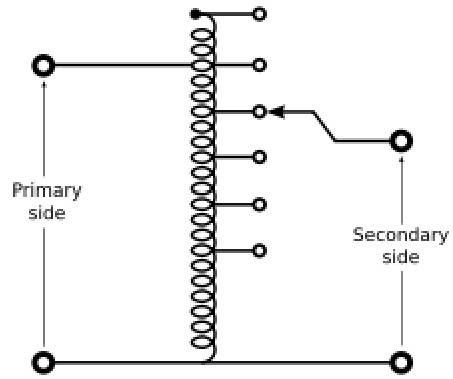
(i) There is a direct connection between the primary and secondary. Therefore, the output is no longer d.c. isolated from the input.

(ii) An autotransformer is not safe for stepping down a high voltage to a low voltage.

(iv) The short-circuit current is much larger than for the two-winding transformer of the same rating.

2. **Explain the working principle of 1 ϕ Auto- Transformer?**

Ans : An autotransformer (sometimes called autostep down transformer)[1] is an electrical transformer with only one winding. The "auto" (Greek for "self") prefix refers to the single coil acting alone and not to any kind of automatic mechanism. In an autotransformer, portions of the same winding act as both the primary and secondary sides of the transformer. In contrast, an ordinary transformer has separate primary and secondary windings which are not electrically connected.



An autotransformer has a single winding with two end terminals, and one or more terminals at intermediate tap points, or it is a transformer in which the primary and secondary coils have part of, or all of their turns in common. The primary voltage is applied across two of the terminals, and the secondary voltage taken from two terminals, almost always having one terminal in common with the primary voltage. The primary and secondary circuits therefore have a number of windings turns in common.[3] Since the volts-per-turn is the same in both windings, each develops a voltage in proportion to its number of turns. In an autotransformer part of the current flows directly from the input to the output, and only part is transferred inductively, allowing a smaller, lighter, cheaper core to be used as well as requiring only a single winding.[4] However the voltage and current ratio of autotransformers can be formulated the same as other two-winding transformers:

$$\mathbf{V_1/V_2 = N_1/N_2}$$

$(0<V_2<V_1)$

The ampere-turns provided by the upper half:

$$\mathbf{F_V = (N_1 - N_2)\ I_1 = (1-1/a)\ N_1 I_1}$$

The ampere-turns provided by the lower half:

$$\mathbf{F_L = N_2\,(I_2 - I_1) = N_1/a\ (I_2 - I_1)}$$

For ampere-turn balance, $F_U=F_L$:

(a-1/a) $N_1I_1 = N_1/a\ (I_2-I_1)$

Therefore:

$I_1/I_2 = 1/a$

One end of the winding is usually connected in common to both the voltage source and the electrical load. The other end of the source and load are connected to taps along the winding. Different taps on the winding correspond to different voltages, measured from the common end. In a step-down transformer the source is usually connected across the entire winding while the load is connected by a tap across only a portion of the winding. In a step-up transformer, conversely, the load is attached across the full winding while the source is connected to a tap across a portion of the winding.

As in a two-winding transformer, the ratio of secondary to primary voltages is equal to the ratio of the number of turns of the winding they connect to. For example, connecting the load between the middle and bottom of the autotransformer will reduce the voltage by 50%. Depending on the application, that portion of the winding used solely in the higher-voltage (lower current) portion may be wound with wire of a smaller gauge, though the entire winding is directly connected.

LONG QUESTIONS

1. **A step-up autotransformer is used to supply a 500 V, 20kVA load from a 400 V supply,(a)show the connection diagram and find (a)currents in primary and secondary side(b)volt-amperes transferred conductively and inductively(c)the apparent power if the coils of this auto-transformer are used as two-winding transformer. 2015(S)6(c)]**

2. **Derive saving of copper for an auto transformer with respect to ordinary transformer. [2016(S)4(c)] [2013(s)6(b)]**

Ans : For the same output and voltage transformation ratio K(N2/N1), an autotransformer requires less copper than an ordinary 2-winding transformer. Fig. shows an ordinary 2-winding transformer whereas Fig. shows an auto transformer having the same output and voltage transformation ratio K.

The length of copper required in a winding is proportional to the number of turns and the area of cross-section of the winding wire is proportional to the current rating. Therefore, the volume and hence weight of copper required in a winding is proportional to current x turns i.e.,

Weight of Cu required in a winding $\propto$ current $\times$ turns

Winding transformer

$$\text{Weight of Cu required} \propto (I_1N_1 + I_2N_2)$$

Autotransformer

$$\text{Weight of Cu required in section 1-2} \propto I_1(N_1 - N_2)$$

$$\text{Weight of Cu required in section 2-3} \propto (I_2 - I_1)N_2$$

$$\therefore \quad \text{Total weight of Cu required} \propto I_1\,(N_1 - N_2) + (I_2 - I_1)N_2$$

$$\frac{\text{Weight of Cu in autotransformer}}{\text{Weight of Cu in ordinary transformer}} = \frac{I_1(N_1 - N_2) + (I_2 - I_1)N_2}{I_1N_1 + I_2N_2}$$

$$= \frac{N_1I_1 - N_2I_1 + N_2I_2 - N_2I_1}{N_1I_1 + N_2I_2}$$

$$= \frac{N_1I_1 + N_2I_2 - 2N_2I_1}{N_1I_1 + N_2I_2}$$

$$= 1 - \frac{2N_2I_1}{N_1I_1 + N_2I_2}$$

$$= 1 - \frac{2N_2I_1}{2N_1I_1} \qquad (\because \ N_2I_2 = N_1I_1)$$

$$= 1 - \frac{N_2}{N_1} = 1 - K$$

$\therefore$ Wt. of Cu in autotransformer (W_a)

= (1 − K) × Wt. in ordinary transformer (W_o)

$$W_a = (1 - K) \times W_o$$

$\therefore$ Saving in Cu = $W_o - W_a = W_a - (1 - K)W_o = K\ W_o$

Saving in Cu = K × Wt. ofCu in ordinary transformer

CHAPTER-05

(3-Φ Transformers)

SHORT QUESTIONS

1. Show the various connections of a 3-Φ transformer. 2015(S)4(a)]

Ans : Star-star(Y-y)

Star-delta(Y-d)

Delta-delta(D-d)

Delta-star(D-y)

2. **What is transformer grouping?[2014(s)5(a)]**

Ans : Group1 : Zero phase displacement (Yy0, Dd0, Dz0)

Group2 : 180 phase displacement (Yy6, Dd6, Dz6)

Group 3 : 30 lag phase displacement (Dy1, Yd1, Yz1)

Group 4 : 30 lead phase displacement (Dy11, Yd11, Yz11)

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