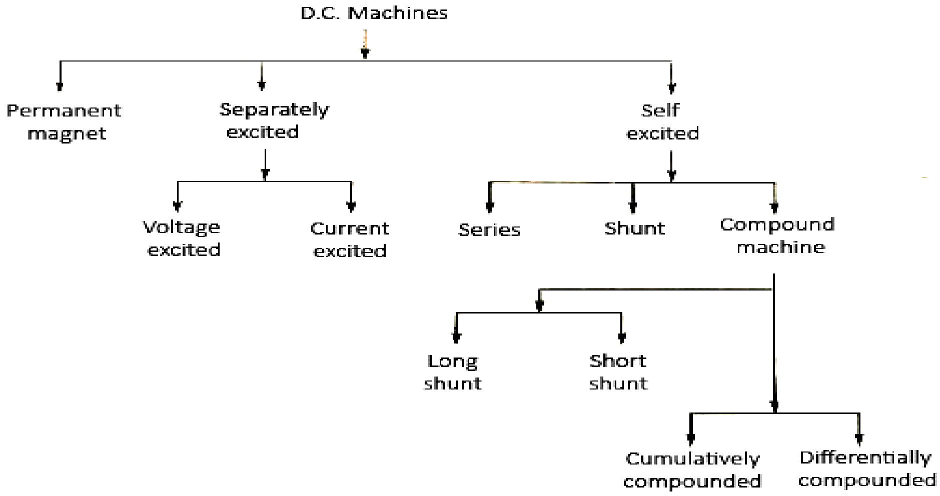
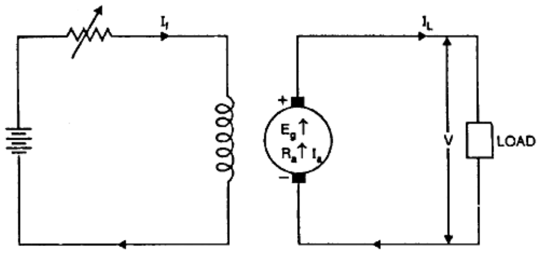
Electrical Machines-I

1. (a) Discuss about the various types of DC generators.

Types of DC generator:



I. Separately excited generator:



Separately Excited DC Generator is A DC Generator Whose Field Magnetic Winding Is Excited From An Independent External Dc source (Eg:Battery)

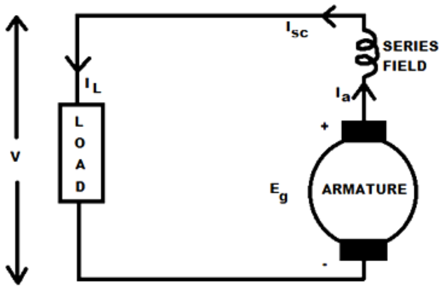
II. Self- excited DC generator:

There are three types of self-excited generator depending upon the manner in which the field windings is connected to the armature winding namely

1. Series generator,
2. Shunt generator,
3. Compound generator.

1. Series Generator :

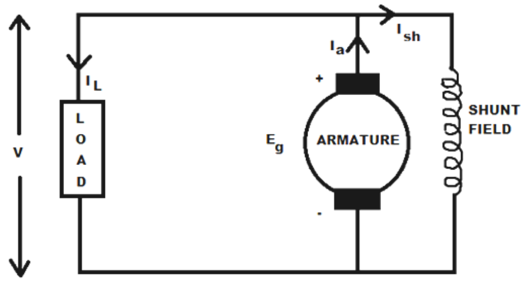
In series wound generator, the field winding a connected in series with armature winding, shows the connection of series wound generator, since the field of series wound generator. Since the field winding carries the whole of load current, it has a few turns of thick wire having low resistance. Series generators are used for specific purposes.



Series Wound Generator

2. Shunt generator:

In shunt generator, the field winding is connected in parallel with armature winding. Here terminal voltage is applied across field winding. The shunt winding has many turns of fine wire having high resistance. Therefore only a small part of armature current flows through shunt field winding and rest flows through the load.

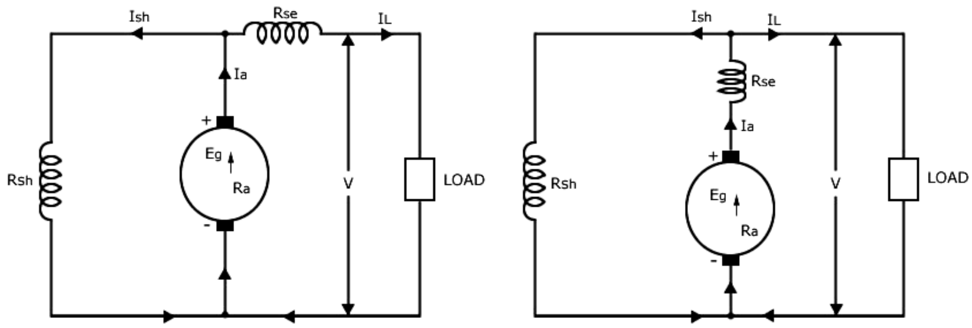


Shunt Wound Generator

3. Compound generator:

In a compound wound generator, there are two sets of field windings on each pole, one is in series and other is in parallel with the armature. There are two types of compound wound generator.

I. Short shunt
II. Long shunt



Short Shunt Compound (a)   Long Shunt Compound (b)

In this type of DC generator, the field is produced by the shunt as well as series winding. The shunt field is stronger than the series field. If the magnetic flux produced by the series winding assists the flux produced by the shunt field winding, the generator is said to be Cumulatively Compounded generator.

If the series field flux opposes the shunt field flux, the generator is said to be Differentially Compounded.

(b) Derive the EMF equation of a DC generator.

EMF equation of DC generator:

In a DC generator when armature conductor cuts the flux an EMF is induced as per Faraday'slaws of electromagnetic induction. The EMF induced is based on the factors mentioned below.

Let

P = Number of poles in the generatorϕ = Flux per pole
Z = Number of armature conductors
N = Speed of rotor in RPM
A = Number of parallel paths in armature

E_g = EMF generated in any of the parallel path in armature.
Average EMF generated per conductor = Eg Volts
Flux cut by the conductor in one revolution of the armature $d\phi = P\phi$ Webers

Number of revolutions made in 1 minute	= N
number of revolutions made in 1 second	= N/60
Time taken to complete one revolution	= 60/N
Average EMF generated per conductor	= Pϕ/60/N
	= ϕNP/60 Volts
EMF generated by Z number of conductors	= Z* ϕNP/60
	= ϕZNP/60 Volts
EMF generated per parallel path	= PϕZN/60A Volts

(c) Discuss the methods of improving commutation process.

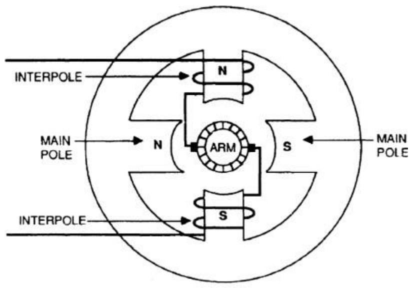
Methods of improving commutation

1. High resistance carbon brush

The current from the coil C tends to flow through coil b. And avoid the path through segment b thus the commutation is improved and the sparking is reduced

2. Interpoles or commutating poles:

By providing small magnetic poles called interpoles between the main poles at the MNA, the armature reaction effect may be reduced.The coils provided around these poles are wound with thick copper wires and connected in series with armature .The coil undergoing commutation cuts the flux and has the emf induced in it. This induced emf acts in the direction opposite to the self - induced emf in the coil undergoing commutation. Since the self-induced emf is also proportional to armature current sparkless commutation is obtained. The polarity of the interpole must be same as that of the main pole and just ahead in the direction of rotation. Interpoles are long but narrow in shape to avoid saturation



Interpole wiring for a two-pole DC motor.

(d) Discuss about the causes of failure to build up voltage and its remedies.

A DC generator may fail to build up its voltage due to several reasons. Here are some common causes and their remedies:

Causes**:**

1. **No Residual Magnetism :** If there's no residual magnetism in the field poles, the generator cannot initiate the self-excitation process.

Remedy :

- **Flashing the Field:** Briefly connect the field winding to a DC source to induce residual magnetism.
- **Magnetizing the Poles:** Use a permanent magnet to magnetize the field poles.

2. **Reversed Field Connections:** If the field winding connections are reversed, the field current opposes the residual magnetism, preventing voltage buildup.
   - Remedy**:** Correct the field winding connections.
3. **High Field Resistance:** If the field resistance is too high, the field current may be insufficient to build up the voltage.
   - Remedy**:** Reduce the field resistance by adjusting the field rheostat.
4. **Low Speed:** If the generator's speed is below the critical speed, it cannot generate sufficient voltage to overcome losses and build up.
   - Remedy**:** Increase the speed of the prime mover.
5. **Open Circuit in the Field Winding:** An open circuit in the field winding prevents the flow of field current, hindering voltage buildup.
   - Remedy**:** Repair or replace the faulty field winding.
6. **Excessive Armature Reaction:** Strong armature reaction can demagnetize the field poles, reducing voltage buildup.
   - Remedy**:** Use compensating windings or interpoles to neutralize armature reaction.
7. **Poor Brush Contact:** Poor brush contact can reduce the effective field current, hindering voltage buildup.
   - Remedy**:** Clean the commutator and brushes, and ensure proper brush tension.
8. **Overload:** A heavy load can reduce the terminal voltage, making it difficult for the generator to maintain voltage.
   - Remedy**:** Reduce the load on the generator.

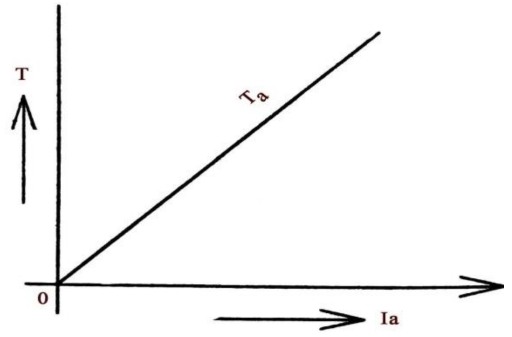
2. (a) Discuss the load characteristics and speed characteristics of DC motors.

DC SHUNT MOTOR CHARACTERISTICS

1) TORQUE Vs ARMATURE CURRENT CHARACTERISTICS

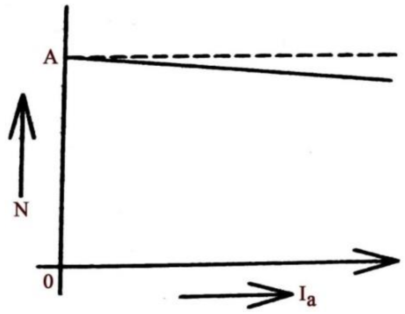
In a DC motor $T \alpha \Phi I_a$

As the shunt field winding is connected directly to the supply voltage, the field is assumed to be constant. So the flux will also be constant. Hence torque developed in a DC shunt motor will be directly proportional to armature current I_a.$T \alpha I_a$



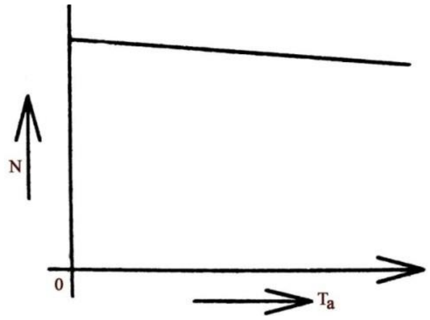
2) SPEED Vs ARMATURE CURRENT CHARACTERISTICS

The speed of the DC shunt motor decreases with the increase in armature current due to loading. The characteristic curve is slightly drooping one. But due to armature reaction the flux is weakened and the speed will increase. This increase in speed compensates the decrease in speed due to $I_aR_a$drop. Therefore the speed of DC shunt motor is almost constant.



3) SPEED Vs TORQUE CHARACTERISTICS

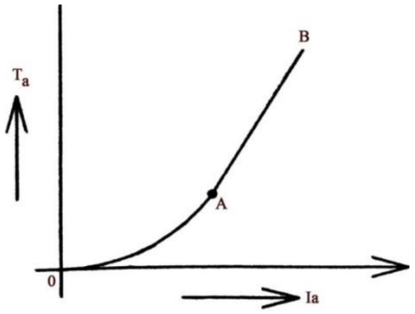
when the torque increases, the speed decreases



DC SERIES MOTOR CHARACTERISTICS

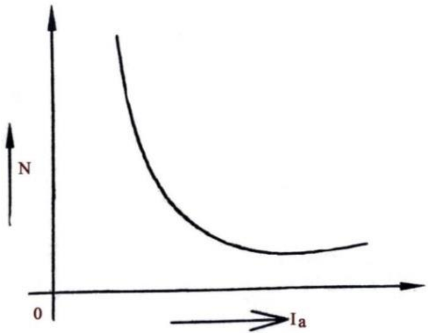
1) TORQUE Vs ARMATURE CURRENT CHARACTERISTICS

In a DC motor T α Φ I_a.Up to magnetic saturation Φ α I_a.So before saturation T α $I_a^2$and the corresponding curve is from O to A.After magnetic saturation Φ becomes constant. Hence T α I_a and is indicated from A to.



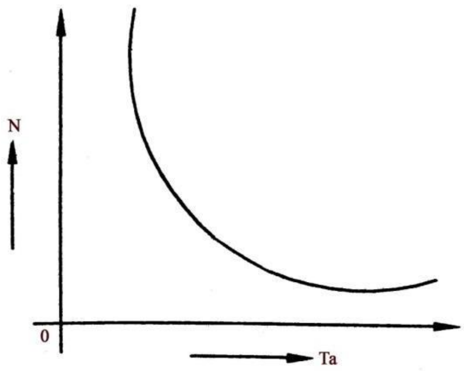
2) SPEED Vs ARMATURE CURRENT CHARACTERISTICS

In series motor I_aR_a drop is very small when compared to supply voltage. Hence N = V/Φ. On light load, the flux will be very low. When the load increases flux also increases. Hence the speed drops rapidly. So the shape of the curve will be hyperbolic. After saturation flux remains constant. Therefore the speed will be constant and low at heavy loads. The series motor should be started with load only to avoid running from dangerously high speed.



3) SPEED Vs TORQUE CHARACTERISTICS

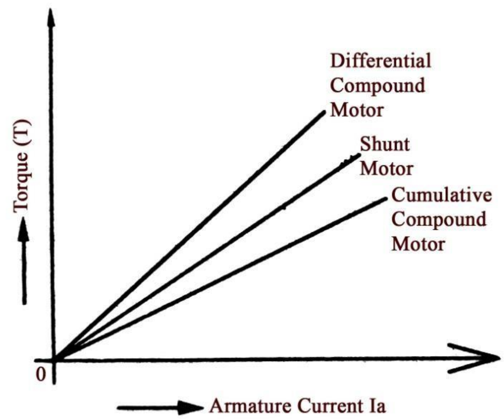
the speed is inversely proportional to torque and the curve ishyperbolic in shape



DC COMPOUND MOTOR

1) TORQUE Vs ARMATURE CURRENT CHARACTERISTICS

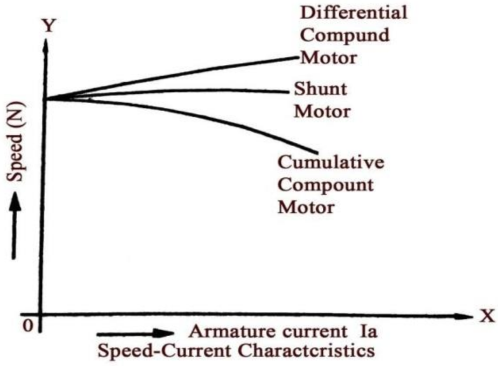
As the load increases, the series field increases but shunt field strength remains constant. Consequently, total flux is increased and hence the armature torque also increases (since T α Φ Ia). So the torque of cumulative compound motor is greater than that of shunt motor for given armature current due to series field



2) SPEED Vs ARMATURE CURRENT CHARACTERISTICS

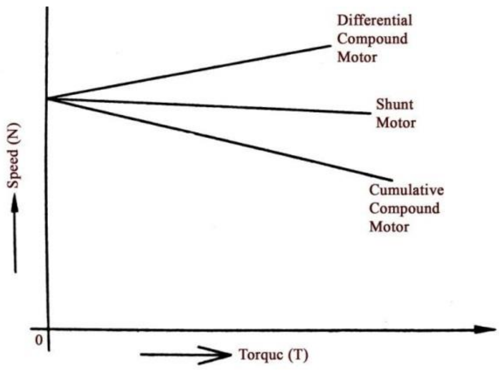
As explained above, as the load increases, the flux per pole increases. Consequently, the speed of the motor falls (N α 1/Φ) as the load increases. It may be noted that as the load is added, the increased amount of flux causes the speed to decrease more than does the speed of the shunt motor. Thus the speed regulation of a cumulative compound motor is poorer than that of a shunt motor.

Note: Due to shunt field, the motor has a definite no load speed and can be operated safely at no load.

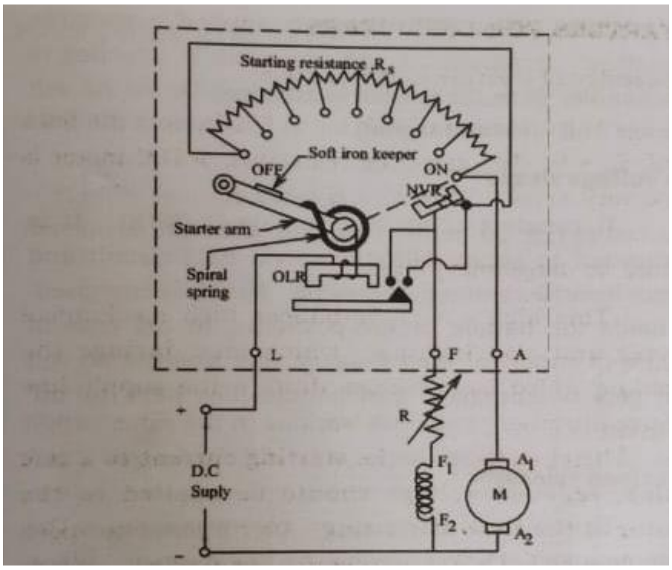


3) SPEED Vs TORQUE CHARACTERISTICS

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.



(b) Explain the working of three point starter with a neat diagram.



It has

i. Three terminals namely line L, field F, armature A,
ii. Handle with soft iron keeper,
iii. Overload relay OLR and
iv. No volt release (NVR).

The connection diagram of a three-point starter. The starter terminals to be connected to the motor are A(Armature); F(field) and L(line). The starting resistance is arranged in steps between conductingraised studs. As the starting handle is rotated about its fulcrum, it moves from one stud to the next, one resistance step is cut out, and it gets added to the field circuit. There is a short time wait at each stud for the motor to build up speed. This arrangement ensures a high average starting torque.

At start the handle is brought to stud one. The line voltage gets applied to the armature with full starting resistance in series with armature and to the field with NVC in series. Thus thestarting current is limited to a safe value and the motor starts with maximum torque. As it pick up speed the handle is moved from stud to stud (notching) to the ON position. The starting resistance has been fully cut out and is now included in the field circuit; being small it makes little difference in the field current. The resistance of NVC is small and forms part of the field resistance. The voltage across the armature is the line voltage.

The handle is held in this position by the electromagnet excited by the field current flowing through NVC.

Two protections are incorporated in the starter.

- NVC (No volt coil): In case of failure of field current(due to accidental or otherwise open circuiting), this coil releases the handle (held electromagnetically), which goes back to the OFF position under the spring action.
- OLR (Over load release): The contact of this relay at armature current above a certain value (over load/ short circuit) closes the NVC ends, again bringing the handle to OFF position due to demagnetizing of NVC.

Disadvantage:

If the motor speed is controlled using field regulator the NVR gets de energized and the handle goes back to OFF position. So field control cannot be applied in 3 points starter.

(c) Discuss about any one method of speed control of DC motors.

There are two types of speed control of DC shunt motor.

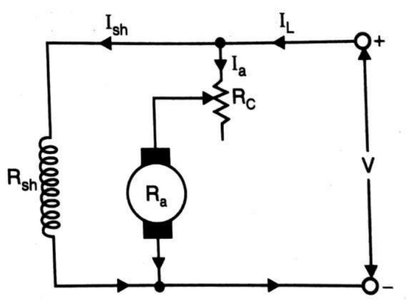
1.Armature control or resistance control method.

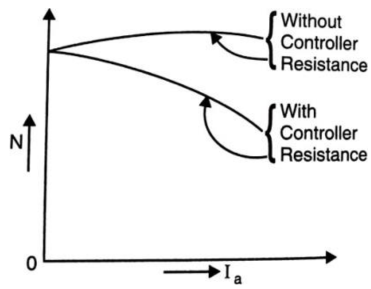
2.Field control method.

1. Armature control or resistance control method:

The relation between speed and supply voltage is given by N α Eb

This method is based on the fact that by varying the voltage available across the armature, the back EMF and the speed of the motor can be changed. This is done by inserting a variable resistance Rc (known as controller resistance) in series with the armature Eb = V-Ia (Ra +Rc)





As this control resistance Rc is increased, the voltage drop across the control resistance increases and the back EMF Eb decreases and hence the speed decreases. This highest speed obtainable is that corresponding to Rc=0; i.e. rated speed. Hence this method can only provide speeds below the rated speed.

Demerits:

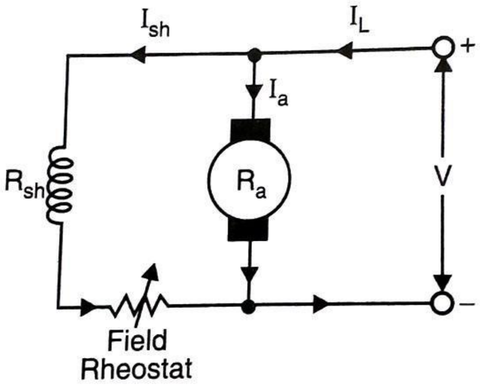
- This method is not widely used because of the large losses in the Rheostat and also efficiency of the motor is reduced.
- Speeds below ratedspeed can only be obtained.
- Requires expensive arrangements to dissipate the heat developed in the control resistance.

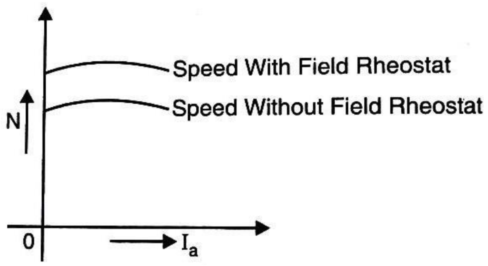
Merits:

- This method is suitable for constant load drives where speed variation from low speed up to rated speed are only required.

2. Field control method

As per the speed equation, the speed is inversely proportional to the field flux. Since flux depends upon the exciting current (field current), if the current is decreased then the speed will be increased. In field control method, the air gap flux is varied by introducing a resistance in the shunt field circuits. It is the most commonly used as well as the most economic method.





A variable resistance (rheostat) is connected in series with the shunt field of shunt or compound motor. By increasing the series resistance, the field current may be decreased and thus the field flux weakens and speed increases. In this case losses are small.

In this method we can only raise the speed of the motor above the rated speed since the flux cannot be increasedbeyond the value corresponds to the rated voltage.

Advantages :

- Higher speeds i.e. above rated speed only can be obtained.
- Speed control is easy, economic, convenientand efficient.
- The speed control by this method is independent of load on the machine.

Disadvantages :

- At high speeds,the flux will be very low and torque is also reduced.
- There is a limit to the maximum speed obtained by this method as the weak field leads to poor commutation.

(d) Write a note on BLDC motor.

BLDC Motor

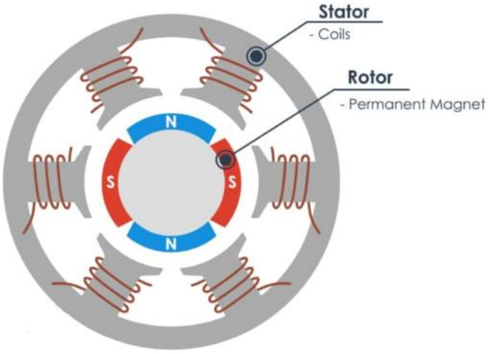
A Brushless DC (BLDC) motor is a type of synchronous electric motor that does not use mechanical brushes. Instead, it employs a sophisticated electronic commutation system to control the timing and sequence of current flow through the stator windings. This design eliminates the need for physical brushes, reducing friction, wear, and maintenance requirements.

A BLDC motor typically consists of:

1.Stator: Contains three phase windings that generate a rotating magnetic field.

2.Rotor: A permanent magnet rotor that aligns itself with the rotating magnetic field.

3.Electronic Controller: This component senses the rotor's position and controls the current flow to the stator windings, ensuring efficient operation.



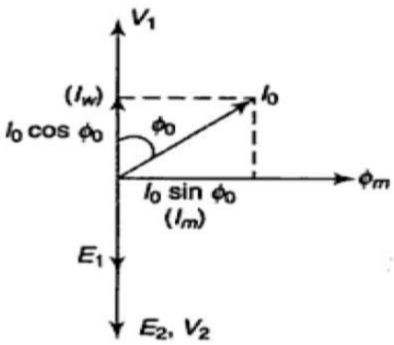
1.Initialization: The electronic controller senses the initial position of the permanent magnet rotor using Hall effect sensors or other position sensing techniques.

2.Commutation: Based on the rotor's position, the controller switches the current to the appropriate stator windings. This creates a rotating magnetic field that interacts with the permanent magnet rotor, causing it to rotate.

3.Continuous Rotation: The controller continuously monitors the rotor's position and adjusts the current flow to maintain the rotating magnetic field, ensuring smooth and efficient operation.

3. (a) Draw and explain the phasor diagrams of a single phase transformer at no-load and load conditions at varying power factors.

Phasor diagram on no load



Phasor diagram under no-load condition

In practical transformer, due to winding resistance, no load current I_o is no longer at 90^0 with respect to V_1. But it lags V_1 by angle Φ_0 which is less than 90^0. Thus $\cos\Phi_0$ is called no load power factor of practical transformer.

It can be seen that the two components of Io are,

$$I_m = I_0 sin\emptyset_0$$

This is magnetising component lagging V1 exactly by 90^0

$$I_w = I_0 cos\emptyset_0$$

This is core loss component which is in-phase with

$$I_0 = \sqrt{I_m^2 + I_w^2}$$

V_1The magnitude of the no-load current is given by,

While $\emptyset_0 = No\ load\ primary\ power\ factor\ angle$

The total power input on no load is denoted as W_o and is given by,

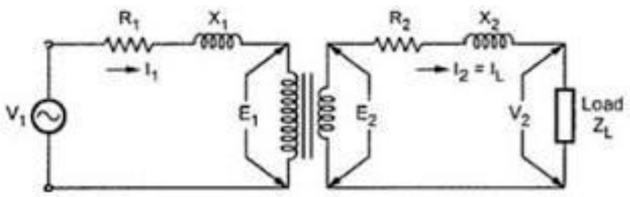
$$W_0 = V_0 I_0 \cos\emptyset_0 = V_0 I_w$$

It may be noted that the current I_o is very small, about 3 to 5% of the full load rated current. Hence the primary copper loss is negligibly small hence I_c or I_W is called core loss or iron loss component. Hence power input W_0 on no load always represents the iron losses as copper loss is negligibly small. The iron losses are denoted as P_i and are constant for all load conditions.

$$\therefore \qquad W_0 = V_0 I_0 \cos\emptyset_0 = P_i = Iron\ loss$$

Phasor Diagram or Vector Diagram On Load (Different Power Factors)

Consider a transformer supplying the load



The various transformer parameters are,

R_1		=	Primary winding resistance
X_1		=	Primary leakage reactance
R_2		=	Secondary winding resistance
X_2		=	Secondary leakage reactance
Z_L		=	Load impedance
I_1		=	Primary current
I_2		=	Secondary current = I_L = Load current
now	$\bar{I}_1$	=	$\bar{I}_o + \bar{I}_2'$
where	I_o	=	No load current
I_2'		=	Load component of current decided by the load
		=	$K\ I_2$ where K is transformer component

The primary voltage V_1 has now three components,

1. $-E_1$, the induced e.m.f. which opposes V_1
2. $I_1\ R_1$, the drop across the resistance, in phase with I_1
3. $I_1\ X_1$, the drop across the reactance, leading I_1 by 90^o

$$\therefore \quad \bar{V}_1 = -\bar{E}_1 + \overline{I_1 R_1} + \overline{I_1 X_1} \qquad \text{... phasor sum}$$

$$= -\bar{E}_1 + \bar{I}_1 (R_1 + j X_1)$$

$$\boxed{\bar{V}_1 = -\bar{E}_1 + \overline{I_1 Z_1}}$$

The secondary induced e.m.f. has also three components,

1. V_2, the terminal voltage across the load
2. $I_2\ R_2$, the drop across the resistance, in phase with I_2

3. $I_2 X_2$, the drop across the reactance, leading I_2 by 90^o

$\therefore \quad \bar{E}_2 = \bar{V}_2 + \overline{I_2 R_2} + \overline{I_2 X_2}$ ... phasor sum

$\therefore \quad \bar{V}_2 = \bar{E}_2 - \bar{I}_2 (R_2 + j X_2)$

$\therefore \quad \boxed{V_2 = \bar{E}_2 - \overline{I_2 Z_2}}$

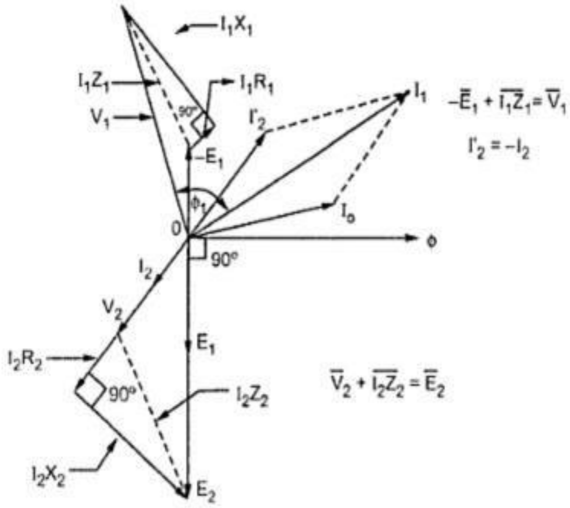
The phasor diagram for the transformer on load depends on the nature of the load power factor. Let us consider the various cases of the load power factor.

1.1 Unity power factor load, $\cos\Phi_2 = 1$

As load power factor is unity, the voltage V_2 and I_2 are in phase. Steps to draw the phasor diagram are,

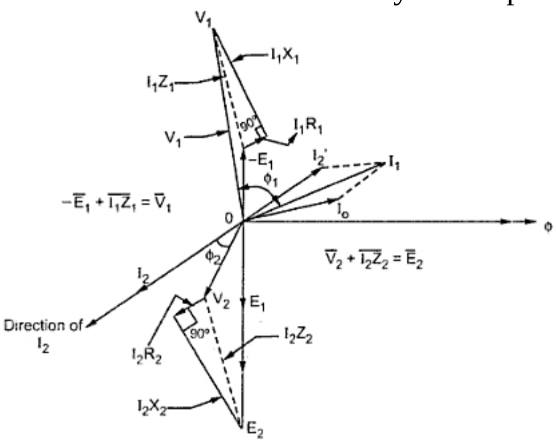
1. Consider flux Φ as reference
2. E_1 lags Φ by 90^o. Reverse E_1 to get $-E_1$.
3. E_1 and E_2 are inphase
4. Assume V_2 in a particular direction
5. I_2 is in phase with V_2.
6. Add $I_2 R_2$ and $I_2 X_2$ to to get E_2.
7. Reverse I_2 to get I_2'.
8. Add I_o and I_2' to get I_1.
9. Add $I_1 R_1$ and to $-E_1$ to get V_1.

Angle between V_1 and I_1 is Φ_1 and $\cos\Phi_1$ is primary power factor. Remember that I_1X_1 leads I_1 direction by 90^o and $I_2 X_2$ leads I_2 by 90^o as current through inductance lags voltage across inductance by 90^o.



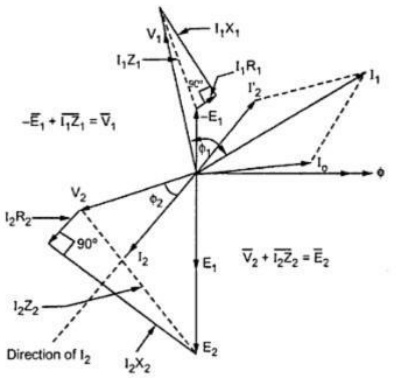
Lagging Power Factor Load, $\cos \Phi_2$

As load power factor is lagging $\cos\Phi_2$, the current I_2 lags V_2 by angle Φ_2. So only changes in drawing the phasor diagram is to draw I_2 lagging V_2 by Φ_2 in step 5 discussed earlier. Accordingly direction of $I_2 R_2$, $I_2 X_2$, I_2', I_1, $I_1 R_1$ and I_1X_1 will change. Remember that whatever may be the power factor of load, I_2X_2 leads I_2 by 90^o and I_1X_1 leads I_1 by 90^o.



Loading Power Factor Load, cos Φ_2

As load power factor is leading, the current I_2 leads V_2 by angle Φ_2. So change is to draw I_2 leading I_2 by angle Φ_2. All other steps remain same as before.



(b) Discuss about the determination of equivalent circuit constants of a single phase transformer.

Determination of Equivalent Circuit Constants:

The equivalent circuit parameters of a transformer are determined by conducting two tests ona transformer which are

1. ***Open Circuit Test (O.C. test)***
2. ***Short Circuit Test (S.C. Test)***

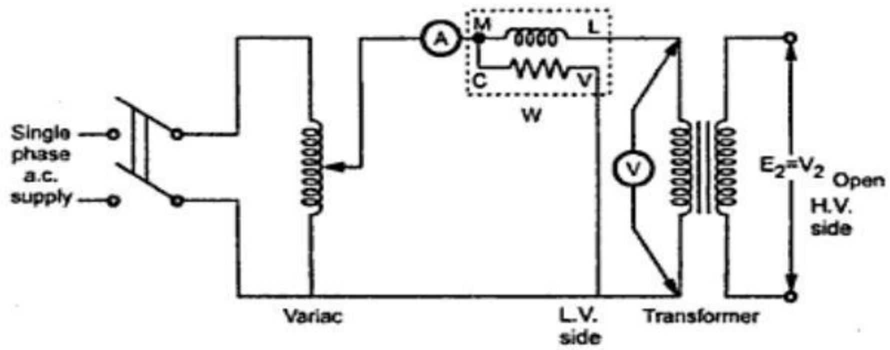
The parameters calculated from these test results are effective in determining the regulation and efficiency of a transformer at any load and power factor condition, without actually loading the transformer. The advantage of this method is that without much power loss the tests can be performed and results can be obtained.

Open Circuit Test (O.C. Test):

The experimental circuit to conduct O.C. test

The transformer primary is connected to a.c. supply through ammeter, wattmeter and variac. The secondary of transformer is kept open. Usually low voltage side is used as primary and high voltage side as secondary to conduct O.C.Test.

The primary is excited by rated voltage, which is adjusted precisely with the help of a variac. The wattmeter measures input power. The ammeter measures input current. The voltmeter gives the value of rated primary voltage applied at rated frequency.



When the primary voltage is adjusted to its rated value with the help of variac, readings of ammeter and wattmeter are to be recorded.

The observation table is as follows.

No load VoltageV_o Volt	No load CurrentI_o Ampere	No load PowerW_o Watt

Where,

V_o = Rated Voltage

I_o = Input current = No Load current

W_o = Input Power

As transformer secondary is open, it is on load. So current drawn by the primary is no load current I_o. The two components of this no load current are,

$$I_m = I_0 \sin\emptyset_0$$

$$I_W = I_0 \cos\emptyset_0$$

$$Where, \qquad \cos\emptyset_0 = No\ load\ power\ factor$$

And hence power input can be written as,

$$W_0 = V_0 I_0 \cos\emptyset_0$$

The transformer no load current is always very smaall, hardly 2 to 4% of its full load value. As I2=0, secondary copper losses are zero. And I1= I0 is very low hence copper losses on primary are also very very low. Thus the total copper losses in O.C test are negligible small.

As output power is zero and copper losses are very low, the total input power is used to supply iron losses.

This power is measured by the wattmeter i.e. Wo. Hence the wattmeter in O.C test gives iron

$$\therefore \qquad W_0 = P_i = Iron\ loeeses$$

losses which remain constant for all the loads.

Calculations: We know that,

$$W_0 = V_0 I_0 \cos\emptyset_0$$

$$\therefore \qquad \cos\emptyset_0 = \frac{W_0}{V_0 I_0} = No\ load\ power\ factor$$

Once $\cos\emptyset_0$ is known we can obtain,

$$I_W = I_0 \cos\emptyset_0$$

and

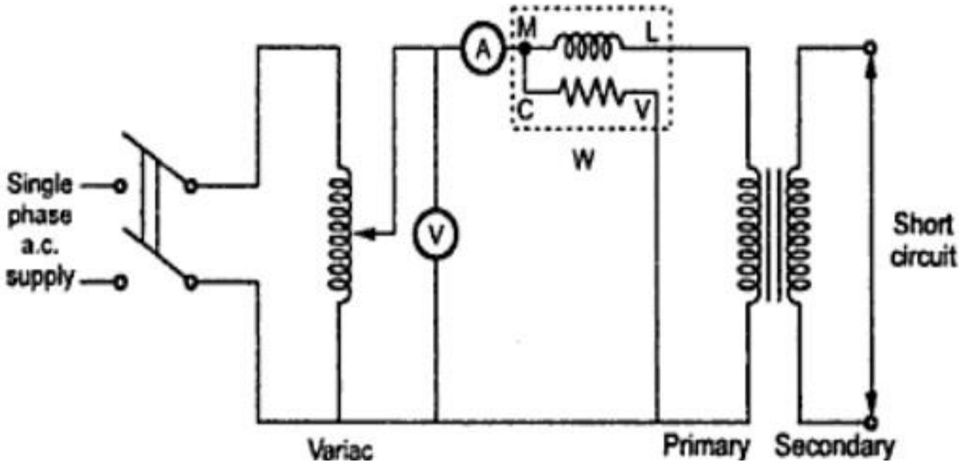
$$I_m = I_0 \sin\emptyset_0$$

Once I_w and I_m are known we can determine exciting circuit parameters as,

$$R_0 = \frac{V_0}{I_W}\ \Omega \quad and\ X_0 = \frac{V_0}{I_m}\Omega$$

Short Circuit Test (S.C. Test):

In this test, primary is connected to a.c supply through variac, ammeter and voltmeter The secondary is short circuited with the help of thick copper wire or solid link.As high voltage side is always low current side, it is convenient to connect high voltage side to supply and shorting the low voltage side.



As secondary is shortted, its resistance is very small and on rated voltage it may draw very large current. Such large current can cause overheating and burning of the transformer. To limit this short circuit current, primary is supplied with low voltage which is just enough to cause rated current to flow through primary which can be observed on an ammeter.

The low voltage can be adjusted with the help of variac. Hence this test is also called low volatge test or reduced voltage test. The wattmeter reading as well as voltmeter, ammeter readings are recorded. The observation table is as follows.

Short circuit VoltageV_{sc} Volt	Short circuit CurrentI_{sc} Ampere	Short circuit PowerW_{sc} Watt

Now the cureent flowing through the winding is rated current hence the total copper loss is the full load copper loss. Now the voltage applied is low whhich is a small fraction of the rrated voltage. The iron losses are fuction of applied voltage.

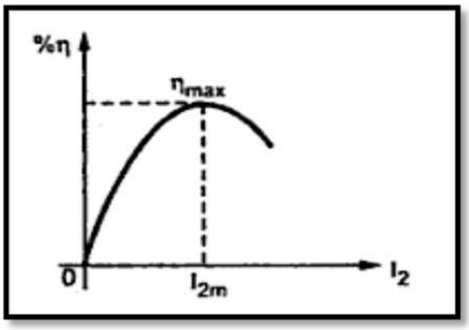
So the iron losses in reduced voltage test are very small. Hence the wattmeter reading is the power loss which is equal to full load copper losses as iron losses are very low.

$\therefore \quad W_{sc} = (P_{cu})F.L = Full\ load\ copper\ loss$

(c) Discuss about the condition for maximum efficiency and all day efficiency.

Condition For Maximum Efficiency:

When a transformer works on a constant input voltage and frequency then efficiecny varies with the load. As load increases, the effciecny increases. At a certain load current, it achieves a maximum value. If the transformer is loaded further the efficiecny starts decreasing. The graph of efficiency against load current I_2



The load current at which the efficiency attains maximum value is denoted as I_{2m} and maximum efficiency is denoted as η_{max}

The efficiency is a function of load .i.e. load current I_2 assuming $\cos\Phi_2$ constant. The secondary terminal voltage V_2 is also assumed constant. So for maximum efficiency,

$$\frac{d\eta}{dI_2} = 0$$

Now

$$\eta = \frac{V_2 I_2 \cos\emptyset_2}{V_2 I_2 \cos\emptyset_2 + P_i + I_2^2 R_{02}}$$

$$\therefore \quad \frac{d\eta}{dI_2} = \frac{d}{dI_2}\left[\eta = \frac{V_2 I_2 \cos\emptyset_2}{V_2 I_2 \cos\emptyset_2 + P_i + I_2^2 R_{02}}\right] = 0$$

$$(V_2 I_2 \cos\emptyset_2 + P_i + I_2^2 R_{02})\frac{d}{dI_2}(V_2 I_2 \cos\emptyset_2) - (V_2 I_2 \cos\emptyset_2).\frac{d}{dI_2}(V_2 I_2 \cos\emptyset_2 + P_i + I_2^2 R_{02}) = 0$$

$$(V_2 I_2 \cos\emptyset_2 + P_i + I_2^2 R_{02})(V_2 \cos\emptyset_2) - (V_2 I_2 \cos\emptyset_2).\left(V_2 \cos\emptyset_2 + 2I_2\ R_{02}\right) = 0$$

$$V_2^2 I_2 cos^2\emptyset_2 + P_i V_2 \cos\emptyset_2 + V_2 I_2^2 R_{02} \cos\emptyset_2 - V_2^2 I_2 cos^2\emptyset_2 - 2V_2 I_2^2 R_{02} \cos\emptyset_2 = 0$$

$$P_i V_2 \cos\emptyset_2 - V_2 I_2^2 R_{02} \cos\emptyset_2 = 0$$

$$P_i V_2 \cos\emptyset_2 = V_2 I_2^2 R_{02} \cos\emptyset_2$$

$$P_i = I_2^2 R_{02} = P_{cu}$$

So condition to achieve maximum efficiency is that, ***Copper losses= Iron losses***

All-Day (or Energy) Efficiency:

The primary of distribution transformer is connected to the line for 24 hours a day. Thus the core losses occur for the whole 24 hours whereas copper losses occur only when the transformer is on load. Distribution transformers operate well below the rated power output for most of the time.

It is therefore necessary to design a distribution transformer for maximum efficiency occurring at the average output power. The performance of a distribution transformer is more appropriately represented by all-day or energy efficiency.

Energy efficiency of a transformer is defined as the ratio of total energy output for a certain period to the total energy input for the same period. The energy efficiency can be calculated for any specific period. When the energy efficiency is calculated for a day of 24 hours it is called the all-day efficiency.

All- day efficiency is defined as the ratio of the energy output to the energy input taken over a24-hour period.

$$\eta_{All\ day} = \frac{Energy\ output\ over\ 24\ hours}{Energy\ input\ over\ 24\ hours} \times 100$$

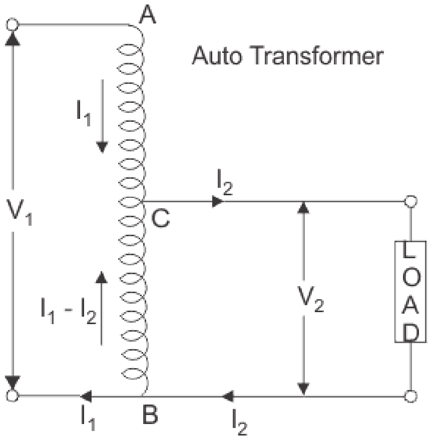
(d) Write a note on Auto transformer.

A transformer in which part of the winding is common to both the primary and secondary circuits is known as an Auto-Transformer. The primary is electrically connected to the secondary, as well as magnetically coupled to it.

AB is primary winding having N_1 turns and BC is secondary winding having N2 turns. If no-load current and iron losses are neglected

$$\frac{V_2}{V_1} = \frac{N_2}{N_1} = K$$

The current in the section BC is vector difference of I2 and I1. But since the two currents are practically in phase opposition, the resultant is (I2-I1) where I2>I1



Saving of Copper (In Comparison To Conventional Two Winding Transformer):

The volume and hence weight of copper is proportional to the length and area of cross-section of the conductors. But the length of conductor is proportional to the number of turns and cross-section depends on current.

Hence the weight of copper is proportional to the product of number of turns and currents to be carried.

$$Weight\ of\ copper\ in\ conventional\ two\ winding\ transformer \propto (N_1 I_1 + N_2 I_2)$$

$$Weight\ of\ copper\ in\ auto - transformer$$

$$= weight\ of\ copper\ in\ section\ LS + weight\ of\ copper\ in\ section\ MS$$

$$But\ weight\ of\ copper\ in\ section\ LS \propto (N_1 - N_2) I_1$$

$$and\ weight\ of\ copper\ in\ section\ MS \propto N_2 (I_2 - I_1)$$

$$\therefore\ Weight\ of\ copper\ in\ auto - transformer \propto (N_1 - N_2) I_1 + N_2 (I_2 - I_1)$$

$$\therefore\ \frac{weight\ of\ copper\ in\ auto - transformer (W_0)}{Weight\ of\ copper\ in\ ordinary\ transformer\ (W_0)} = \frac{(N_1 - N_2) I_1 + N_2 (I_2 - I_1)}{N_1 I_1 + N_2 I_2}$$

$$= \frac{(N_1 - 2N_2) I_1 + N_2 I_2}{N_1 I_1 + N_2 I_2}$$

4. (a) Explain the constructional details of a three phase transformer.

Construction of Three Phase Transformer:

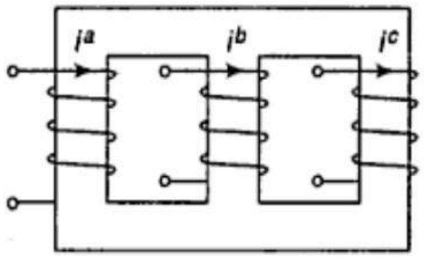
The present day system is a three-phase system. The change of voltage in a three phase system is performed either by a single three phase transformer or by a three single phase transformers. **Advantages of a**

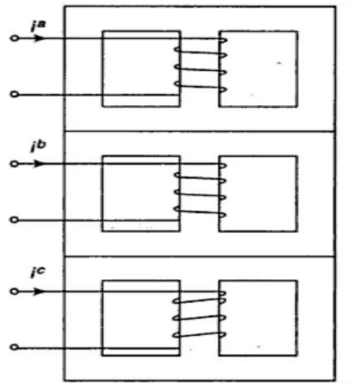
3-phase unit Transformer:

A three phase unit transformer has the following advantages over three single phase transformer bank of the same kVA rating.

1. It takes less space
2. It is lighter, smaller and cheaper
3. It is slightly more efficient

A single unit three phase transformer has a three limbed core, one limb for each phase winding. On each limb the low voltage winding is placed over the core and the high voltage winding is placed over the low voltage winding with suitable insulation between the core and low voltage winding as well as between the two windings.

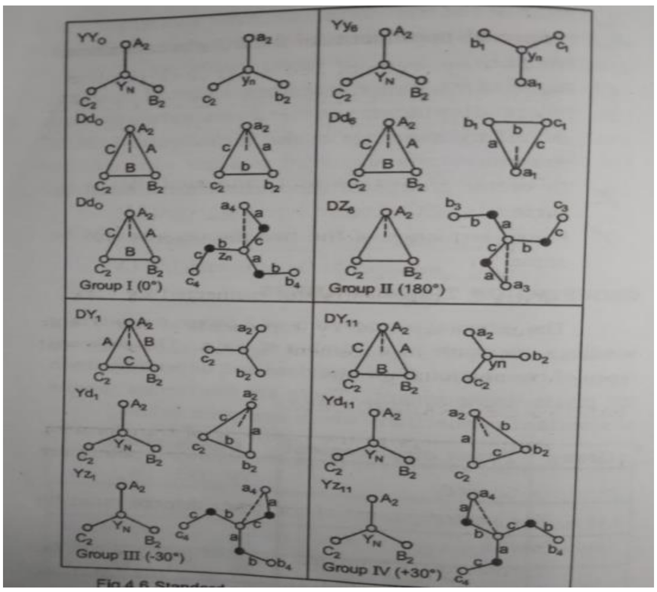




(b) Discuss about the grouping of three phase transformers.

GROUPING OF TRANSFORMERS

The internal connections of 3 phase transformer windings are made in a number of ways. The different types of connections are standardised depending upon the phase displacement. The HV and LV terminals of the windings are brough out. Normally, the HV terminals are denoted by capital letters and LV terminals are denoted by small letters. Each winding has two ends, and they arc marked as below.



Thus for

Phase displacement zero: 12'O clock position

Phase displacement 180°: 6'0 clock position

Phase displacement 30° lag: 1'0 clock position

Phase displacement 30° lead: 110 clock position

Letter Y represents star connected HV

Lettery y represents star connected LV

Lettery D - represents Delta connected HV

Letter d - represents Delta connected LV

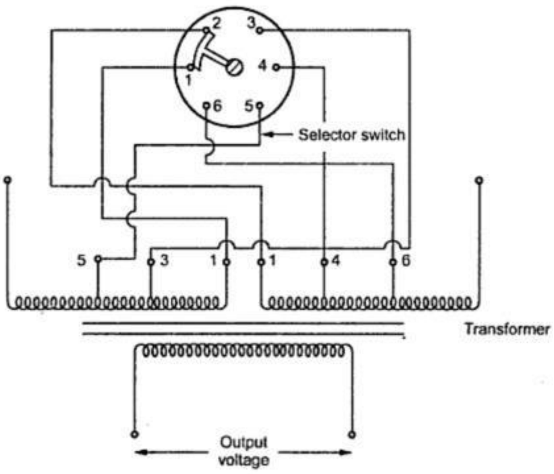
Letter Z represents star connected zig-zag.

Thus the symbol Yy, represents a star / star windings with 0º displacement

(c) Write about OFF load tap changers.

Off-Load Tap Changer:

In this method of tap changing, the tappings are changed when the transformer is disconnected from the supply. As per the requirement the tappings are taken out on the respective winding and the connections are brought out near the top of transformer. Manually operated selector switches are provided for change in tappings. The commonly used switches are vertical tapping switches and faceplate switches.



The above arrangement is normally used to get ±5 % change in the steps of ±2.5 %. It consists of an insulating base on which six brass or copper terminals are mounted. The contactor is mounted on an arm of the shaft. The central or middle part of the winding contains the taps and the taps are connected to terminals of tap changer. The shaft can be rotated from one position to another so that the selector switch is connected to adjacent pairs of stationary terminals.

Let us consider that the selector switch is at a position connecting taps 1 and 2. Hence total winding is in use. When contactor is moved one point to the left, it makes a connection between 1 and 6 thus cutting out part of the winding between taps 2 and 6. The next step connects taps 6 and 5 cutting out part of winding between taps 1 and 5. Thus the parts of the windings cut out gradually in steps with minimum number of turns remain in the winding with the position 5 and 6. Corresponding to each position of the selector switch different voltage regulation on positive as well as on negative side can be obtained.

(d) Write a note on cooling of transformers.

Cooing of Transformer

When transformer supplies a load, two types of losses occur inside the transformer. The iron losses occur in the core while copper losses occur in the windings. The power lost due to these losses appears in the form of heat. This heat increases the temperature of the transformer.
To keep the temperature, rise of the transformer within limits, it is necessary to dissipate the heat developed to the surroundings.

A suitable coolant and cooling method is necessary for each transformer to dissipate the heat, effectively to the surroundings.

Basically there are two types of transformers, dry type transformers and oil immersed transformers. In dry type, the heat is taken to the walls of tank and dissipate to the surrounding air through convection. In oil immersed type, the oil is used as coolant. The entire assembly including core and windings is kept immersed in a suitable oil. The heat developed is transferred to the walls of tank by convection through oil. And finally heat is transferred to the surroundings from the tank walls by radiation.

The various cooling methods are designated using letter symbols which depend upon :
i) Cooling medium used and ii) Type of circulation employed

The various coolants used along with their symbols are,
1. Air - A,
2. Gas - G,
3. Synthetic oil - L,
4. Mineral oil - O,
5- Solid insulation - S and
6. Water - WThere are two types of circulations which are,
1. Neutral - N and 2. Forced - F

In natural cooling, the coolant circulating inside the transformer transfers entire heat to the tank walls from where it is dissipated to the surroundings and transformers gets cooled by natural air circulating surrounding the tank walls.

In forced cooling, the coolant circulating inside the transformer gets heated as it comes in contact with windings and core. The coolant partly transfers heat to the tank walls but mainly coolant is taken to the external heat exchanger where air or water is used in order to dissipate heat of the coolant.

5. (a) Discuss about the defects and remedies in commutators.

1. Commutator surface pitted and rough

Due to excessive sparking the commutator surfaces get pitted and become rough. Hence causes for the sparking must be checked and rectified first. Then the surface must be smoothened with fine sandpaper.

2. High bar

If one of the commutator segments rises from its original position, it is called High bar. This can be corrected by tapping down with a mallet. If it is not possible to place it in position with tapping, the projecting portion should be filed or it should be turned in a lathe.

3. Low bar

If any commutator segment is at a slightly lower level than the other segment it is called low bar. This can be rectified by pulling up the particular commutator segment to its former level and tightened.

4. Loose segments

If the clamping ring of the commutator becomes loose, commutator segments become loose. Therefore the clamping ring should be tightened.

5. Projecting mica between the bars

If the mica insulation between the successive commutator segment rises from its original position, it is called projection of mica. Due to projection of mica, sparking will be produced.

6. Flats on the commutator

If there is a pit on the commutator segment, it is called flats on the commutator. Pitting of commutator segment is due to flaw or difference in composition of the metal of the particular bar. Due to pitting sparking will occur. The pitting on the commutator surface is rectified by filing.

7. Ridges formation on commutator

If the brush holders on different rocker arms are not properly staggered over the commutator surface, ridges will be formed. These ridges may be filed off by a smooth file or by means of a grinding stone. After grinding is over, finish off with fine sand paper

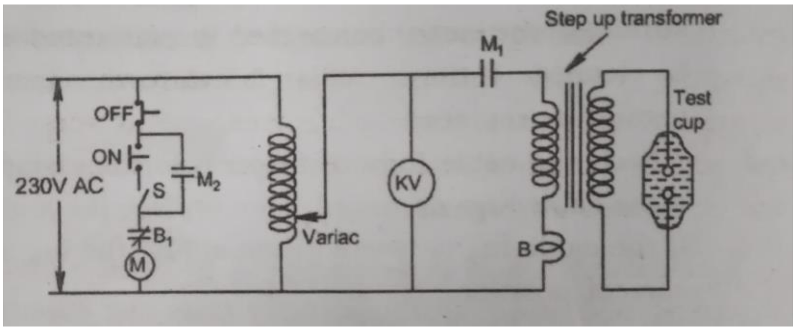
8. Flash over of commutator

When there is heavy accumulation of dust and dirt over the commutator surface, flash over will occur between the adjacent segments. Hence the dust and dirt should be cleaned by washing and brushing with petrol.

(b) Explain about the BDV test in a transformer.

The dielectric strength of transformer oil is determined by using BDV test. The BDV test should be conducted when the oil sample is cold and not hot because hot oil gives a higher BDV.

In the testing equipment there is a test cup which has two electrodes in the form of spheres (13 mm diameter). The sphere gap should be exactly 4mm. We can adjust the gap suitably by using the test cup screws.



The primary winding of the transformer is supplied through a variac. By operating this variac wecan gradually increase the test voltage as required. It has been so arranged that the contact "S" will be closed only when the variac output is zero volts.

The test cup is filled with sample of oil. The level of the oil should be atleast 1 cm above the level of the electrodes. The cup is then covered with a clean glass plate and allowed to rest for 5 minutes. So that any air bubble that may be present will disappear.

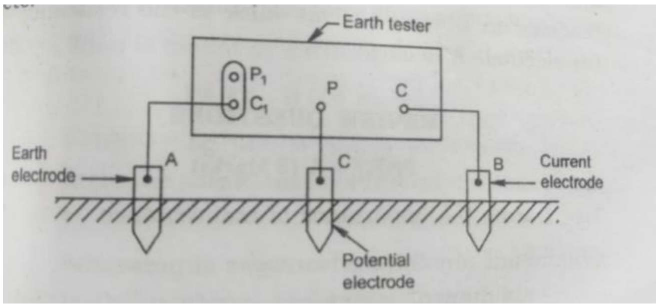
When the 'ON' button is momentarily pressed, the coil 'M' is energised. Hence the main contact M closes and connects the varaic to the primary winding of the step up transformer. The contact S is in closed condition only the variac is in minimum position. The sealing contact M_2 also closes. Now the no-load current has no effect on the coil B to open the normally closed contact B. The test voltage is increased gradually. The voltmeter connected is calibrated to show the HV side voltage. When breakdown occurs across the electrodes, there is a corresponding surge in the primary winding and coil B hence the B energises and B, immediatly opens.

Now the coil M is de-energised and the contact M opens disconnecting the primary from the supply. The breakdown voltage is that voltage at which the arcing takes place. The reading of the voltmeter should be noted at the time of breakdown. A good sample of oil withstand 22kv - 33kv for the minute.

(c) Discuss about the measurement of earth resistance.

Earth resistance can be measured directly by "earth resistance tester". It essentially consists of a hand driven DC generator, rectifier, metering system etc

The DC voltage generated is converted into AC and then applied to earth inorder to avoid electrolytic action. The current coil is energised by the earth current. The pressure coil gets the voltage drop caused by the earth current for its energisation. These two coils are forming an ohm meter



The earth tester also works nearly on the same principle of a meggar. The earth resistance of the electrode 'A' .C and B are two auxiliary electrodes of 15-20 mm diameter and 40 cm long bars. The electrode 'B' is planted at a distance of approximately 25 M from A and C is fixed centrally between A & B. Rotate the handle of the generator at normal speed and note the meter reading.

Two more readings are taken by shifting 'C' aб distance of 3 meters on either side of its central position. The instrument should indicate nearly constant readings in the three position. If it does not, B should be moved away from 'A'by approximately 6 metres and the experiment must be repeated till constant readings are obtained. This value is the resistance of the electrode A to earth

(d) Write a note on maintenance of transformer oil.

MAINTENANCE OF TRANSFORMER OIL

1) Check the oil level in the transformer tank and conservator.

2) The oil level indicator should be kept clean.

3) If any leakage of oil is detected, seal it

4) Check the oil pump

5) Check the di- electric strength of oil by using BDV test.

6) Conduct the acidity test to check any acid present in the oil.

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