UNIT I – MAGNETIC CIRCUITS AND MAGNETIC MATERIALS

PART - A

1. Define magnetic flux density. (Nov - 2017)

It is the flux per unit area at right angles to the flux it is denoted by B and unit is Weber/m2.

2. Define self-inductance. (Nov - 2017)

The property of a coil that opposes any change in the amount of current flowing through it is called self-inductance.

3. Define relative permeability. (May - 2017)

It is equal to the ratio of flux density produced in that material to the flux density produced in air by the same magnetizing force $\mu_r = \mu / \mu_0$

4. Give the expression for hysteresis losses and eddy current losses. (May - 2017)

Hysteresis loss = $W_\eta = \eta (B_{max}^{1.6})^2 fV Watts$

Eddy Current Loss = $W_e = K_e (B_{max}^2) f^2 t^2 V Watts$

5. What is a hysteresis loss? (Nov - 2016)

- Energy loss takes place due to the molecular friction in the material.
- This loss is in the form of heat
- Hysteresis loss = $W_\eta = \eta (B_{max}^{1.6})^2 fV Watts$

6. Define flux linkage. (Nov - 2016)

Flux linkage is the magnetic flux running through, or "linked" to a coil, so the field strength times the coil area. The product of the magnetic flux and the number of turns in a given coil.

$$\Phi = n\varphi = nBA$$

Where, n is Number of turns in a coil, B is Field Strength, A is area of coil.

7. State Ampere's law. (May - 2016)

The line integral of the magnetic field around some closed loop is equal to the times the algebraic sum of the currents which pass through the loop.

8. Define leakage flux. (May - 2016)

The flux does not follow desired path in a magnetic circuit is called leakage flux.

9. Define stacking factor. (Nov - 2015)

Magnetic cores are made up of thin, lightly insulated laminations to reduce the eddy current loss. As a result, the net cross sectional area of the core occupied by the magnetic material is less than its gross cross section; their ratio being is called the stacking factor. The stacking value is normally less than one .its value varies from 0.5 to 0.95 .the stacking factor value is also reaches to one as the lamination thickness increases.

10. What are quasi static fields? (Nov - 2015)

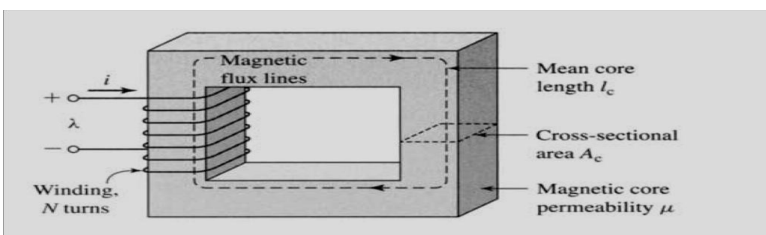
The field which is slowly varying i.e., the time required by electromagnetic field wave needs to propagate through a typical dimension of the system of interest is small compared with the time scale of field evolution of the system then the field is called quasi static field.

PART - B

1. Draw and explain the typical magnetic circuit with air gap and its equivalent electric circuit. Hence drive the expression for air gap flux. (Nov - 2017)

In a magnetic circuit, the magnetic lines of force leaves the north poles passes through the entire circuit and return the starting point. A magnetic circuit usually consist of materials having high permeability such as iron, soft steel etc.,

These materials offer very small opposition to the flow of magnetic flux. Consider a coil of N turns would on an iron core.



MMF = NI AT

The magnetising force inside the ring is

H=(NI)/l AT/m

Flux density in the ring B= μH

Total flux produced = ϕ=Ba

Reluctance S=l/(μa)

Composite magnetic circuits

Total mmf = $H_1l_1+H_2l_2+H_gl_g$

Leakage flux = $\varphi_l=\varphi_1-\varphi_g$

Leakage coefficient = (Total flux)/Useful flux= $(\varphi_1)/(\varphi_g)$

2. Derive the expression for self-inductance and mutual inductance and also define coefficient of coupling. (May - 2017)

Self – Inductance

The property of a coil that opposes any change in the amount of current flowing through it is called its self-inductance.

The self-inductance of a coil depends upon

- Shape and number of turns
- Relative permeability of the material surrounding the coil
- The speed with which the magnetic field changes
- L=(Nφ)/I

Mutual inductance

The property of a coil to produce emf in the nearby coil due to change in the value of current or flux in it is called mutual inductance.

- $M=(N_2\varphi_{12})/(I_1)$

Coefficient of coupling

The coefficient of coupling between two coils is defined as the fraction of magnetic flux produced by the current in one coil that links the other coil.

- $K=(M)/(L_1L_2)^{1/2}$

3. The core of an electromagnet is made of an iron rod of 1cm diameter, bent in to a circle of mean diameter 10cm, a radial air gap of 1mm being left between the ends of the rod. Calculate the direct current needed in coil of 2000 turns uniformly spaced around the core to produce a magnetic flux of 0.2 mwb in the air gap. Assume that the relative permeability of the iron is 150, that the magnetic leakage factor is 1.2 and that the air gap is parallel.

Mean diameter = D=10cm=$10X10^{-2}$m

Area a= $(\pi/4)*(1)^2=0.785X10^{-4}m^2$

N=2000

$l_i=\pi D=0.3141$m

AT for air gap

$B_g=(\varphi_g)/a=2.547wb/m^2$

$H_g=(B_g)/\mu_0=2026838$ AT/m

$AT_g=H_gl_g=2026.83AT$

$AT_i=H_il_i=16217.8*0.3141=5094AT$

Total AT = 7120.83AT

Direct current I = (Total AT)/N=3.56A

4. Obtain the expression for dynamically induced emf and force. (Nov – 2016/Nov -2014/Nov-2013)

Dynamically Induced emf

An induced emf is produced by the movement of the conductor in a magnetic field. Yhis emf is called dynamically induced emf.

$$e = Blv \sin\theta$$

Statically induced emf

In this case, the conductor is held stationary and the magnetic field is moving or changing. The emf induced in the conductor is called statically induced emf.

Self-induced emf

When a coil carries a current a flux will be set up in it. If the current in the coil changes, then flux linking the coil also changes. This change in flux will induce an emf in the coil. This kind of emf is known as self-induced emf.

- $L=(N\varphi)/I$

Mutually induced emf

The emf induced in a circuit due to the changing current in the neighbouring circuit is called mutually induced emf.

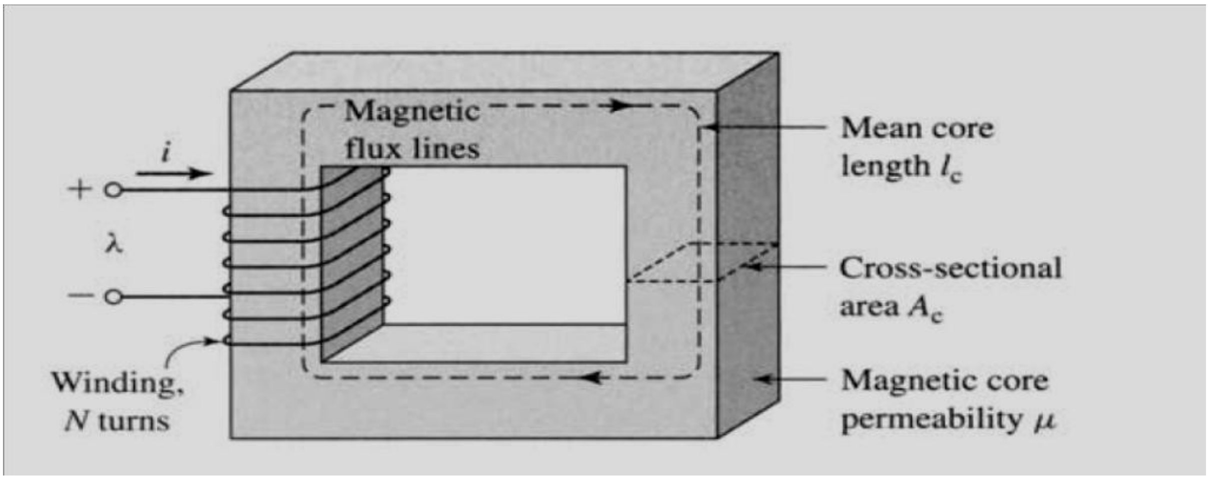
- $M=(N_2\varphi_{12})/(I_1)$

5. Explain the AC operation of magnetic circuit. (Nov – 2016/Nov - 2014)

For establishing a magnetic field, energy must be spent, though to energy is required to maintain it. Take the example of the exciting coils of an electromagnet.

The energy supplied to it is spent in two ways, (i) Part of it goes to meet I2R loss and is lost once for all (ii) part of it goes to create flux and is stored in the magnetic field as potential energy, and is similar to the potential energy of a raised weight, when a mass M is raised through a height of H, the potential energy stored in it is mgh.

Work is done in raising this mass, but once raised to a certain height. No further expenditure of energy is required to maintain it at that position. This mechanical potential energy can be recovered so can be electric energy stored in a magnetic field. Consider a coil having N turns wound on iron core as shown in fig .



The coil carries an alternating current i varying sinusoidally. Thus the flux produced by the exciting current I is also sinusoidally varying with time.

According to Faraday's law,

$$e=N(d\varphi/dt)$$

Finally $E=4.44fN\varphi_m$

6. Summarize the properties of magnetic materials. (May – 2016/May-2015)

Magnetic materials are classified based on the property called permeability as

1. Dia Magnetic Materials
2. Para Magnetic Materials
3. Ferro Magnetic Materials

1. Dia Magnetic Materials

The materials whose permeability is below unity are called Dia magnetic materials. They are repelled by magnet.

Ex. Lead, gold, copper, glass, mercury

- Diamagnetic materials repel magnetic lines of force
- There are no permanent dipoles; consequently magnetic effects are very small
- Each atom has no permanent magnetic moment.

2. Para Magnetic Materials

The materials with permeability above unity are called Para magnetic materials. The force of attraction by a magnet towards these materials is low.

Ex.: Copper Sulphate, Oxygen, Platinum, Aluminum.

- Attract magnetic lines of force
- They possess permanent magnetic dipoles
- If we apply the external magnetic field there is an enormous magnetic moment along the field direction and the magnetic induction will increase.

3. Ferro Magnetic Materials

The materials with permeability thousands of times more than that of paramagnetic materials are called Ferro magnetic materials. They are very much attracted by the magnet.

Ex. Iron, Cobalt, Nickel.

- Magnetic susceptibility is very large and positive
- If a material acquires a relatively high magnetization in a weak field, then it is ferromagnetic
- During heating they loss their magnetization slowly
- They attract the lines of force very strongly
- When temperature is greater than curie temperature then it is converted into paramagnetic

7. Explain the Hysteresis and Eddy current losses and obtain its expression. (May – 2016/ May -2015)

Iron or Core losses

These losses occur in the armature of a d.c. machine and are due to the rotation of armature in the magnetic field of the poles.

They are of two types

(i) hysteresis loss

(ii) eddy current loss.

Hysteresis loss

Hysteresis loss occurs in the armature of the d.c. machine since any given part of the armature is subjected to magnetic field reversals as it passes under successive poles.

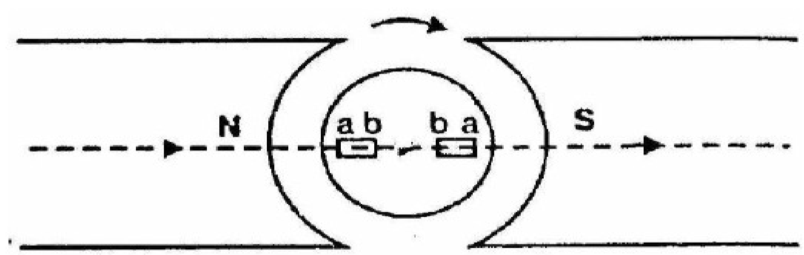


Figure shows an armature rotating in two-pole machine. Consider a small piece ab of the armature. When the piece ab is under N-pole, the magnetic lines pass from a to b.

Half a revolution later, the same piece of iron is under S-pole and magnetic lines pass from b to a so that magnetism in the iron is reversed. In order to reverse continuously the molecular magnets in the armature core, some amount of power has to be spent which is called hysteresis loss. It is given by Steinmetz formula. This formula is Hysteresis loss,

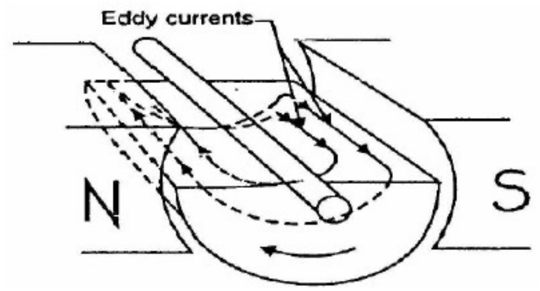
Hysteresis loss = $W_\eta = \eta({B_{max}}^{1.6})^2 fV Watts$

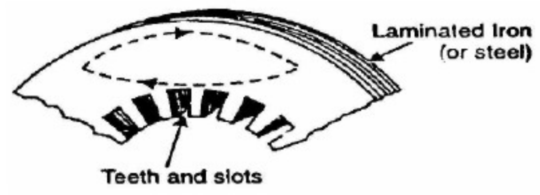
where Bmax = Maximum flux density in armature
f = Frequency of magnetic reversals
V = Volume of armature in m3

In order to reduce this loss in a d.c. machine, armature core is made of such materials which have a low value of Steinmetz hysteresis co-efficient e.g., silicon steel.

Eddy current loss

In addition to the voltages induced in the armature conductors, there are also voltages induced in the armature core. These voltages produce circulating currents in the armature core as shown in Figure.





These are called eddy currents and power loss due to their flow is called eddy current loss. The eddy current loss appears as heat which raises the temperature of the machine and lowers its efficiency. If a continuous solid iron core is used, the resistance to eddy current path will be small due to large cross-sectional area of the core. Consequently, the magnitude of eddy current and hence eddy current loss will be large. The magnitude of eddy current can be reduced by making core resistance as high as practical.

The core resistance can be greatly increased by constructing the core of thin, round iron sheets called laminations. The laminations are insulated from each other with a coating of varnish. The insulating coating has a high resistance, so very little current flows from one lamination to the other.

Eddy Current Loss = $W_e = K_e({B_{max}}^2) f^2 t^2 V Watts$

It may be noted that eddy current loss depends upon the square of lamination thickness. For this reason, lamination thickness should be kept as small as possible.

8. The total core loss of a specimen of silicon steel is found to be 1500W at 50Hz keeping the flux density constant the loss become 3000W when the frequency is raised to 75Hz. Calculate separately the hysteresis and eddy current losses for each of these frequencies. (Nov – 2015/Nov- 2013)

Hysteresis loss = $W_\eta = \eta({B_{max}}^{1.6})^2 fV Watts$

Eddy Current Loss = $W_e = K_e({B_{max}}^2) f^2 t^2 V Watts$

W_η=Af and W_e=Bf^2

P=Af+Bf^2

30=A+50B

40=A+75B

A=10

B=0.4

At 50Hz, W_η=500W

W_e=1000W

At 75Hz, W_η=750W

W_e=2250W

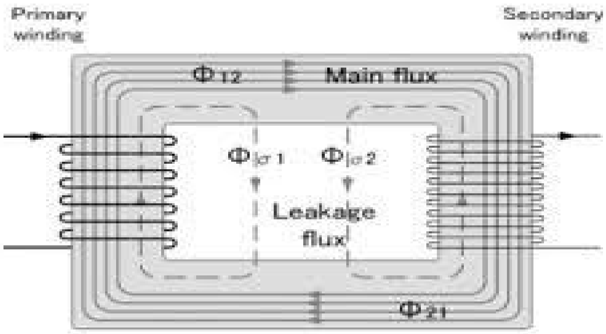
9. Two coils A and B are wound on same iron core. There are 600 turns on A and 3600 turns on B. The current of 4 A through coils. A produces a flux of $500X10^{-6}$ Wb in the core. If this current is reversed in 0.02 second. Calculate average emf induced in coils A and B. (Nov - 2012)

$L_A=(N_A\varphi)/I_A$=0.075H

$M=(N_B\varphi)/ I_A$=0.45H

e_A=30V and e_B=180V

10. Transformer as a Magnetically Coupled Circuit



A two winding transformer where R1 and R2 are the primary and secondary winding resistance. The primary current i1 into the dotted terminal produces

Core flux = ϕ21

Leakage flux = ϕ1

Total flux = ϕ1 + ϕ21

UNIT II – TRANSFORMERS

PART –A

1. List out the merits and demerits of core and shell type transformer. (Nov - 2017)

Core type Transformer:

Merits:

- Easy Construction
- Better Cooling
- Easy Insulation

Demerits:

- Less Coupling
- Less Mechanical Protection
- Less Efficient

Shell type Transformer:

Merits:

- More Coupling
- More Mechanical Protection
- More Efficient

Demerits:

- Construction is not Easy
- Less Cooling
- Require more Insulation

2. How do you reduce leakage flux in a transformer? (Nov - 2017)

The combined effect of the leakage flux and the electric field around the windings is what transfers energy from the primary to the secondary. In some applications increased leakage is desired, and long magnetic paths, air gaps, or magnetic bypass shunts may deliberately be introduced in a transformer design to limit the leakage flux.

3. Why transformer rating is expressed in KVA? (May – 2017/ Nov - 2015)

Copper loss of a transformer depends on current & iron loss on voltage. Hence total losses depend on Volt-Ampere and not on PF. That is why the rating of transformers is in kVA and not in kW.

4. Why wattmeter in OC test on transformer reads core loss and that in SC test reads copper loss at full load? (May - 2017)

In an open circuit test, current is very low because the circuit is incomplete on the secondary side hence the only losses are those due to inductance of the core. For this reason, we can neglect the variable copper losses and whatever power is injected that may be considered as core losses.So in OC test, we are getting the approximate rated voltage co re losses. In short circuit test, voltage is low but the current is standard. So the only losses are due to resistance of conductor. Since the core loss occurring here is negligible as compared to rated voltage core losses, so the losses incurred here are approximated to rated copper losses.

5. Define voltage regulation of a transformer. (Nov -2016)

When a transformer is loaded with a constant primary voltage, the secondary voltage decreases for lagging PF load, and increases for leading PF load because of its internal resistance and leakage reactance. The change in secondary terminal voltage from no load to full load expressed as a percentage of no loads or full load voltage is termed as regulation.

%regulation =E2-V2/E2*100

6. Draw Scott connection of a transformer. (Nov - 2016)

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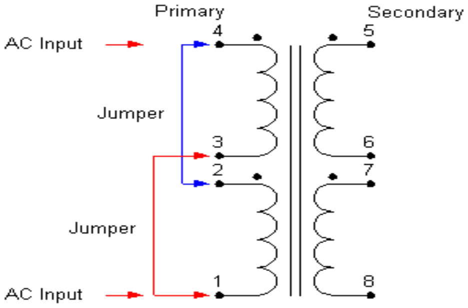


7. Define all day efficiency of a transformer. (May - 2015)

It is computed on the basis of energy consumed during a certain period, usually a day of 24 hrs. All day efficiency=output in kWh/input in kWh for 24 hrs.

8. What is inrush current in a transformer? (May - 2015)

Inrush Current, Input surge current or switch on surge is the maximum, instantaneous input current drawn by an electrical device when first is turned on. Alternating current of Transformers may draw several times their normal full-load current when first energized, for a few cycles of the input waveform.

9. What happen when a DC supply is applied to a transformer? (Nov - 2015)

If dc supply is given the current will not change due to constant supply hence mutual induction is not possible and transformer will not work. The resistance of primary winding is very small and inductive reactance is zero for dc. Hence primary will draw very high current for dc supply which cause damage to the transformer due to extra heat generated. This may cause saturation of the core. Hence dc supply is not applied to the transformers.

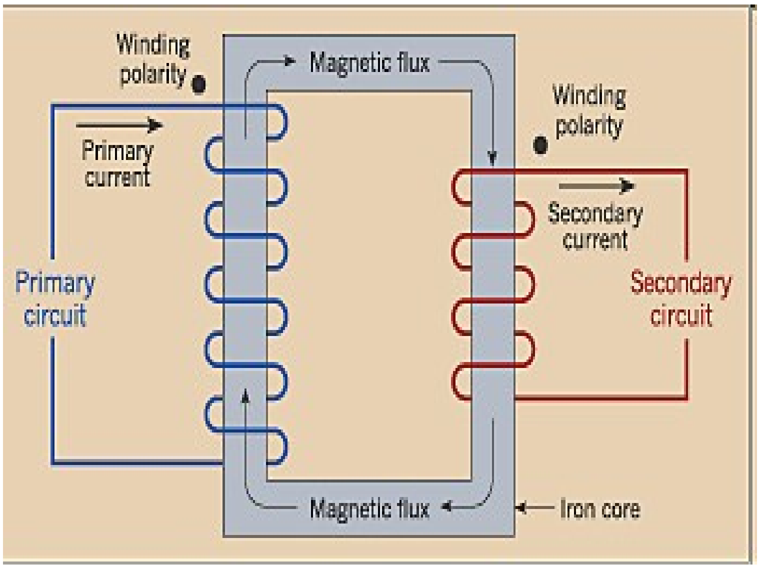
10. Specify the applications of autotransformer. (May - 2015)

- Autotransformers are used for starting induction motors and synchronous motors
- Used as boosters to increase the voltage in AC feeder.
- Electrical testing laboratories.

PART – B

1. Explain the principle of operation of a transformer. Derive its EMF equation. (Nov – 2017/ May - 2014)

A transformer is a device that transfers electrical energy from one circuit to another through inductively coupled conductor. A varying current in the first or primary winding creates a varying magnetic flux in the transformer core, and thus a varying magnetic field through the secondary winding. This varying magnetic field induces a varying electromotive force EMF or voltage in the secondary winding. This effect is called mutual induction.



When primary winding is connected to an ac supply mains, current flows through it. Since this winding links with an iron core, so current flowing through this winding produces an alternating flux in the core. Since this flux is alternating and links with the secondary winding also, so induces an emf in the secondary winding.

The frequency of induced emf in secondary winding is the same as that of the flux or that of the s supply voltage. The induced emf in the secondary winding enables it to deliver current to an external load connected across it. Thus the energy is transformed from primary winding to the secondary winding by means of electro-magnetic induction without any change in frequency.

EMF – Equation

$E_1=4.44f\varphi_m N_1$

$E_2=4.44f\varphi_m N_2$

Transformation ratio

The ratio of secondary voltage to primary voltage is known as the voltage transformation ratio and is designated by letter K. i.e. Voltage transformation ratio.

$$K = (E_2)/(E_1)$$

Current ratio

The ratio of secondary current to primary current is known as current ratio and is reciprocal of voltage transformation ratio in an ideal transformer.

2. Draw and explain the phasor diagram of transformer when it is operating under load. (Nov – 2017/Nov - 2016)

The transformer is said to be loaded, when its secondary circuit is completed through an impedance or load. The magnitude and phase of secondary current (i.e. current flowing through secondary) with respect to secondary terminals depends upon the characteristic of the load i.e. current will be in phase, lag behind and lead the terminal voltage respectively when the load is non-inductive, inductive and capacitive.

The net flux passing through the core remains almost constant from no-load to full load irrespective of load conditions and so core losses remain almost constant from no-load to full load. Secondary windings Resistance and Leakage Reactance In actual practice, both of the primary and have got some ohmic resistance causing voltage drops and copper losses in the windings.

In actual practice, the total flux created does not link both of the primary and secondary windings but is divided into three components namely the main or mutual flux linking both of the primary and secondary windings, primary leakage flux linking with primary winding only and secondary leakage flux linking with secondary winding only.

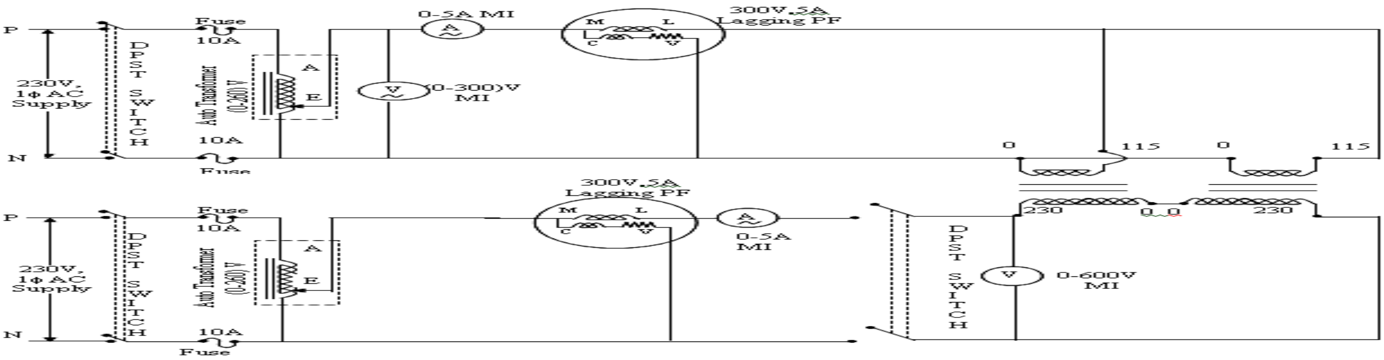
The primary leakage flux is produced by primary ampere-turns and is proportional to primary current, number of primary turns being fixed. The primary leakage flux is in phase with and produces self-induced emf is in phase with and produces self-induced emf E given as 2f in the primary winding. The self-induced emf divided by the primary current gives the reactance of primary and is denoted by

$$E=2\pi f$$

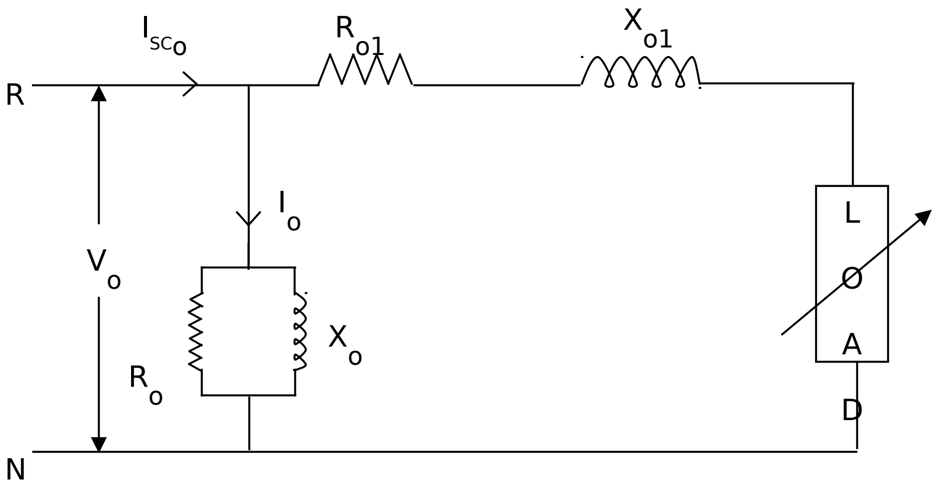
3. Explain the back to back method of testing for two identical single phase transformers.

(May - 2017)

- Rated voltage of 110V is adjusted to get in voltmeter by adjusting the variac of the Auto Transformer which would be in zero before switching on the supply at the primary side.
- The readings of voltmeter, ammeter and wattmeter are noted on the primary side.
- A voltmeter is connected across the secondary and with the secondary supply off i.e switch S is kept open. The voltmeter reading is noted.
- If the reading of voltmeter reads higher voltage, the terminals of any one of secondary coil is interchanged in order that voltmeter reads zero.
- The secondary is now switched on and SPST switch is closed with variac of auto transformer is zero.
- After switching on the secondary the variac of transformer (Auto) is adjusted so that full load rated secondary current flows.
- Then the readings of wattmeter, Ammeter and voltmeter are noted.
- The Percentage Efficiency and percentage regulation are calculated and equivalent circuit is drawn.



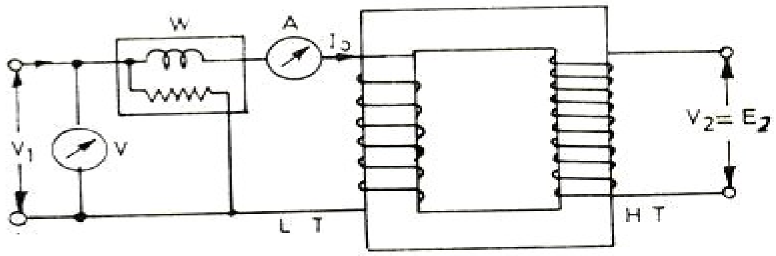
EQUIVALENT CIRCUIT:



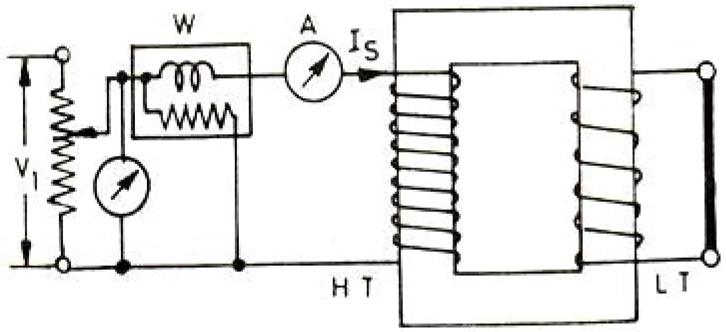
4. With a circuit explain how to obtain equivalent circuit by conducting OC & SC test in a single phase transformer. (May – 2016/ May - 2012)

Open-circuit or No-load Test.

In this test secondary (usually high voltage) winding is left open, all metering instruments (ammeter, voltmeter and wattmeter) are connected on primary side and normal rated voltage is applied to the primary (low voltage) winding, as illustrated below.



Short-circuit or Impedance Test



This test is performed to determine the full-load copper loss and equivalent resistance and reactance referred to secondary side. In this test, the terminals of the secondary (usually the low voltage) winding are short circuited, all meters (ammeter, voltmeter and wattmeter) are connected on primary side and a low voltage, usually 5 to 10 % of normal rated primary voltage at normal frequency is applied to the primary, as shown in fig below.

The applied voltage to the primary, say Vs' is gradually increased till the ammeter A indicates the full load current of the side in which it is connected. The reading Ws of the wattmeter gives total copper loss (iron losses being negligible due to very low applied voltage resulting in very small flux linking with the core) at full load. Le the ammeter reading be Is..

Equivalent Circuit parameters

Open Circuit Test

1. No load Power Factor ($\cos\Phi_0$) = $\dfrac{W_{oc}}{V_{oc} \times I_{oc}}$

Where, W_{OC} - Open circuit power in watts
V_{OC} - Open circuit voltage in volts
I_{OC} - Open circuit current in A

2. No load working component resistance (R_0) = $\dfrac{V_{oc}}{I_{oc} \times \cos\Phi_0}$ in Ohms

Where, V_{OC} - Open circuit voltage in volts
I_{OC} - Open circuit current in A

3. No load magnetizing component reactance (X_0) = $\dfrac{V_{OC}}{I_{oc} \times \sin\Phi_0}$ in Ohms

Where, V_{OC} - Open circuit voltage in volts
I_{OC} - Open circuit current in A

Short Circuit Test

4. Equivalent impedance referred to HV side (Z_{02}) = V_{SC} / I_{SC} in Ohms

Where, V_{SC} - Short circuit voltage in volts
I_{SC} - Short circuit current in A

5. Equivalent resistance referred to HV side (R_{02}) = $\frac{W_{SC}}{I_{SC}^2}$ in Ohms

Where , W_{SC} – Short circuit power in Watts.

6. Equivalent reactance referred to HV side (X_{02}) = $\sqrt{Z_{02}^2 - R_{02}^2}$ in Ohms

7. Transformation ratio (K) = $\frac{V_2}{V_1}$

Where , V_1 – Primary voltage in Volts

V_2 – Secondary voltage in volts

8. Equivalent resistance referred to LV side (R_{01}) = $\frac{R_{02}}{K^2}$ in Ohms

9. Equivalent reactance referred to LV side (X_{01}) = $\frac{X_{02}}{K^2}$ in Ohms

Efficiency And Regulation

10. Output Power = (X x KVA x cosΦ) in Watts

Where, X - Fraction of load

KVA - power rating of transformer

cosΦ - power factor

11. Copper loss = (X^2 x W_{SC}) in watts

Where, W_{SC} - Copper loss in short circuit condition.

12. Total loss = (Cu loss + Iron loss) in watts

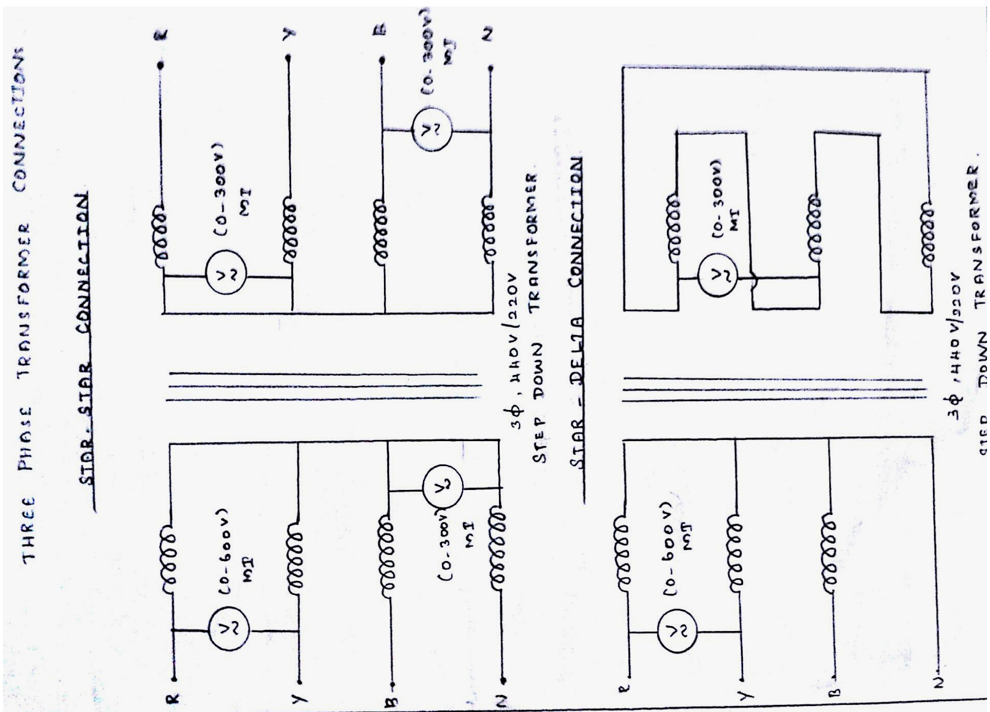
13. Efficiency = $\frac{\text{Output power}}{\text{(Output power + Total losses)}}$ x 100 in %

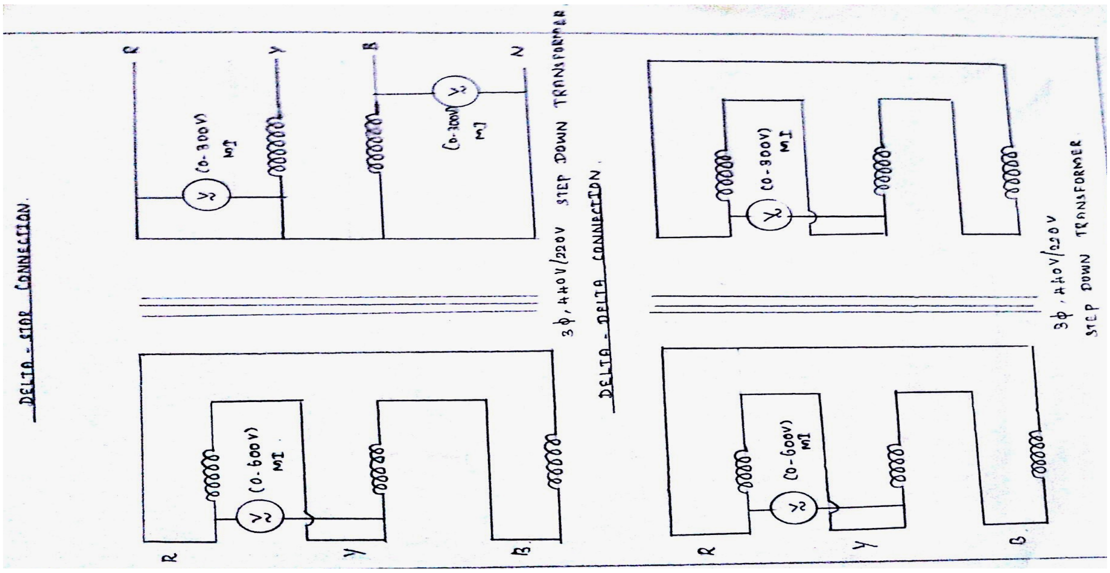
14. Regulation = $\frac{X \times I_{SC} [R_{02} \times \cos\Phi \pm X_{02} \times \sin\Phi]}{V_{20}}$ x 100 in %

Where, V_{20} - Open circuit voltage on HV side

+ for lagging, - for leading

5. Explain the various three phase transformer connection and parallel operation of three phase transformer.





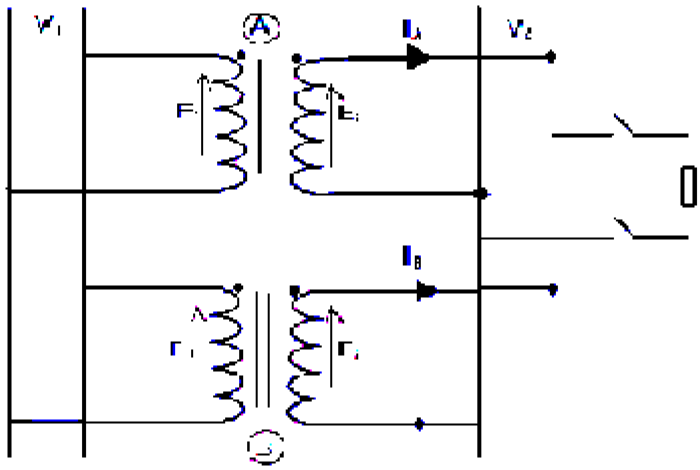
Parallel Operation of Transformers

By parallel operation we mean two or more transformers are connected to the same supply bus bars on the primary side and to a common bus bar/load on the secondary side. Such requirement is frequently encountered in practice. The reasons that necessitate parallel operation are as follows.

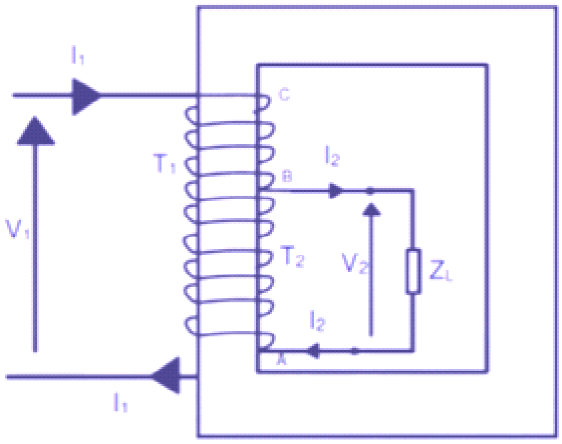
1. Non-availability of a single large transformer to meet the total load requirement.
2. The power demand might have increased over a time necessitating augmentation of the capacity. More transformers connected in parallel will then be pressed into service.
3. To ensure improved reliability. Even if one of the transformers gets into a fault or is taken out for maintenance/repair the load can continued to be serviced.
4. To reduce the spare capacity. If many smaller size transformers are used one machine can be used as spare. If only one large machine is feeding the load, a spare of similar rating has to be available. The problem of spares becomes more acute with fewer machines in service at a location.
5. When transportation problems limit installation of large transformers at site, it may be easier to transport smaller ones to site and work them in parallel.

Fig. shows the physical arrangement of two single phase transformers working in parallel on the primary side. Transformer A and Transformer B are connected to input voltage bus bars. After ascertaining the polarities they are connected to output/load bus bars. Certain conditions have to be met before two or more transformers are connected in parallel and share a common load satisfactorily. They are,

1. The voltage ratio must be the same.
2. The per unit impedance of each machine on its own base must be the same.
3. The polarity must be the same, so that there is no circulating current between the transformers.
4. The phase sequence must be the same and no phase difference must exist between the voltages of the two transformers.



6. Derive the expression for saving of copper in autotransformer. (Nov – 2015/Nov-2014)



The primary and secondary windings of a two winding transformer have induced emf in them due to a common mutual flux and hence are in phase. The currents drawn by these two windings are out of phase by 180°. This prompted the use of a part of the primary as secondary. This is equivalent to fusing the secondary turns into primary turns. The fused section need to have a cross sectional area of the conductor to carry (I2−I1) ampere! This ingenious thought led to the invention of an auto transformer. Fig. 28 shows the physical arrangement of an auto transformer. Total number of turns between A and C are T1. At point B a connection is taken. Section AB has T2 turns. As the volts per turn, which is proportional to the flux in the machine, is the same for the whole winding,

V1 : V2 = T1 : T2

For simplifying analysis, the magnetizing current of the transformer is neglected. When the secondary winding delivers a load current of I2 ampere the demagnetizing ampere turns is I2T2 . This will be countered by a current I1 flowing from the source through the T1 turns such that,

I1T1 = I2T2 (77)

A current of I1 ampere flows through the winding between B and C . The current in the winding between A and B is (I2 − I1) ampere. The cross section of the wire to be selected for AB is proportional to this current assuming a constant current density for the whole winding. Thus some amount of material saving can be achieved compared to a two winding transformer. The magnetic circuit is assumed to be identical and hence there is no saving in the same. To quantify the saving the total quantity of copper used in an auto transformer is expressed as a fraction of that used in a two winding transformer,

$$\frac{copper\ in\ auto\ transformer}{copper\ in\ two\ winding\ transformer} = \frac{(T_1 - T_2)I_1 + T_2(I_2 - I_1)}{T_1 I_1 + T_2 I_2}$$

$$= 1 - \frac{2T_2 I_1}{T_1 I_1 + T_2 I_2}$$

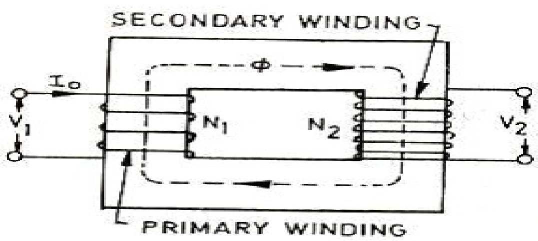
$$\text{But } T_1 I_1 = T_2 I_2$$

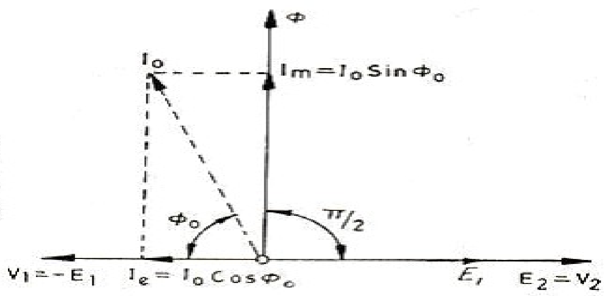
$$\therefore \text{The Ratio} = 1 - \frac{2T_2 I_1}{2T_1 I_1} = 1 - \frac{T_2}{T_1}$$

This means that an auto transformer requires the use of lesser quantity of copper given by the ratio of turns. This ratio therefore denotes the savings in copper. As the space for the second winding need not be there, the window space can be less for an auto transformer, giving some saving in the lamination weight also. The larger the ratio of the voltages, smaller is the savings. As T2 approaches T1 the savings become significant. Thus auto transformers become ideal choice for close ratio transformations. The savings in material is obtained, however, at a price. The electrical isolation between primary and secondary.

7. Explain operation of a transformer with necessary vector diagrams on no load and on load with UPF, lagging and leading power factors. (Nov - 2014)

When the primary of a transformer is connected to the source of an ac supply and the secondary is open circuited, the transformer is said to be on no load. This will create alternating flux.





ON LOAD

The transformer is said to be loaded, when its secondary circuit is completed through an impedance or load. The magnitude and phase of secondary current (i.e. current flowing through secondary) with respect to secondary terminals depends upon the characteristic of the load i.e. current will be in phase, lag behind and lead the terminal voltage respectively when the load is non-inductive, inductive and capacitive. The net flux passing through the core remains almost constant from no-load to full load irrespective of load conditions and so core losses remain almost constant from no-load to full load.

Secondary windings Resistance and Leakage Reactance In actual practice, both of the primary and have got some ohmic resistance causing voltage drops and copper losses in the windings. In actual practice, the total flux created does not link both of the primary and secondary windings but is divided into three components namely the main or mutual flux linking both of the primary and secondary windings, primary leakage flux linking with primary winding only and secondary leakage flux linking with secondary winding only.

The primary leakage flux is produced by primary ampere-turns and is proportional to primary current, number of primary turns being fixed. The primary leakage flux is in phase with and produces self-induced emf is in phase with and produces self-induced emf E given as 2f in the primary winding. The self-induced emf divided by the primary current gives the reactance of primary and is denoted by .

E=2пf

8. Derive an expression for maximum efficiency of a transformer. (Nov - 2013)

Transformer efficiency = η=(Output Power)/ (Input Power)

η=(Output Power)/ (Output Power+Losses)

η=(Output Power)/ (Output Power+Iron Loss+ Copper Loss)

Output Power = $V_2I_2\cos\phi$

$\eta=(n V_2I_2\cos\phi)/(n V_2I_2\cos\phi+P_i+n^2P_{cu})$

Iron loss = Copper loss (Or)Constant loss=Variable loss

η=Full load KVA * (Iron loss/Full load copper loss)$^{1/2}$

9. **The following data were obtained on a 20KVA, 50Hz, 2000/20V distribution transformer:**

	Voltage(V)	**Current(A)**	**Power(W)**
OC Test(HV)	**200**	**4**	**120**
SC Test(LV)	**60**	**10**	**300**

Draw the approximate equivalent circuit of the transformer referred to the HV and LV sides respectively.

From OC test

$V_o=200V$: $I_o=4A$: $W_o=120W$

$\cos\phi_o=(W_o)/(V_oI_o)=0.15$

K=0.1

$R_o=33.33k\Omega$ and $X_o=5.057k\Omega$

From SC Test

$V_{sc}=60V$: $I_{sc}=10A$:$W_{sc}=300W$

$Z_{1e}=6\Omega$

$R_{1e}=3\Omega$

$X_{1e}=5.1961\Omega$

$R_{2e}=K^2 R_{1e}=0.03\Omega$

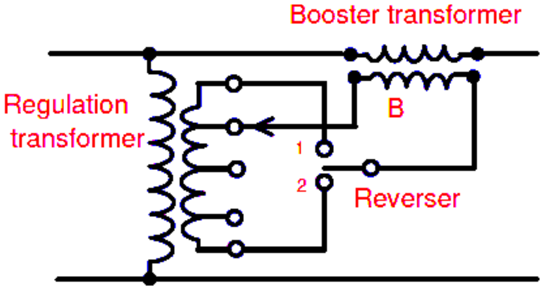
$X_{2e}=K^2 X_{1e}=0.051961\Omega$

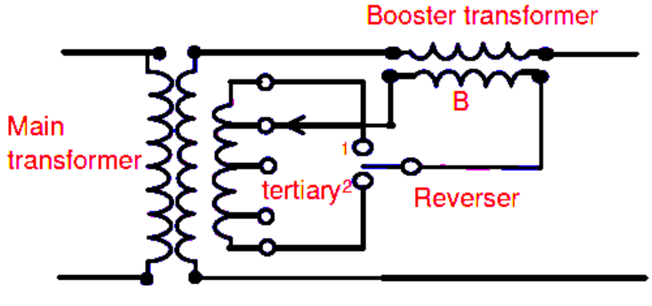
10. Write short notes on tap changing transformer.

Regulating the voltage of a transformer is a requirement that often arises in a power application or power system. In an application it may be needed

1. To supply a desired voltage to the load.
2. To counter the voltage drops due to loads.
3. To counter the input supply voltage changes on load.

On a power system the transformers are additionally required to perform the task of regulation of active and reactive power flows.





The voltage control is performed by changing the turn's ratio. This is done by provision of taps in the winding. The volts per turn available in large transformers is quite high and hence a change of even one turn on the LV side represents a large percentage change in the voltage. Also the LV currents are normally too large to take out the tapping from the windings. LV winding being the inner winding in a core type transformer adds to the difficulty of taking out of the taps. Hence irrespective of the end use for which tapping is put to, taps are provided on the HV winding. Provision of taps to control voltage is called tap changing. In the case of power systems, voltage levels are sometimes changed by injecting a suitable voltage in series with the line.

The advantage of this type of tap changer is

1. Load need not be switched.
2. More steps than taps are obtained.
3. Switches need not interrupt load current as a alternate path is always provided.

UNIT III – ELECTROMECHANICAL ENERGY CONVERSION AND CONCEPTS IN ROTATING MACHINES

PART – A

1. State the principle of electromechanical energy conversion. (Nov - 2017)

The mechanical energy is converted in to electrical energy which takes place through either by magnetic field or electric field.

2. Predominant energy storage occurs in the air gap of an electromechanical energy conversion device. Is this statement correct? (Nov - 2017)

Yes, this statement is correct, because the magnetic circuits have air gaps between the stationary and moving members in which considerable energy is stored in the magnetic field. This field acts as the energy-conversion medium, and its energy is the reservoir between the electric and mechanical system. In most such cases the reluctance of the air gap is much larger than that of the magnetic material. Thus the predominant energy storage occurs in the air gap, and the properties of the magnetic circuit are determined by the dimensions of the air gap.

3. Define the synchronous speed. Write the expression also. (May - 2017)

The speed of the synchronous machine for which it produces alternating emf at a specified rated frequency for a fixed number of poles is called its synchronous speed. It is denoted as N_s.

$N_s = 120f/P$

4. Define the term pole pitch and coil pitch. (May – 2017)

It is centre to centre distance between the two adjacent poles. 1 pole is responsible for 180^0 electrical of induced emf. So 180^0 electrical is also called one pole pitch.

The factor by which there is a reduction in the emf due to short pitching of the coils is called coil pitch.

5. What is magnetic saturation? (Nov - 2016)

The unit beyond which Magnetic Flux density in a magnetic area does not increase sharply further with increase of MMF.

6. What is meant by distributed winding? (Nov -2016)

If Number of Slot is more than number of Pole means, Winding is Distributed in many slot under a Pole. All the winding turns are arranged in several full pitch or fractional pitch coils. These coils are then housed in the slots spread around the air-gap periphery to form phase or commutator winding.

7. What is meant by winding inductance? (May - 2016)

Mutual inductance is where the magnetic flux of two or more inductors is “linked” so that voltage is induced in one coil proportional to the rate-of-change of current in another. A transformer is a device made of two or more inductors, one of which is powered by AC, inducing an AC voltage across the second inductor.

8. Compare lap and wave winding. (May - 2016)

Lap	**Wave**
A=P	A=2
Number of brush sets required is equal to number of poles	Number of brush sets required is always equal to two
Normally used for generators of capacity more than 500A	Preferred for generators of capacity less than 500A

9. Give examples for multiple excitation systems? (May -2013)

Alternator, Electro-Mechanical Transducer and Synchronous motors

10. Define field energy. (Nov - 2014)

In both Motor and Generator the field energy is converted either into electric or mechanical energy. In permanent magnet machine the magnetic flux is generated by the magnet and in case of electromagnet the magnetic field is generated by the current.

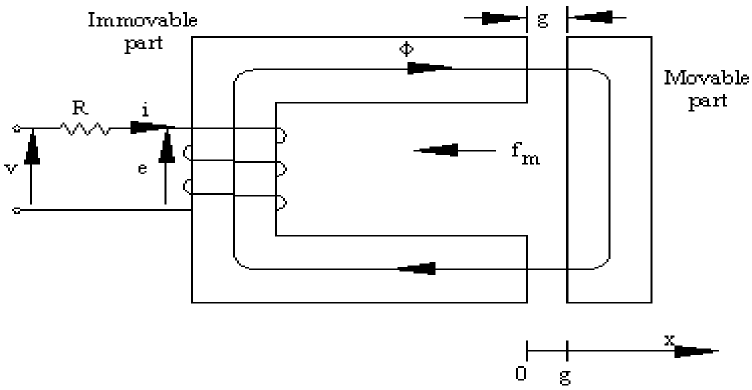
PART – B

1. Discuss in detail the production of mechanical force for an attracted armature relay excited by an electric source. (Nov – 2017/Nov – 2016/May - 2016)

Assumptions

- The resistance of the exciting coil is assumed to be present in limped form, outside the coil. Thus coil is lossless and ideal.

- The leakage flux does not take part in energy conversion process. So it is neglected.
- The leakage inductance is negligible
- There is no energy loss in the magnetic core.



Electric Energy Input

$$dw_e = id\lambda = id(N\phi) = Nid\phi$$

Magnetic field energy stored

The armature is held fixed at position x. As armature is not moving the mechanical work done is aero.

$$dw_e = dw_m = eidt = id\lambda$$

Let us consider an attracted armature relay set up which is excited by an electric source. When the coil is energised by the electric source a magnetic flux is set up in it. This magnetic field attracts the armature and hence produces a mechanical force.

Electrical energy input = Mechanical energy output + Magnetic energy stored in the field

$V=e+ir$

$P=ie+i^2r$

If the armature moves a small distance dx in the positive direction, the work done by the mechanical force in driving the mechanical system through the distance dx is given by

$$dw_f = F_f dx$$

$$F_f dx = id\lambda - dw_f$$

$$dw_f = id\lambda + \lambda di - \{\frac{\partial w_f^{'}}{\partial i} di + \frac{\partial w_f^{'}}{\partial x} dx\}$$

$$F_f = \frac{\partial w_f^{'}}{\partial x}(i, x)$$

2. Explain the concept of electromechanical energy conversion with neat diagram. (May - 2017)

The electromechanical energy conversion process involves the transfer of energy between electrical and mechanical systems, via the electric field or magnetic field.

In practice three types of electromechanical energy conversion devices are in use.

Microphones, Loud speakers: These device handle low energy signals. These devices mostly operate on vibrating motion.

The device which produces the mechanical force or torque based on translator motion such as electromagnets, relays, solenoids, actuators etc., and these devices handle large energy signals than the transducer.
The devices used for continuous energy conversion using rotational motion such as generators, motors etc. These devices handle very large energy signals.

Generating Device

Mechanical System → Input Device → Coupling medium magnetic field → Output device Electrical System

Motoring Device

Electrical System → Input Device → Coupling medium magnetic field → Output device Mechanical System

The process of energy transformation is reversible but there are certain losses due to practical devices. In energy conversion process the entire energy cannot be converted from one form to another. The loss in the process is called energy loss. In addition to the loss some part of energy gets stored in the medium like magnetic field. This is called energy stored.

Energy balance Equation

Motor

Electrical System = Mechanical Output Energy + Energy Stored + Total Energy Loss

Generator

Mechanical System = Electrical Output Energy + Energy Stored + Total Energy Loss

$$dw_e = dw_m + dw_f + dw_{loss}$$

$$dw_m = dw_e + dw_f + dw_{loss}$$

dw_e=Differential Electrical Energy
dw_m=Differential Mechanical Energy
dw_{loss}=Differential Energy Loss
dw_f= Differential Energy Stored

3. Explain in detailed MMF distribution in AC synchronous machine and derive the expression for fundamental MMF. (May -2017)

When the synchronous machine behaves as a generator then the induced emf supplies the load current which is an armature current. Hence both emf and current have the same positive direction.

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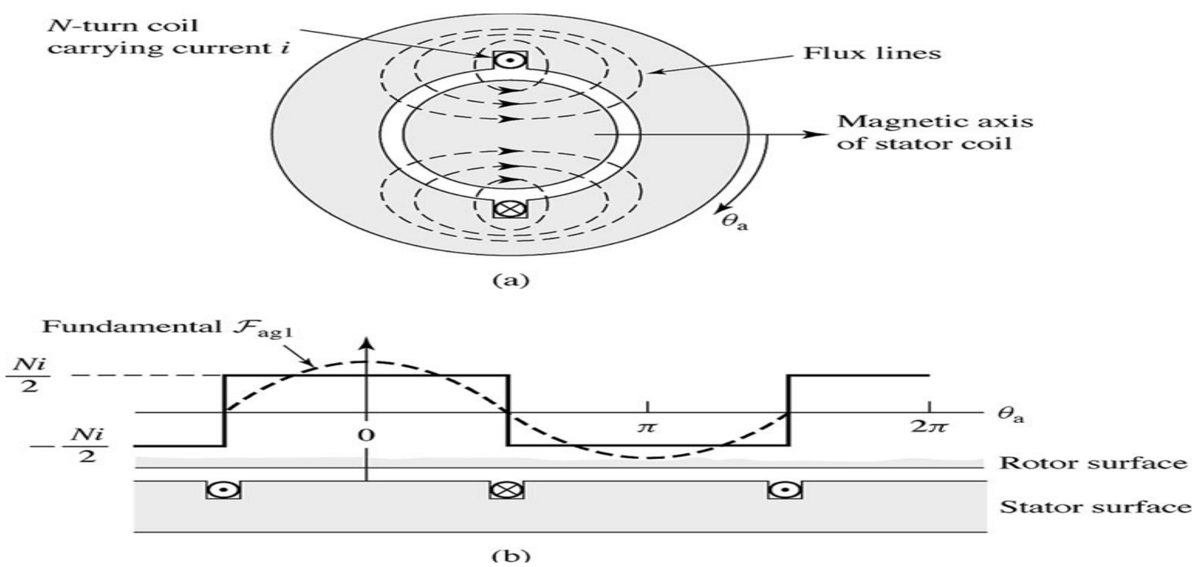


$$\gamma = \frac{\pi P}{S} rads$$

If N_{ph} = Number of turns per phase
i_c = Current in coil
A = Number of parallel paths
AT/ Parallel path = $N_{ph}i_c$
Armature current = $i_a = i_c * A$
AT/Phase/Pole = $(N_{ph}/p)i_a$

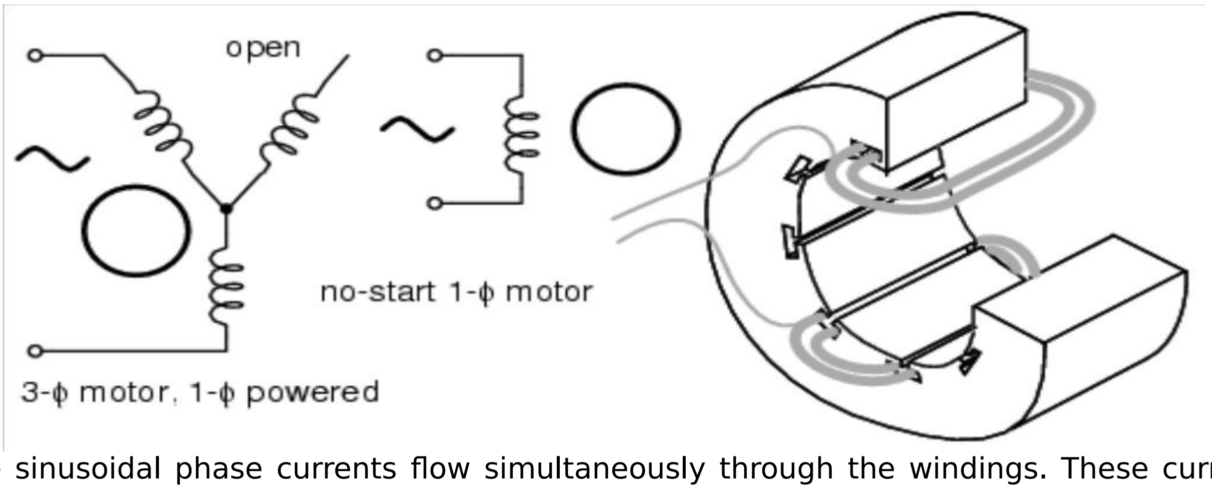
Peak value of fundamental $F_P = \frac{4}{\pi}\frac{N_{ph}}{p} i_a k_b$

$$k_w = k_p \times k_b$$

$$F_a = \frac{4}{\pi}\frac{N_{ph}}{p} i_a k_w \cos\theta$$

4. Explain about the magnetic field in rotating machines. (Nov - 2016)

Thus a magnetic field having constant amplitude but whose axis continuously rotates in a plane with a certain speed is called rotating magnetic field.



The three sinusoidal phase currents flow simultaneously through the windings. These currents are displaced from each other by 120^0 electrical. These currents can be mathematically expressed as ,

$$i_a = I_m \cos\omega t$$
$$i_b = I_m \cos(\omega t - 120^0)$$
$$i_c = I_m \cos(\omega t - 240^0)$$

The principle of mutual inductance these currents develop a magnetic field which is also separated by 120^0 with respect to the magnetic axes. These develop mmfs that can be expressed as

$$F_a = F_m \cos\omega t \cos\theta$$
$$F_b = F_m \cos(\omega t - 120)\cos(\theta - 120)$$
$$F_c = F_m \cos(\omega t - 240)\cos(\theta - 240)$$

The resulting mmf is given by

$$F = F_a + F_b + F_c$$

$$F(\theta, t) = \frac{3}{2} F_m \cos(\theta - \theta t)$$

Peak value of the mmf developed

$$F_p = \frac{3}{2} F_m$$

$$F_m = 3\frac{2\sqrt{2}}{\pi}\frac{N_{ph}}{p}K_\omega I_{rms}$$

$$F(\theta, 0) = 3\frac{2\sqrt{2}}{\pi}\frac{N_{ph}}{p}k_\omega I_{rms}\cos\theta$$

5. With an example explain the multiple excited magnetic field system. (May - 2016)

Example: Alternator, Electro-Mechanical Transducer and Synchronous motors.

For certain applications like that of electromechanical transducers it may be required specially two excitations where one is used for establishing the required magnetic field and the other for producing an electrical signal proportional to the fore (or) velocity that is to be measured.

$$F_x = -\frac{\partial w_f}{\partial x}$$

$$F_f dx = -\partial w_f$$

$$w_f(\lambda_1, \lambda_2, \theta) = \int_0^{\lambda_1} i_1 d\lambda_1 + \int_0^{\lambda_2} i_2 d\lambda_2$$

Flux linkages can be represented as,

$$\lambda_1 = L_{11} i_1 + L_{12} i_2$$
$$\lambda_2 = L_{21} i_1 + L_{22} i_2$$
$$i_1 = \beta_{11}\lambda_1 + \beta_{12}\lambda_2$$
$$i_2 = \beta_{12}\lambda_1 + \beta_{22}\lambda_2$$
$$\beta_{11} = \frac{L_{22}}{L_{11}L_{22} - L_{12}^{\ 2}}$$
$$\beta_{22} = \frac{L_{11}}{L_{11}L_{22} - L_{12}^{\ 2}}$$
$$\beta_{12} = \beta_{21} = -\frac{L_{12}}{L_{11}L_{22} - L_{12}^{\ 2}}$$
$$w_f(\lambda_1, \lambda_2, \theta) = \beta_{11}\frac{\lambda_1^{\ 2}}{2} + \beta_{22}\frac{\lambda_2^{\ 2}}{2} + \beta_{12}\lambda_1\lambda_2$$
$$w_f(i_1, i_2, \theta) = L_{11}\frac{i_1^{\ 2}}{2} + L_{22}\frac{i_2^{\ 2}}{2} + L_{12} i_1 i_2$$

6. Derive the torque equation of a round rotor machine. Also clearly state the assumption made.
(May - 2015)

Assumptions

The rotor is considered to be smooth cylindrical so as to maintain an uniform air gap
Reluctance of the iron path is negligible
Stator and rotor mmfs are sinusoidal waves
The type of ac windings is that of distributed windings
The leakage flux affects the net voltage at the terminals of the machine
The mutual flux links with both the stator and rotor windings

$$T = -\frac{\pi}{2}\frac{\mu_0 Dl}{g}F_1F_2\sin\alpha$$

$$T = -\frac{\pi}{2}(p/2)^2\phi F_2\sin\delta$$

7. Two windings one mounted in stator and other at rotor have self and mutual inductance of L_{11}=4.5 and L_{22}=2.5, L_{12}=2.8CosθH, where θ is the angle between axes of winding. Winding 2 is short circuited and current in winding as a function of time is i_1=10sinωtA. Determine the expression for numerical value in N-M for the instantaneous value of torque in terms of θ, compute the time average torque in N-M when θ=45^0 and if the rotor is allowed to move will it continuously

(a) $$T_{fld} = i_1 i_2\frac{dL(\theta)}{d\theta} = -2.8 i_1 i_2\sin\theta$$

Winding 2 short-circuited

$$e_2 = v_2 = 0 \;\Rightarrow\; \lambda_2 = L_{21}i_1 + L_{22}i_2 = 0 \;\Rightarrow\; i_2 = -\frac{L_{21}}{L_{22}}i_1 = -1.12 i_1\cos\theta$$

$$T_{fld} = -2.8 i_1 i_2\sin\theta = -3.14 i_1^2\sin\theta\cos\theta = -314\sin^2(\omega t)\sin\theta\cos\theta$$

(b) Time-averaged torque

$$\langle T_{fld}\rangle = -157\sin\theta\cos\theta \quad \theta = 45^\circ \;\Rightarrow\; \langle T_{fld}\rangle = -157\left(\frac{1}{\sqrt{2}}\right)\left(\frac{1}{\sqrt{2}}\right) = -78.5 \quad \text{N-m}$$

Note: $$\langle\sin^2(\omega t)\rangle = \frac{1}{\pi}\int_0^{\pi}\frac{1-\cos(2\omega t)}{2}d(\omega t) = \frac{1}{2}$$

(c) The rotor will not rotate because the average torque with respect to θ is zero. It will come to rest when

$$\sin\theta\cos\theta = \frac{1}{2}\sin(2\theta) = 0 \;\Rightarrow\; \theta = \frac{\pi}{2}$$

rotate or it will come to rest? If later at which value θ_0. (Nov-2015)

UNIT IV – DC GENERATORS

PART – A

1. What is the purpose of yoke in a dc machine? (Nov - 2017)

- It serves the purpose of outermost cover of the dc machine. So that the insulating materials get protected from harmful atmospheric elements like moisture, dust and various gases.
- It provides mechanical support to the poles.

2. What is critical resistance of a dc shunt generator? (Nov - 2017)

Critical field resistance is defined as the resistance of the field circuit which will cause the shunt generator just to build up its emf at a specified field.

3. What is meant by armature reaction? (May - 2017)

The interaction between the main flux and armature flux cause disturbance called as armature reaction.

4. State the conditions under which a DC shunt generator fails to excite. (May - 2017)

Absence of residual flux, initial flux setup by field may be opposite in direction to residual flux, shunt field circuit resistance may be higher than its critical field resistance; load circuit resistance may be less than its critical load resistance.

5. Write emf equation of dc generator. (Nov - 2016)

E= (ΦNZP/60A

P---------no of poles

Z---------Total no of conductor

Φ---------flux per pole

N---------speed in rpm.

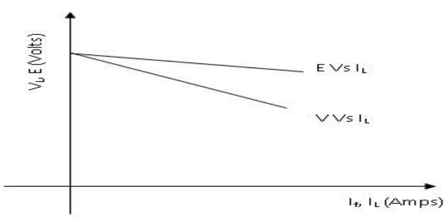
6. What is the use of inter pole in dc machine? (Nov - 2016)

In modern dc machines commutating poles or inter poles are provided to improve commutation.

7. Compare lap and wave windings. (May - 2016)

Lap	Wave
A=P	A=2
Number of brush sets required is equal to number of poles	Number of brush sets required is always equal to two
Normally used for generators of capacity more than 500A	Preferred for generators of capacity less than 500A

8. Draw various characteristics of dc shunt generator.



9. Why the external characteristics of a dc shunt generator is more drooping than that of a separately excited generator? (May - 2014)

In separately excited generator $I_a=I_L$ and I_{sh} is not supplied by armature. In dc shunt generator $I_a=I_L+I_{sh}$ hence the drop I_aR_a is more than in separately excited generator. Hence the external characteristic of dc shunt generator is more drooping than that of a separately excited generator.

10. What are the conditions for parallel operation of dc generators? (May - 07)

- The voltage of both the generators must be equal
- The polarities of the generators must be same or the connections must be interchanged till they become same.
- The change of voltage with change of load should be of same character

PART – B

1. Explain in detail about commutation and list out the various methods of improving commutation in detail with a neat sketch. (Nov – 2017/ Nov – 2016/ Nov-2015)

The process by which the current in the short circuited coil of the armature gets reversed along the magnetic neutral axis is called commutation. The time duration of the current reversal (or the short circuit of the coil is called commutation period.

Mechanical Causes

- Any change in shape of the commutator rather than cylindrical may enhance inefficient current reversal.
- Any mechanical imbalance of commutator segments may cause projection of bars.
- Vibrations on brush holder may also aggravate the chances of spark over across the brushes.

Electrical Causes

- An increase in the voltage across the commutating bars may exceed the permitted limits. This may causer a high sparking current to flow through the commutator segments.
- The most important electrical cause for commutation to be poor is the reactance voltage.
- The armature coils possess appreciable amount of self-inductance as they are embedded in the armature core made up of high magnetic permeability material.

Methods to improve commutation

- Resistance commutation
- EMF commutation

Resistance commutation

This method of improving commutation is by replacing the low resistance copper brushes with high resistance carbon brushes. The role of high resistance carbon brushes becomes well pronounced at the start and end of the commutation period.

Merits

- To some extent carbon brush can act as s self-lubricating brush
- On moment polishes the commutator segments

De Merits

- Larger commutators are required
- Larger brush holders are needed for carbon brushes

EMF Commutation

Resistance value is not only the deciding factor for poor commutation, whereas the reactance voltage is the main cause for sparking. Hence it is not enough that the copper brushes are replaced by carbon brushes. The reactance voltage should also be neutralized so as to enhance ideal commutation.

2. Explain the effect of armature reaction in a DC generator. How is its demagnetizing and cross magnetizing ampere turns calculated? (May – 2017/May - 2016)

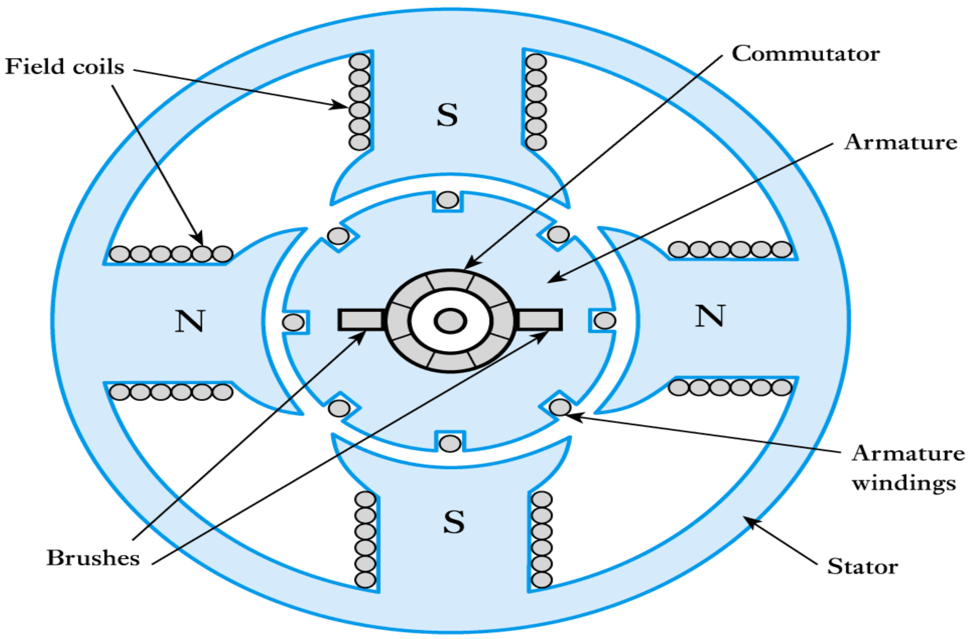
In a unloaded d.c machine armature current is vanishingly small and the flux per pole is decided by the field current alone. The uniform distribution of the lines of force gets upset when armature too carries current due to loading. In one half of the pole, flux lines are concentrated and in the other half they are rarefied. Qualitatively one can argue that during loading condition flux per pole will remain same as in no load operation because the increase of flux in one half will be balanced by the decrease in the flux in the other half. Since it is the flux per pole which decides the emf generated and the torque produced by the machine, seemingly there will be no effect felt so far as the performance of the machine is concerned due to armature reaction.

This in fact is almost true when the machine is lightly or moderately loaded However at rated armature current the increase of flux in one half of the pole is rather less than the decrease in the other half due to presence of *saturation*. In other words there will be a net decrease in flux per pole during sufficient loading of the machine. This will have a direct bearing on the emf as well as torque developed affecting the performance of the machine.

Apart from this, due to distortion in the flux distribution, there will be some amount of flux present along the q-axis (brush axis) of the machine. This causes commutation difficult. In the following sections we try to explain armature reaction in somewhat detail considering motor and generator mode separately.

Cross magnetizing ampere turns per pole = $AT_c = ZI\left(\frac{1}{2P} - \frac{\theta}{360}\right)$

3. Explain the construction and operation of dc generator. (Nov - 2016)



- Magnetic frame / Yoke
- Poles, Inter poles, Windings, Pole shoes
- Armature

- Commutator
- Brushes, bearings and shaft

4. Obtain EMF equation of dc generator. (May - 2016)

Let ϕ be the flux per pole in webers
P be the number of poles
Z be the total number of conductors in the armature

All the Z conductors are not connected in series. They are divided into groups and let A be the number of parallel paths into which these conductors are grouped.
So each parallel path will have Z/A conductors in series
N be the speed of rotation in revolutions per minute

Consider one conductor on the periphery of the armature. As this conductor makes one complete revolution it cuts Pϕ webers. As the speed is N rpm, the time taken for one revolution is 60/N sec.

The emf induced in the conductor =rate of change of flux cut

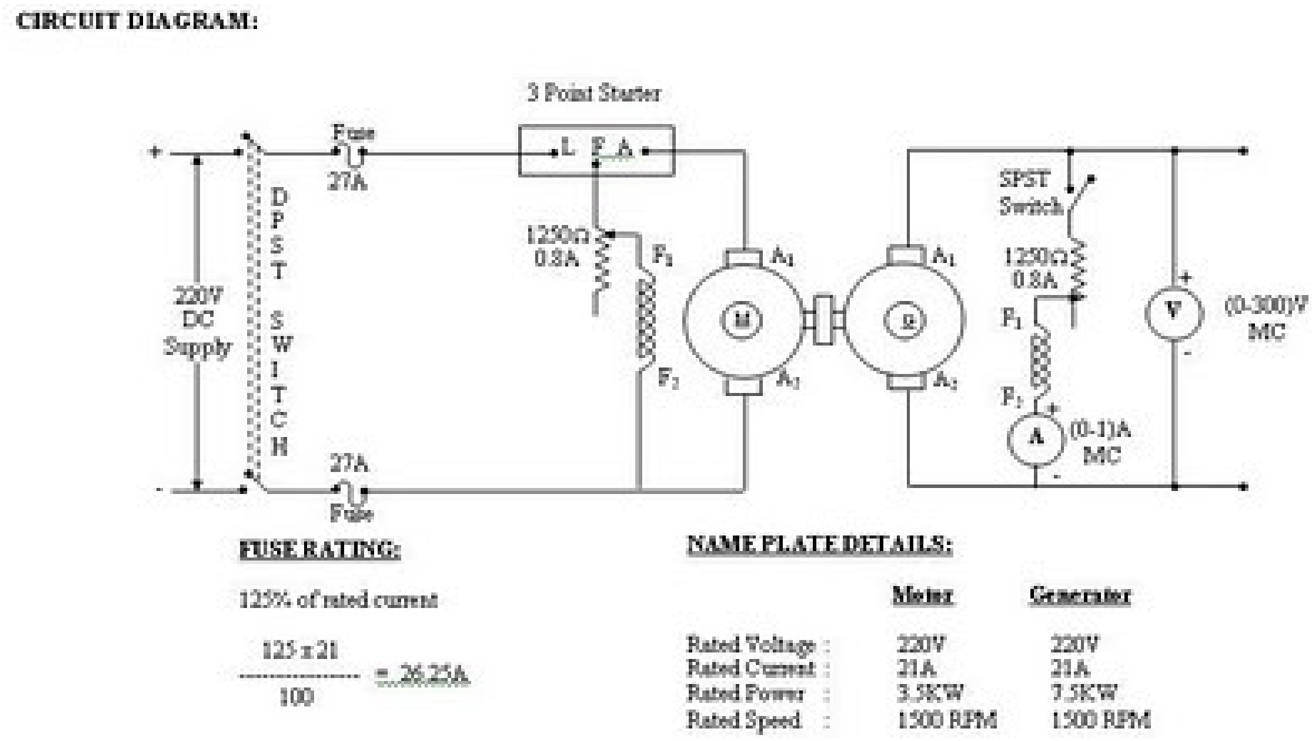
$$e \alpha \frac{d\phi}{dt} = \frac{P\phi}{\frac{60}{N}}$$

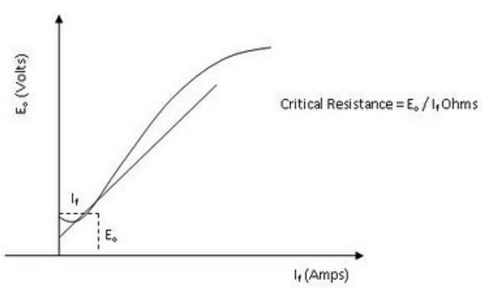
$$e = \frac{P\phi N}{60}$$

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

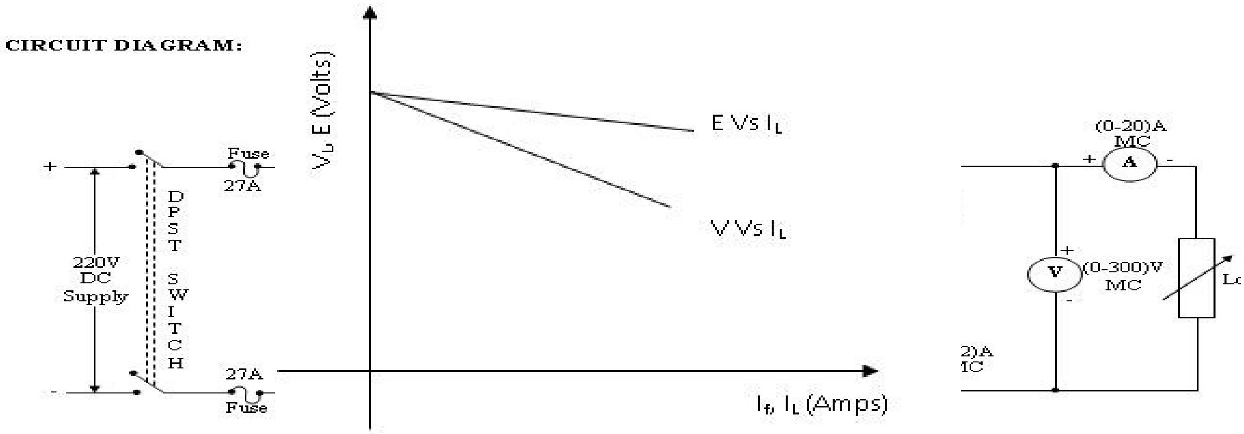
5. Explain the different methods of excitation and characteristics of a dc generator with suitable diagrams. (May - 2012)

OPEN CIRCUIT CHARACTERISTICS OF SELF EXCITED DC SHUNT GENERATOR





LOAD CHARACTERISTICS OF SELF EXCITED DC SHUNT GENERATOR



FUSE RATING:

125% of rated current

$$\frac{125 \times 21}{100} = 26.25A$$

NAME PLATE DETAILS:

	Motor	Generator
Rated Voltage :	220V	220V
Rated Current :	21A	21A
Rated Power :	3.5KW	7.5KW
Rated Speed :	1500 RPM	1500 RPM

UNIT V – DC MOTORS

PART – A

1. What will happen to the speed of a dc motor when its flux approaches zero? (Nov - 2017)

In fact physically the rotor is moving because of field flux interacting with armature current flux. So physically if reduce flux the speed must be reduce, since reduced the cause of motion.

2. Mention the effects of differential compounding and cumulatively compound on the performance of dc compound motor. (Nov - 2017)

In cumulative compound motor the two field winding fluxes aid each other i.e., flux due to the series field winding strengthens the flux due to the shunt field winding. In differential compound motor the two field winding fluxes oppose each other. Flux due to series field winding weakness the field due to shunt field winding.

3. Why a starter is necessary for a dc motor? (May - 2017)

When a dc motor is directly switched on, at the time of starting the motor back emf is zero, Due to this the armature current is very high nearly 25times the rated current. Due to the very high current the motor gets damaged. To reduce the starting current of the motor a starter is used.

4. What are the applications of dc motor? (May - 2017)

Shunt Motors : Driving centrifugal pumps, Wood working machines, lathes

Series Motors : Cranes, Hoist, Lifts, Blowers, Conveyors

Compound Motors: Driving heavy machine tools, Punches machines

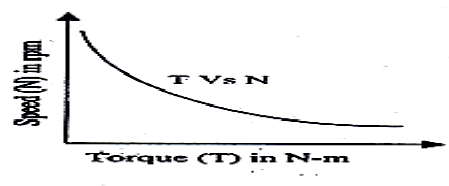
5. What are the different types of testing of dc machines?

Brake Test, Swinburne's Test, Retardation Test and Hopkinson's Test

6. What is meant by dynamic braking in dc motor? (Nov - 2016)

When an electric motor rotates a kinetic energy is stored in its rotating mass. During dynamic braking the kinetic energy of the motor is converted in to electric energy. This energy is dissipated in resistive elements.

7. Draw the speed – torque characteristics of dc series motor. (May - 2016)



8. What is meant by plugging? (May - 2016)

The plugging operation can be obtained by changing the polarity of the motor. For ac machines the phase sequence of the stator windings and dc machines the polarities of the field or armature terminals.

9. State Fleming's left hand rule? (Nov - 2015)

The thumb, forefinger & middle finger of left hand are held so that these fingers are mutually perpendicular to each other, then forefinger gives the direction of magnetic field, middle finger gives the direction of the current and thumb gives the direction of the force experienced by the conductor.

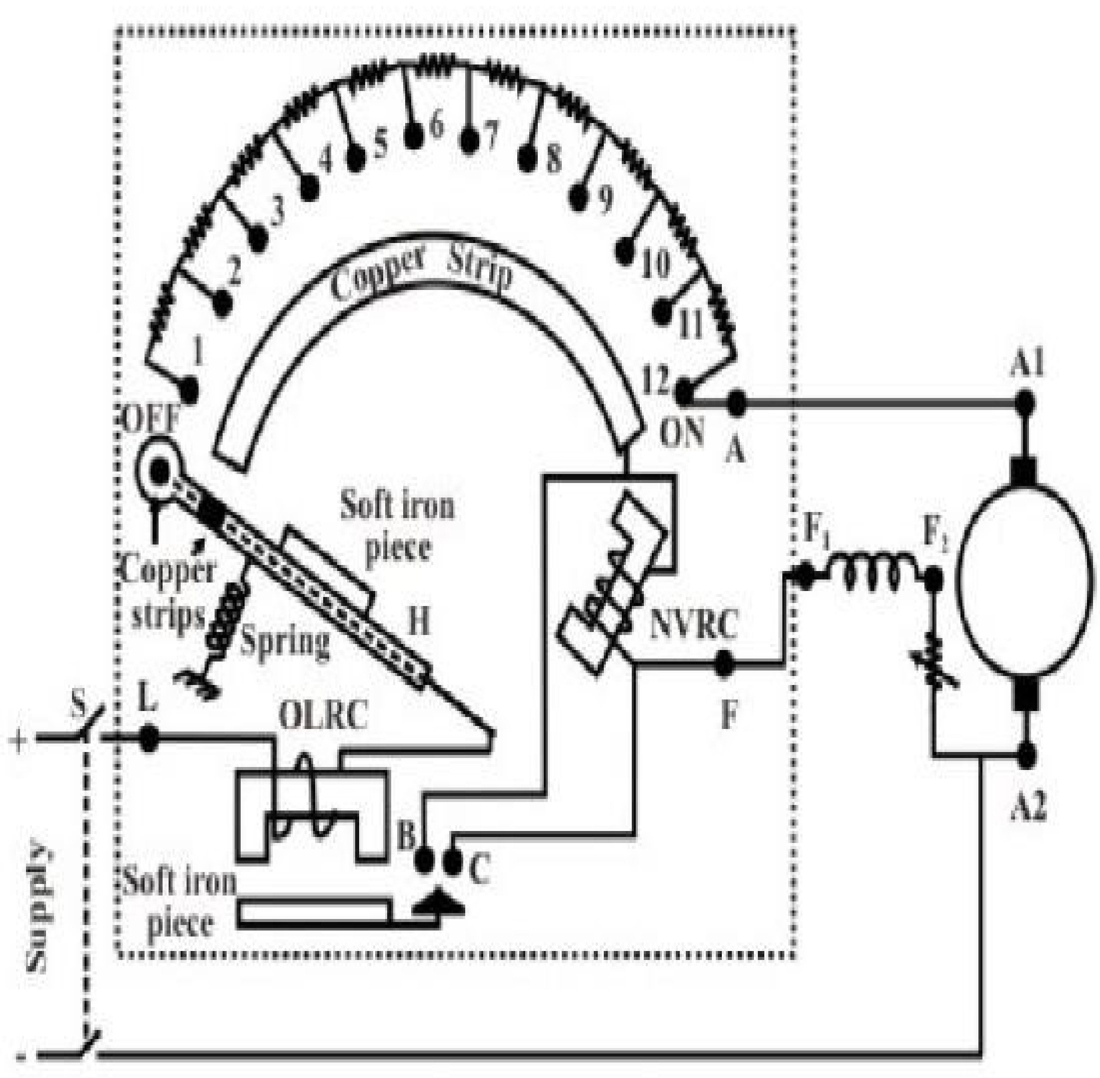
10. Why DC series motor is called as variable speed motor? (Nov - 2015)

The speed of a DC motor can be controlled by changing the voltage applied to the armature. The introduction of variable resistance in the armature circuit or field circuit allowed speed control.

PART – B

1. Draw a neat sketch of 3 – Point starter and explain its working. (Nov - 2017)

A "3-point starter" is extensively used to start a D.C shunt motor. It not only overcomes the difficulty of a plain resistance starter, but also provides additional protective features such as over load protection and no volt protection.



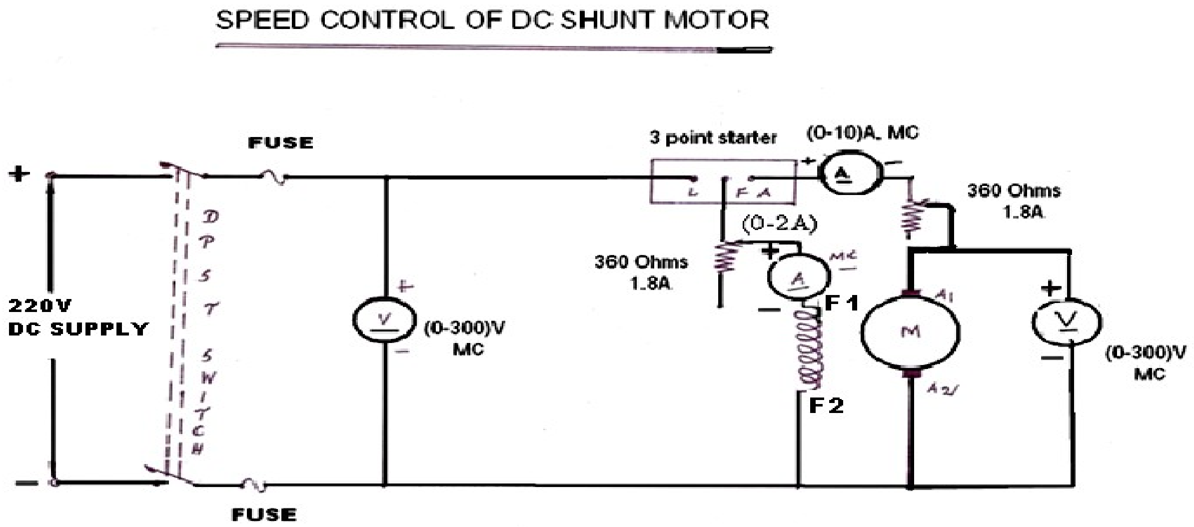
In the operation of the starter, initially the handle is in the OFF position. Neither armature nor the field of the motor gets supply. Now the handle is moved to stud number 1. In this position armature and all the resistances in series gets connected to the supply. Field coil gets full supply as the rectangular strip makes contact with arc copper strip. As the machine picks up speed handle is moved further to stud number 2.

In this position the external resistance in the armature circuit is less as the first resistance is left out. Field however, continues to get full voltage by virtue of the continuous arc strip.

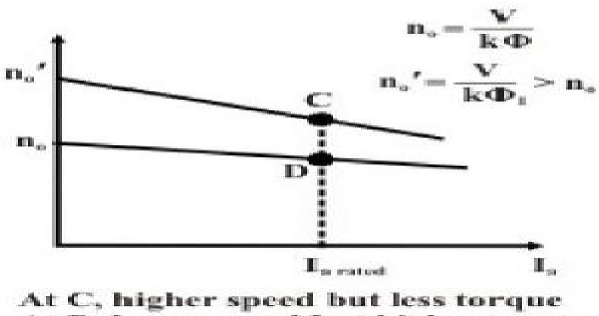
Continuing in this way, all resistances will be left out when stud number 12 (ON) is reached. In this position, the electromagnet (NVRC) will attract the soft iron piece attached to the handle. Even if the operator removes his hand from the handle, it will still remain in the ON position as spring restoring force will be balanced by the force of attraction between NVRC and the soft iron piece of the handle.
The no volt release coil (NVRC) carries same current as that of the field coil. In case supply voltage goes off, field coil current will decrease to zero. Hence NVRC will be de-energized and will not be able to exert any force on the soft iron piece of the handle. Restoring force of the spring will bring the handle back in the OFF position.

2. Explain the different methods of speed control of dc shunt motor with neat circuit diagrams. (Nov – 2017/May – 2017/Nov – 2014/May – 2012/Nov-2013)

Field Control Method (Flux Control Method)



- Using the three-point starter the motor is started to run.
- The armature rheostat is adjusted and a particular armature voltage is set.
- Now the field rheostat is varied gradually and the corresponding field current and Speeds are noted upto 120% of the rated speed keeping the armature current as constant. This procedure is repeated for 2 more armature voltages.
- The motor is switched off using the DPST(Double pole single Throw)switch after bringing all rheostats to their initial position



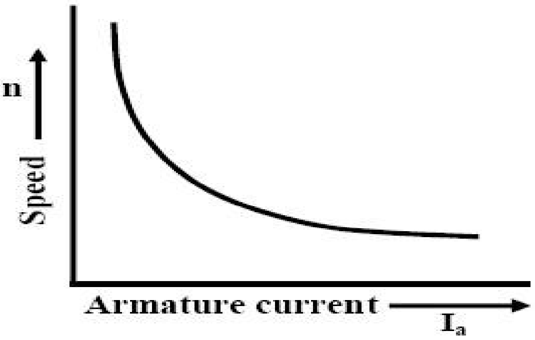
At C, higher speed but less torque
At D, lower speed but higher torque

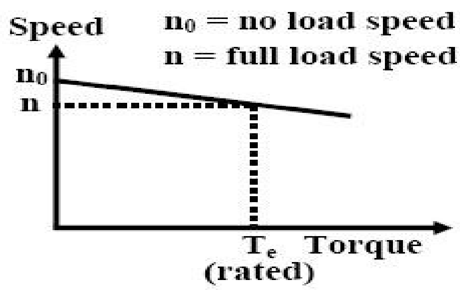
Armature Control Method (Voltage Control Method)

- Using the three-point starter the motor is started to run.

- The armature rheostat is adjusted to run the motor at rated speed by means of applying the rated voltage.
- The field rheostat is adjusted and for a particular field current is set. By varying armature rheostat, corresponding armature voltage, armature current and speed are noted up to the rated voltage.
- The motor is switched off using the DPST(Double pole single Throw)switch after bringing all rheostats to their initial position.

3.

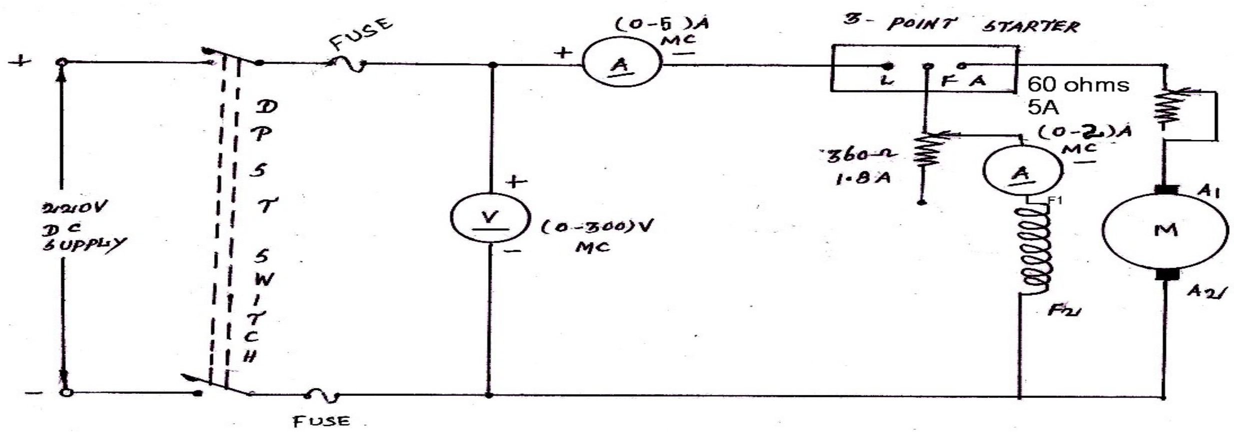




With the help of neat circuit diagram, explain Swinburne's test and derive the relations for efficiency (Both for generator and motor). (May – 2017/Nov - 2016)

For a d.c shunt motor change of speed from no load to full load is quite small. Therefore, mechanical loss can be assumed to remain same from no load to full load. Also if field current is held constant during loading, the core loss too can be assumed to remain same.

In this test, the motor is run at rated speed under *no load* condition at rated voltage. The current drawn from the supply *IL*0 and the field current *If* are recorded



1.

Armature resistance (R_a)=1.6x R_{dc} in ohms   where 1.6 adds the skin effect

R_{dc}- Resistance of the armature coil when it is energized by D C supply

2.Constant loss (W_{co})=($V.I_o$ - I_{ao}^2 R_a)   in watts Where   V-terminal voltage in volts

I_o-no load current in A I_{ao}-no load armature current in A

3.Armature current : (I_a) = (I_L + If) in A ------- for generator

(I_a) = (I_L - If) in A -------- for motor

4.Copper loss (w_{cu})=I_a ^{2}.R_a watts

5.Total loss (w_{Total})=Constant loss+ Copper loss in watts

6. Input power: W_{in} = $V.I_L$ -------for motor

W_{in} = $V.I_L$ + W_{Total} -------for generator

7. output power: W_{out} = $V.I_L$ - W_{Total} -----------for motor

W_{out} = $V.I_L$ ----- for generator

8.Percentage efficiency = (output power/input power)x100

AS MOTOR:

Load Current I_L = _____ Amps (Assume 15%, 25%, 50%, 75% of rated current)

Armature current Ia = $I_L - I_f$ Amps

Copper loss = $I_a^2 R_a$ watts

Total losses = Copper loss + Constant losses

Input Power = VI_L watts

Output Power = Input Power – Total losses

$$\text{Efficiency } \eta\% = \frac{\text{Output power}}{\text{Input Power}} \times 100\%$$

AS GENERATOR:

Load Current I_L = _____ Amps (Assume 15%, 25%, 50%, 75% of rated current)

Armature current Ia = $I_L + I_f$ Amps

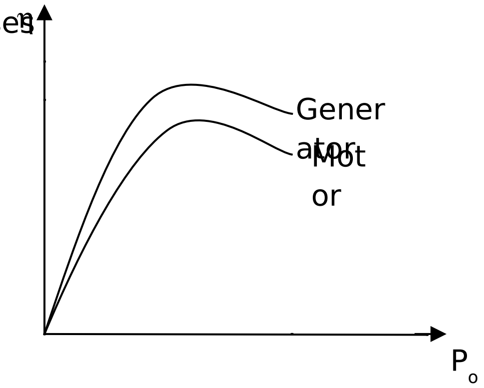
Copper loss = $I_a^2 R_a$ watts

Total losses = Copper loss + Constant losses

Output Power = VI_L watts

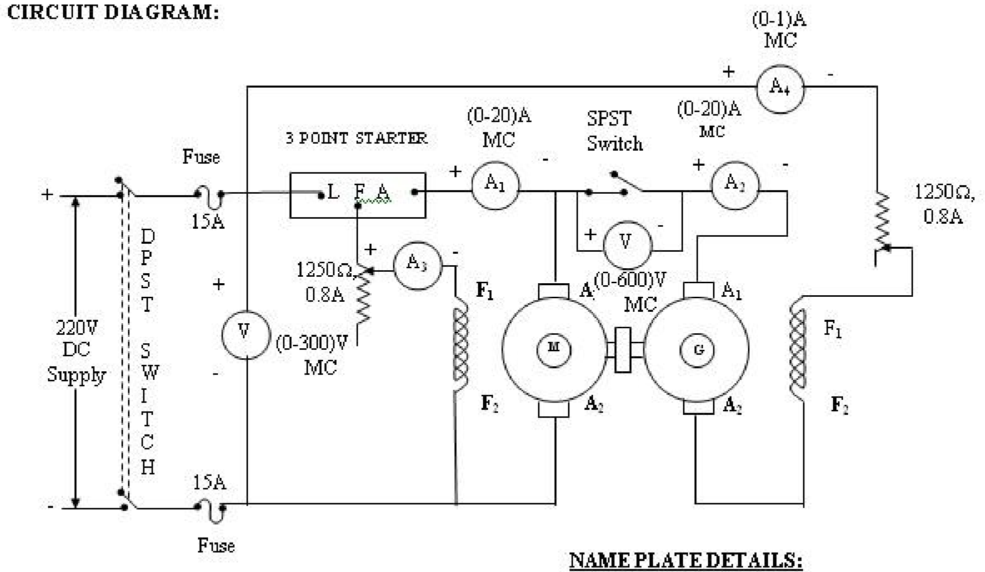
Input Power = Input Power +Total losses

$$\text{Efficiency } \eta\% = \frac{\text{Output power}}{\text{Input Power}} \times 100\%$$



4. Explain the method to obtain efficiency at full load by conducting Hopkinson's test. (May - 2016)

CIRCUIT DIAGRAM:



NAME PLATE DETAILS:

	SHUNT MOTOR	SHUNT GENERATOR
Rated Voltage :	220V	220V
Rated Current :	21A	21A
Rated Power :	3.5KW	7.5KW
Rated Speed :	1500 rpm.	1500rpm.

Connect the two similar (same rating) coupled machines as shown in figure. With switch S opened, the first machine is run as a shunt motor at rated speed. It may be noted that the second machine is operating as a separately excited generator because its field winding is excited and it is driven by the first machine. Now the question is what will be the reading of the voltmeter connected across the opened switch S? The reading may be (i) either close to twice supply voltage or (ii) small voltage. In fact the voltmeter practically reads the difference of the induced voltages in the armature of the machines. The upper armature terminal of the generator may have either + ve or negative polarity. If it happens to be +ve, then voltmeter reading will be small otherwise it will be almost double the supply voltage

Since the goal is to connect the two machines in parallel, we must first ensure voltmeter reading is small. In case we find voltmeter reading is high, we should switch off the supply, reverse the armature connection of the generator and start afresh. Now voltmeter is found to read small although time is still not ripe enough to close S for paralleling the machines. Any attempt to close the switch may result into large circulating current as the armature resistances are small. Now by adjusting the field current *Ifg* of the generator the voltmeter reading may be adjusted to zero (*Eg* ≈ *Eb*) and S is now closed. Both the machines are now connected in parallel

FORMULAE:

Input Power = VI_1 watts

Motor armature cu loss = $(I_1 + I_2)^2$ Ra watts

Generator armature cu loss = I_2^2 Ra watts

Total Stray losses W = $V I_1 - (I_1+I_2)^2 Ra + I_2^2 Ra$ watts.

Stray loss per machine = W/2 watts.

AS MOTOR:

Input Power = Armature input + Shunt field input

= $(I_1 + I_2) V + I_3 V = (I_1+I_2+I_3) V$

Total Losses = Armature Cu loss + Field loss + stray loss

= $(I_1 + I_2)^2$ Ra + VI_3 + W/2 watts

Efficiency η% = (Input power – Total Losses) / (Input Power) x 100%

AS GENERATOR:

Output Power = VI_2 watts

Total Losses = Armature Cu loss+ Field Loss + Stray loss

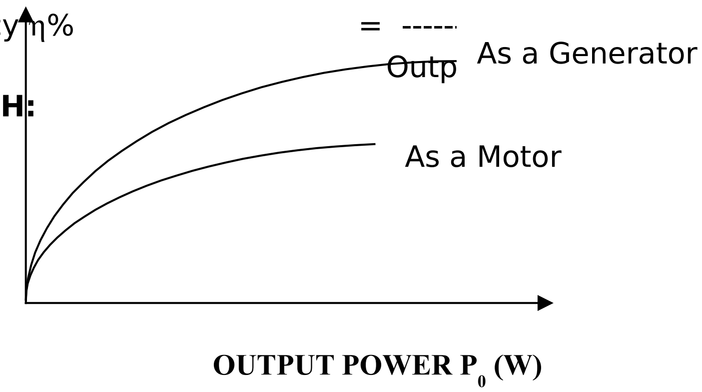
= I_2^2 Ra + VI_4 + W/2 watts

Output power

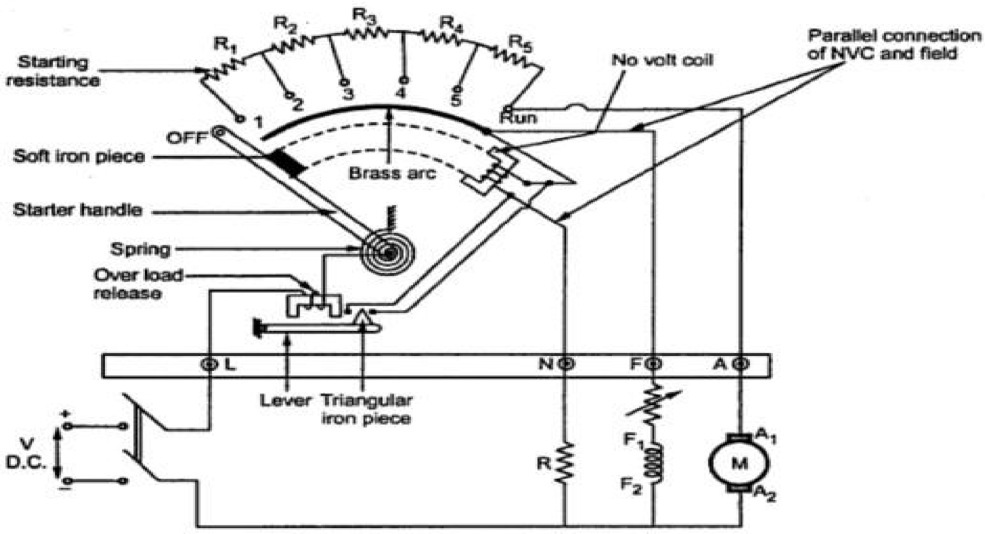
Efficiency η% = ----- --- x 100%

Outp es

MODE % η H:



5. Why starters are necessary? Explain in detail the construction and working operation of 4 point starter. (Nov - 2015)



The four-point starter eliminates the drawback of the three-point starter. In addition to the same three points that were in use with the three-point starter, the other side of the line, L1, is the fourth point brought to the starter when the arm is moved from the "Off" position. The coil of the holding magnet is connected across

The holding magnet and starting resistors function identical as in the three-point starter. The possibility of accidentally opening the field circuit is quite remote. The four-point starter provides the no-voltage protection to the motor. If the power fails, the motor is disconnected from the line.

6. Explain in detail the construction and working operation of Retardation test on dc motor. (Nov- 2015)

This test is also known as running down test. It is used for finding out the stray losses of shunt wound dc machines. In this method of testing the machine under test is made to run slightly above its normal speed and supply to armature is cut off. Consequently the armature slows down and its kinetic energy is used to meet the rotational losses.

Kinetic Energy of the Armature = $(1/2)I\omega^2$

Where I=Moment of inertia of the armature

ω = Angular speed

Rotational Losses W= Rate of change of kinetic energy

$$\frac{dN}{dT} = \frac{Speed in rpm}{Time in \sec}$$

$$I = \frac{I_1 \frac{dN}{dt_2}}{\frac{(dN)}{(dt_1)} - \frac{(dN)}{(dt_2)}}$$

$$W = W' \frac{t_2}{(t_1 - t_2)}$$

7. Derive in detail the condition for maximum efficiency of dc machine. (Nov - 2015)

Generator output = VI

Generator input power = Output power + Total losses

$= VI + I_a^2 R_a + W_c$

$I_a = I + I_{SH}$

Efficiency = (Output power)/(Input power)

$= (VI)/(VI + I_a^2 R_a + W_c)$

$I_a^2 R_a = W_c$

Variable loss = Constant loss

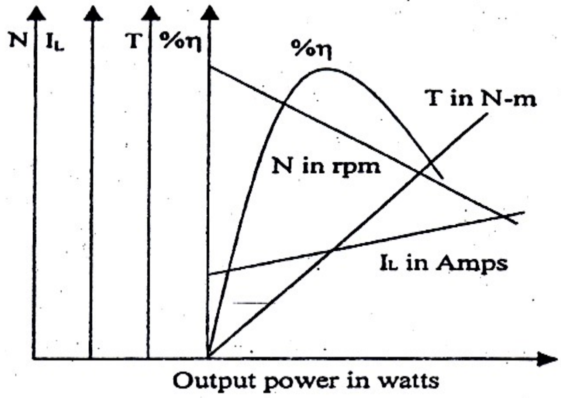
At this condition constant loss is equal to variable loss and the machine efficiency is maximum.

8. Explain the different methods of excitation and characteristics of a dc motors with suitable diagrams. (Nov - 2014)

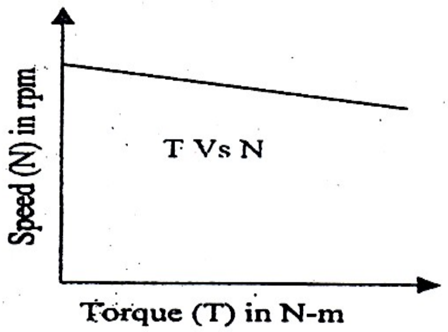
Compound Motor

Model Graph

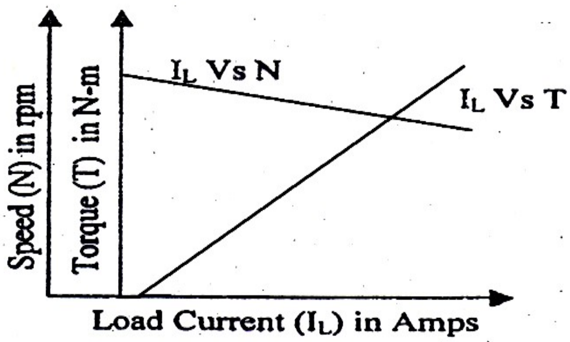
(A) Electrical Characteristics



(B) Mechanical Characteristics



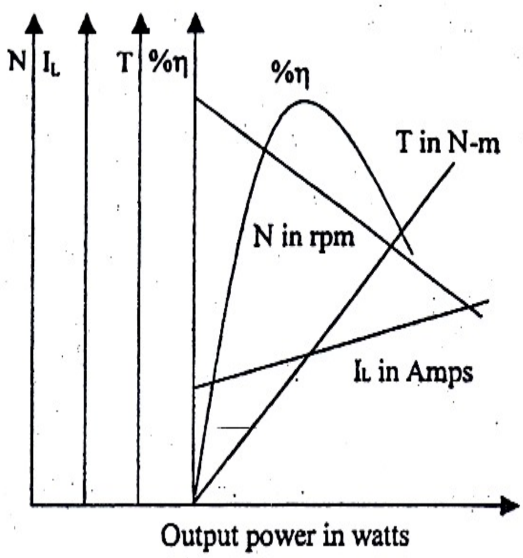
(C) Torque, Speed Vs Load Current



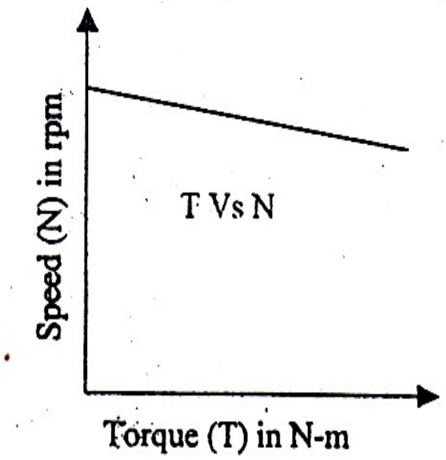
Shunt Motor

Model Graph

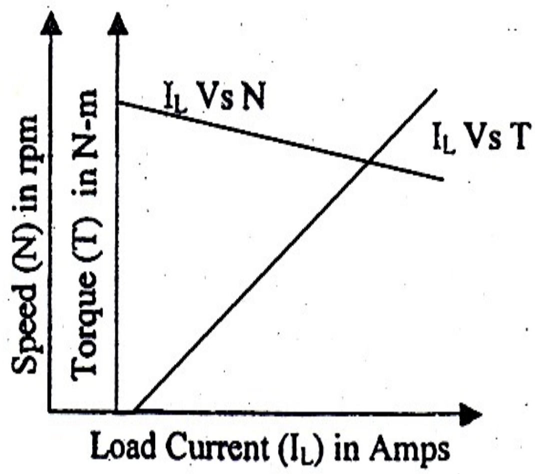
(A) Electrical Characteristics



(B) Mechanical Characteristics



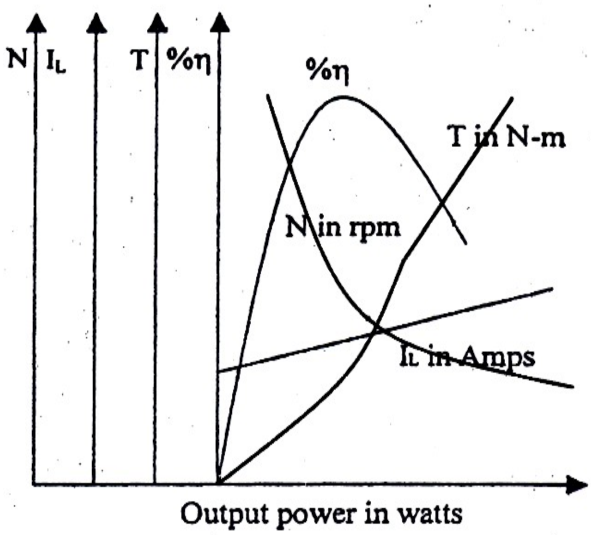
(C) Torque, Speed Vs Load Current



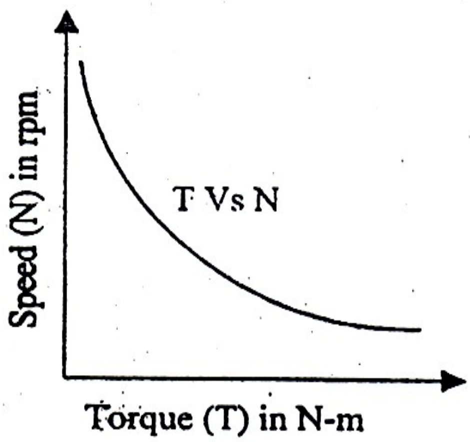
Series Motor

Model Graph

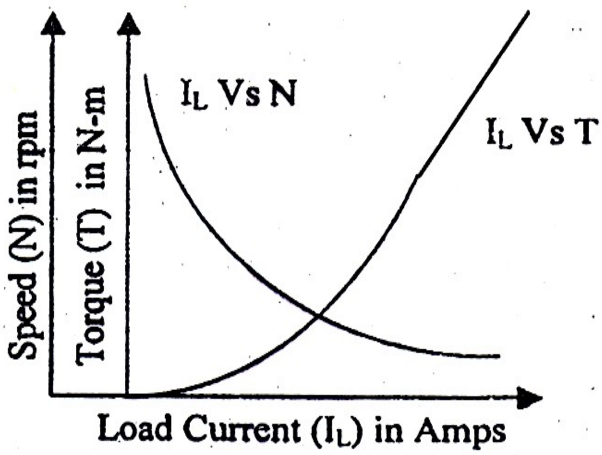
(A) Electrical Characteristics



(B) Mechanical Characteristics



(C) Torque, Speed Vs Load Current



9. Different types of braking

Dynamic Braking

When an electric motor rotates a kinetic energy is stored in its rotating mass. During dynamic braking the kinetic energy of the motor is converted in to electric energy. This energy is dissipated in resistive elements.

Plugging

The plugging operation can be obtained by changing the polarity of the motor. For ac machines the phase sequence of the stator windings and dc machines the polarities of the field or armature terminals.

Regenerative braking

In the regenerative braking operation the motor operates as a generator while it is still connected to the supply. Here the motor speed is greater than the synchronous speed.