UNIT – 1

DC Circuit

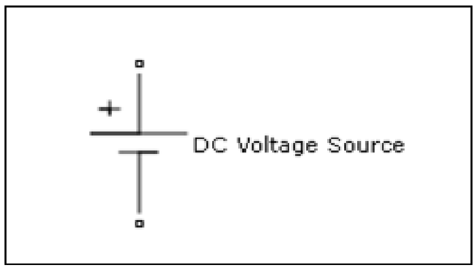
Unit-01/Lecture-01

Sources can be either independent or dependent upon some other quantities.

i) Independent Sources [RGPV Dec 2014]

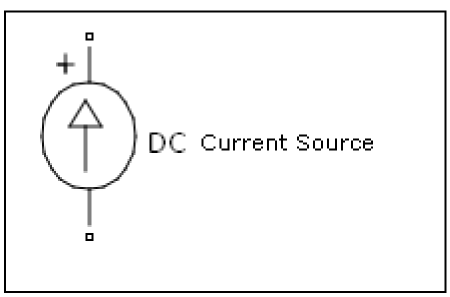
a) Voltage Source- [RGPV June 2013]

Voltage source is defined as the energy source which gives constant voltage across its terminals irrespective of the current drawn through its terminals. The symbols for ideal voltage source is shown in fig. this is connected to load, at any terminals the value of voltage at load terminals remains same.



b) Current Source-

It is the source which gives constant current at its terminals irrespective of the voltage appearing across its terminals. the symbol for current source is shown in fig (a).this is connected to the load as shown in fig. at any time its value is same irrespective of voltage across its terminals.



ii) Dependant Source

Dependant source are those source whose value of source depends on voltage or current in the circuit. such sources are indicated by diamond and further classified as :-
(i)Voltage dependant voltage source
(ii) voltage dependant current source
(iii) Current dependant current source
(iv) Current dependant voltage source

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Ohm's law

Ohm's law states that at constant temperature, the current through a conductor between two points is directly proportional to the potential difference across the two points.

V= I R

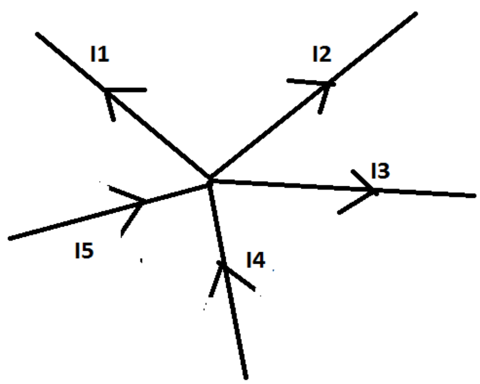
Where, I is the current through the conductor in units of amperes,

V is the potential difference measured across the conductor in units of volts, and

R is the resistance of the conductor in units of ohms (*R in this relation is constant, independent of the current*)

Kirchhoff's Current Law- [RGPV Feb. 2010]

Algebraic sum of currents at a node is zero conversely algebraic sums of currents flowing towards a node is equal to algebraic sum of currents flowing away from the node.



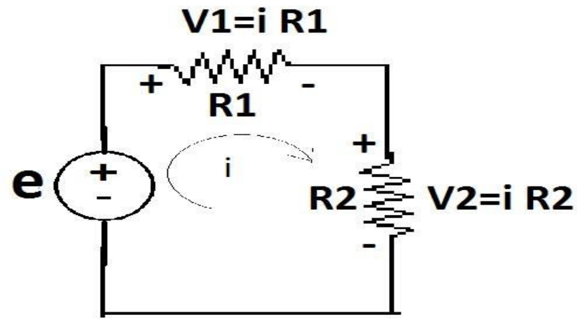
At A Node-

I1+I2+I3-I4-I5=0

I1+I2+I3= I4+I5

Kirchhoff’s Voltage Law-

Algebraic sum of voltages in a close loop is zero conversely in a close loop algebraic sums of emfs are equal to algebraic sum of voltage drops.

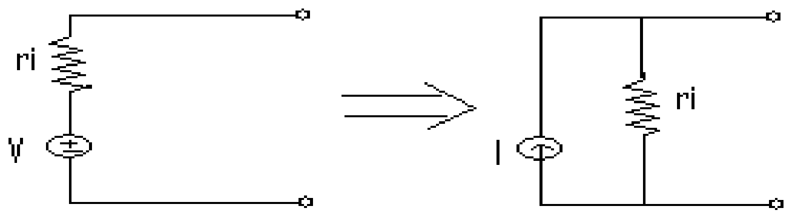


e-v1-v2=0
e=v1+v2

S.NO	RGPV QUESTIONS	Year	Marks
Q.1	Explain Voltage Source and Current Source	June 2013	4
Q.2	State and explain Kirchoff’s current and Voltage law	Feb 2010	4

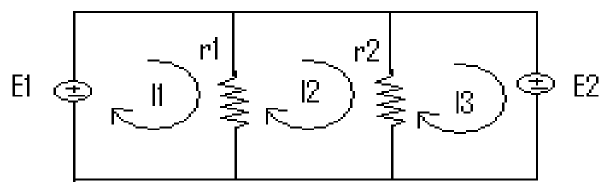
Source Conversion-

Every voltage source can be converted to an equivalent current source and vice versa by transferring the position of their internal resistances**.**



Mesh Analysis [RGPV Dec 2008]

It works on the basis of Kirchhoff's voltage law.



Considering mesh 1

$$\mathbf{E1 = I1r1 - I2r1}$$

Considering mesh 2

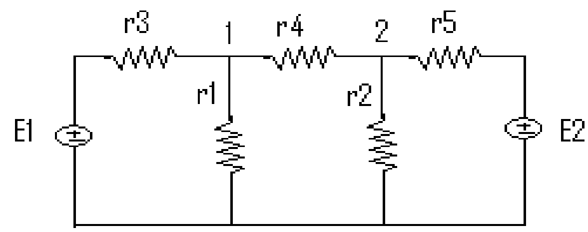
0 = I2(r2 + r3) – I1r1 – I3r2

Considering mesh3

-E2 = I3r2 – I2r2

Nodal Analysis

It works on the basis of KCL



At node1

$$\frac{V1 - E1}{r3} + \frac{V1 - V2}{r4} + \frac{V1}{r1} = 0$$

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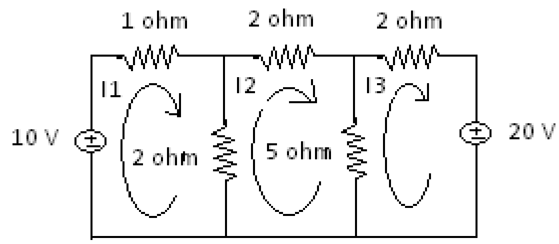
At node 2

$$\frac{V2 - V1}{r4} + \frac{V2}{r2} + \frac{V2 - E2}{r5} = 0$$

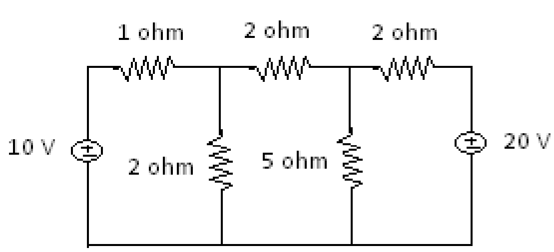
Q. Calculate the current through 5 ohm resistance using loop analysis-



Loop 1 $I1 \times 1 + 2(I1 - I2) = 10$
Loop 2 $I2 \times 2 + 5(I2 - I3) + 2(I2 - I1) = 0$
Loop 3 $I3 \times 2 + 5(I3 - I2) = -20$

$$\begin{bmatrix} 3 & -2 & 0 \\ -2 & 9 & -5 \\ 0 & -5 & 7 \end{bmatrix} \times \begin{bmatrix} I1 \\ I2 \\ I3 \end{bmatrix} = \begin{bmatrix} 10 \\ 0 \\ -20 \end{bmatrix}$$

I1=11.3A
I2=12A
I3=6.7A

S.NO	RGPV QUESTIONS	Year	Marks
Q.1	Calculate the current through 5 ohm resistance using loop analysis- 	Dec 2013	7
Q.2	State and explain Mesh analysis to solve a network	Dec 2008	10

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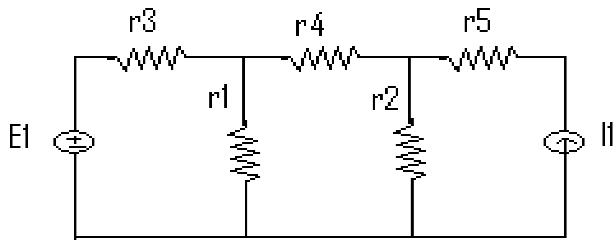
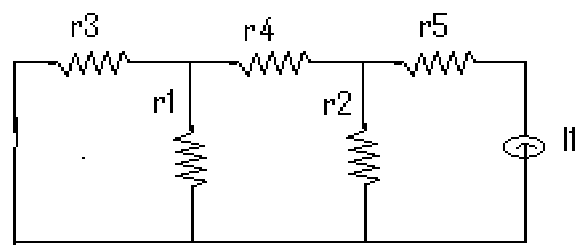
Superposition Theorem [RGPV June 2013][Dec 2010]

In a linear active bilateral network containing more than one source. The current through any branch is the algebraic sum of currents flowing thorough the branch when we consider one source at a time while replacing all other sources by their internal resistances.



Considering current source first Deactivating voltage source by its internal resistance, therefore making it short at the terminals.

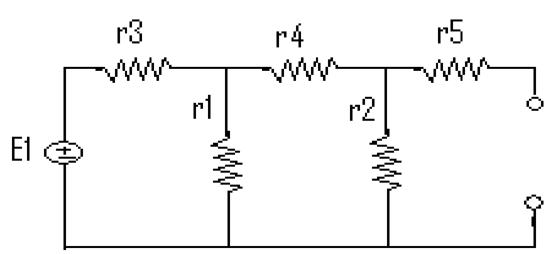


At node 1

$$\frac{V1}{r3} + \frac{V1}{r1} + \frac{V1 - V2}{r4} = 0$$

At node 2

$$\frac{V2 - V1}{r4} + \frac{V2}{r2} - I1 = 0$$



Now considering voltage source and deactivating current source by its internal resistance, therefore making it open at the terminals.

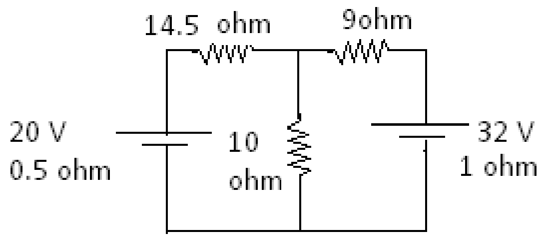
At node1

$$\frac{V1 - E1}{r3} + \frac{V1}{r1} + \frac{V1 - V2}{r4} = 0$$

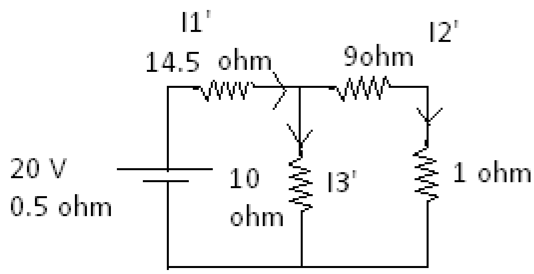
At node 2

$$\frac{V2 - V1}{r4} + \frac{V2}{r2} = 0$$

Q. Determine branch current using Superposition Theorem. [RGPV Feb 2010]

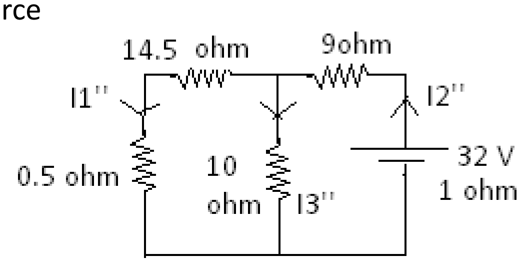


Step 1- Considering 12 V source



I1'=1.02A
I2'=0.93A
I3'=0.93A

Step 2- Considering 32 V source



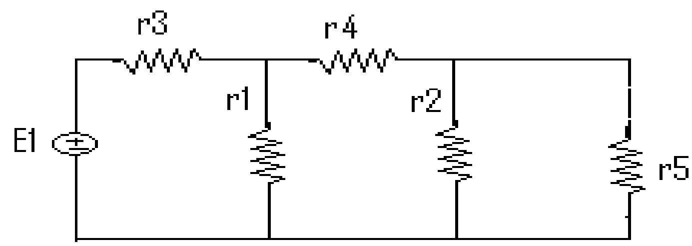
I1''=0.85A
I2''=2.13A
I3''=1.278A

I1=I1'-I1''=1.02-0.85=0.17A
I2=I2''-I2'=2.13-0.93=1.2A
I3=I3'+I3''=0.93+1.278=2.208A

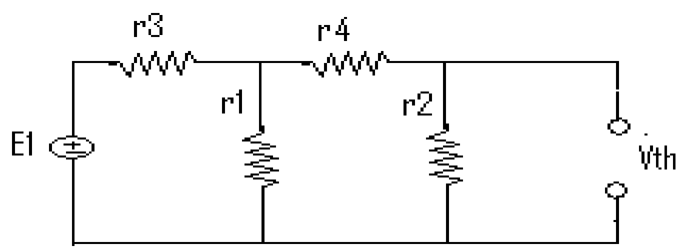
Thevenin’s theorem [RGPV Dec. 2010, June 2013]

Any linear active bilateral network can be replaced by a equivalent circuit known as thevenin’s equivalent circuit which is having a thevenin voltage source in series with thevenin resistance.

Let we have to find the current through the resistor r5.



Open circuit the terminals of r5, and find the thevenin voltage at the open terminals.



At node1

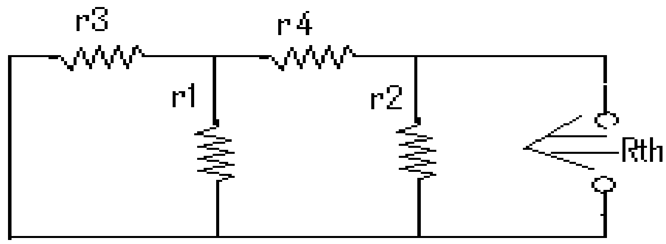
$$\frac{V1-E1}{r3}+\frac{V1}{r1}+\frac{V1-V2}{r4}=0$$

At node 2

$$\frac{V1}{r2}+\frac{V2-V1}{r4}=0$$

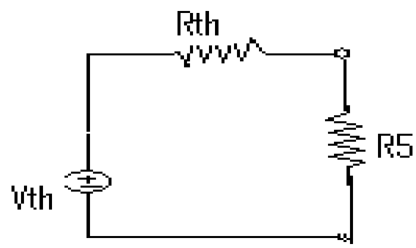
The voltage at node 2 is the thevenin voltage.

Now we have to find the thevenin resistance,for finding the thevenin resistance all the independent sources are deactivated by their internal resistances. In this case a voltage source is present therefore replacing it with short circuiting the terminals of E1.Now finding the equivalent resistance from the open side.



$$\{(r3 \parallel r1) + r4\} \parallel r2 = Rth$$

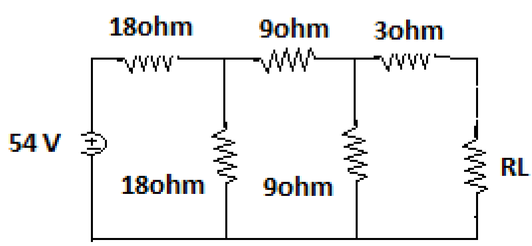
Now the thevenin equivalent circuit can be drawn by connecting Vth and Rth in series with the Load resistance i.e r5



Find the current in r5,by applying kvl in the loop.

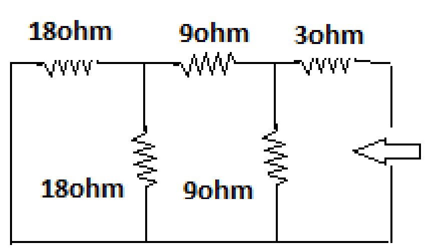
$$\frac{\boldsymbol{Vth}}{\boldsymbol{Rth + r5}} = \boldsymbol{I}$$

Q. For a network shown in figure , determine current through Rl when the value of load resistance is (i) 3ohm (ii) 9 ohm. [RGPV Feb. 2010]



Sol^{n} –

Using Thevenins theorem-



$$\boldsymbol{Rth} = \frac{\left(\frac{18\times18}{18+18} + 9\right) \times 9}{\left(\frac{18\times18}{18+18} + 9 + 9\right)} + 3$$

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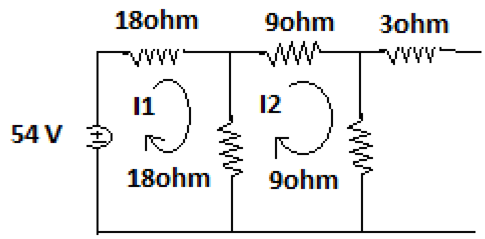
$$Rth = 9$$

Vth



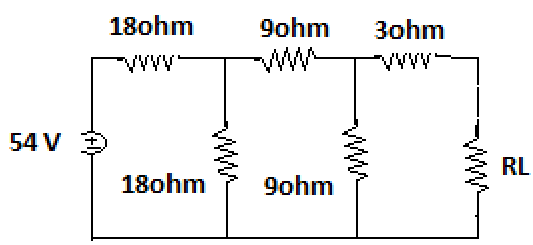
$$Loop\ 1 \quad 54 - 18I1 - 18(I1 - I2) = 0$$
$$Loop\ 2 \quad 9I2 + 9I2 + 18(I2 - I1) = 0$$
$$I2=0.65$$

Vth=I2×9=5.92 volts

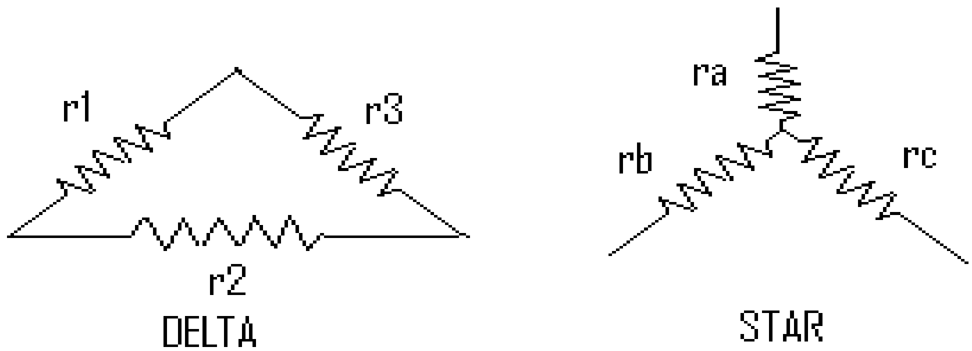
I=Vth/Rth+RL

I=5.92/15=0.39 A for 6ohm Rl

I=5.92/12=0.49 for 3 ohm Rl

S.NO	RGPV QUESTIONS	Year	Marks
Q.1	Q. For a network shown in figure , determine current through Rl when the value of load resistance is (i) 3ohm (ii) 9 ohm 	Feb. 2010	7
Q.6	Explain Thevenin's and Superposition with example for each	June 2013	07

Star Delta Transformation- [RGPV April 2009]



Star to delta

$$R_a = R_1R_3/(R_1+R_2+R_3)$$

$$R_b= R_1R_2/(R_1+R_2+R_3)$$

$$R_c = R_3R_2/(R_1+R_2+R_3)$$

Delta to star

$$R_1 = (R_aR_b + R_bR_c + R_cR_a)/R_c$$

$$R_2 = (R_aR_b + R_bR_c + R_cR_a)/R_a$$

$$R_3 = (R_aR_b + R_bR_c + R_cR_a)/R_b$$

S.NO	RGPV QUESTIONS	Year	Marks
Q.1	Deduce the relation for conversion from Star to Delta Circuit	April 2009	10

UNIT – 2

1-phase AC Circuits

Unit-02/Lecture-01

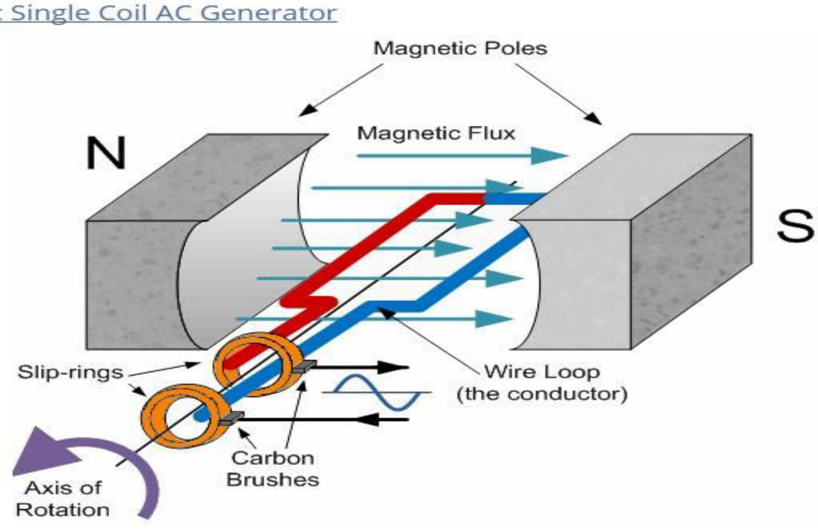
Generation of Sinusoidal Waveforms

By application of Electromagnetism, an electric current flowing through a conductor can be used to generate a magnetic field around itself, and also if a single wire conductor is moved or rotated within a stationary magnetic field, an “EMF”, (Electro-Motive Force) will be induced within the conductor due to this movement.

A relationship exists between Electricity and Magnetism giving us, the effect of “Electromagnetic Induction” and it is this basic principal that electrical machines and generators use to generate a Sinusoidal Waveform for our mains supply.

An AC generator uses the principal of Faraday's electromagnetic induction to convert a mechanical energy such as rotation, into electrical energy, a Sinusoidal Waveform. A simple generator consists of a pair of permanent magnets producing a fixed magnetic field between a north and a south pole. Inside this magnetic field is a single rectangular loop of wire that can be rotated around a fixed axis allowing it to cut the magnetic flux at various angles as shown below.

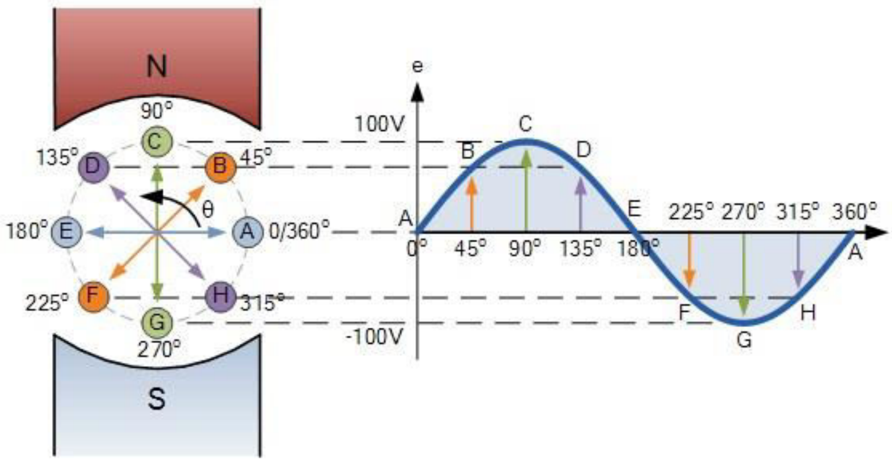
Basic Single Coil AC Generator



As the coil rotates anticlockwise around the central axis which is perpendicular to the magnetic field, the wire loop cuts the lines of magnetic force set up between the north and south poles at different angles as the loop rotates. The amount of induced EMF in the loop at any instant of time is proportional to the angle of rotation of the wire loop.

As this wire loop rotates, electrons in the wire flow in one direction around the loop. Now when the wire loop has rotated past the 180° point and moves across the magnetic lines of force in the opposite direction, the electrons in the wire loop change and flow in the opposite direction. Then the direction of the electron movement determines the polarity of the induced voltage.

So we can see that when the loop or coil physically rotates one complete revolution, or 360°, one full sinusoidal waveform is produced with one cycle of the waveform being produced for each revolution of the coil. As the coil rotates within the magnetic field, the electrical connections are made to the coil by means of carbon brushes and slip-rings which are used to transfer the electrical current induced in the coil.



The amount of EMF induced into a coil cutting the magnetic lines of force is determined by the following three factors.

· Speed – the speed at which the coil rotates inside the magnetic field.

· Strength – the strength of the magnetic field.

· Length – the length of the coil or conductor passing through the magnetic field.

Unit-02/Lecture-02

AC CIRCUITS: [RGPV Dec. 2013]

Definitions

1) AC – The quantity which changes its magnitude and direction w.r.t. time is called an alternating quantity (voltage or current).

2) Waveform- The shape of the curve obtained by plotting alternating quantity (voltage or current) along X-axis is known as waveform.

3) Frequency- No. of cycles per second.

4) Time period- It is the time taken by any alternating quantity (voltage or current) to complete 1cycle.

5) Instantaneous Value- It is the value of an alternating quantity (voltage or current)at a particular instant of time.

6) Amplitude – It is the maximum value of waveform over a cycle. It is also known as crest value. It is also called as peak value.

7) Average value- It is the arithmetic average of ac quantity over a complete cycle.

$I_{avg} = I_m / (\pi/2)$

8) RMS value- RMS value is the root mean square value of an alternating quantity.RMS value of an alternating quantity is given by that value of DC which will produce same amount of heat in same duration of time in the same resistor as produced by AC.

$$I_{rms} = I_m / \sqrt{2}$$

9) Power Factor- It is the Cosine angle between Voltage and current or it can be calculated by ratio of resistance to impedance.

Relation between RMS value, Average value and Maximum value

Form Factor : It is the ratio between RMS value to average value.

F.F = RMS value / Average value

F.F = 1.11

Peak Factor : It is the ratio between maximum value to RMS value.

P.F = Maximum value / RMS value

P.F = 1.414

Unit-02/Lecture-03

Definitions- [RGPV Feb. 2010]

Active Power : it is the power which is actually consumed in the circuit in any form (heat, light etc.).it is also known as true power or real power and it is given by P = VICosϕ its unit is watt.
Where ϕ is the angle between voltage and current.

Reactive Power : It is the power which not actually consumed in the circuit but oscillates from source to load & load to source in a cycle.and it is given by Q = VISinϕ VAR(Volt Ampere Reactive)

Apparent Power : It is the combination of active and reactive power and it is given by vector sum of active and reactive power.it is given as S = VI its unit is VA(Volt Ampere)

Impedance

Electrical impedance is the measure of the opposition that a circuit presents to a current when a voltage is applied. The symbol for impedance is usually Z and it may be represented by writing its magnitude and phase in the form $|Z|\angle\theta$. In general, impedance will be a complex number, with the same units as resistance, for which the SI unit is the ohm (Ω).

Resistance is a measure of the opposition of a circuit to the flow of a steady current; while impedance takes into account not only the resistance but also dynamic effects (known as reactance). The reactance forms the imaginary part of complex impedance whereas resistance forms the real part.

$Z=R+jX$

Where,

Z is the impedance, measured in ohms.

R is the resistance, measured in ohms.

X is the reactance, measured in ohms.

.

Admittance

The reciprocal of impedance is admittance (i.e., admittance is the current-to-voltage ratio).

Admittance is a measure of how easily a circuit or device will allow a current to flow. The SI unit of admittance is the siemens (symbol S). Admittance is defined as

$Y = 1/ Z$

Where,

Y is the admittance, measured in Siemens

Z is the impedance, measured in ohms

The synonymous unit mho, and the symbol ℧.

Resistance is a measure of the opposition of a circuit to the flow of a steady current, while impedance takes into account not only the resistance but also dynamic effects (known as reactance). Likewise, admittance is not only a measure of the ease with which a steady current can flow, but also the dynamic effects of the material's susceptance to polarization:

$Y = G + j B$,

where

Y is the admittance, measured in siemens.

G is the conductance, measured in siemens.

B is the susceptance, measured in siemens.

Phasor Diagrams

sinusoidal waveforms of the same frequency can have a Phase Difference between themselves which represents the angular difference of the two sinusoidal waveforms. Also the terms "lead" and "lag" as well as "in-phase" and "out-of-phase" were used to indicate the relationship of one waveform to the other with the generalized sinusoidal expression given as:

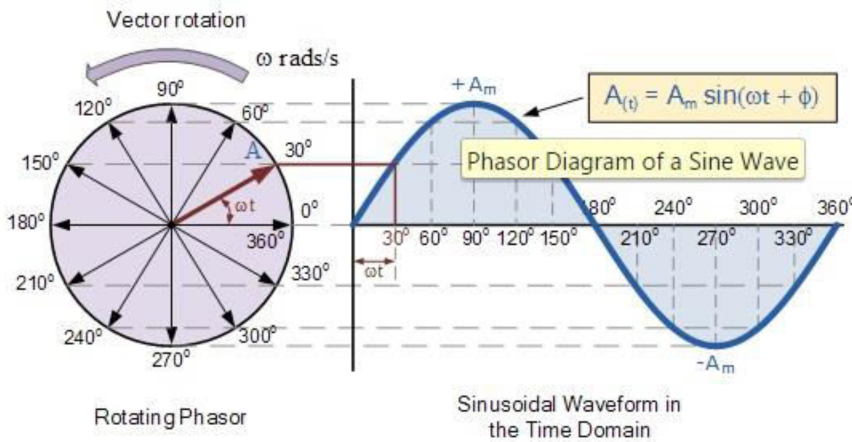
$A(t) = A_m \sin(\omega t \pm \Phi)$ representing the sinusoid in the time-domain form.

But when presented mathematically in this way it is sometimes difficult to visualise this angular or phasor difference between two or more sinusoidal waveforms. One way to overcome this problem is to represent the sinusoids graphically within the spacial or phasor-domain form by using Phasor Diagrams, and this is achieved by the rotating vector method.

Basically a rotating vector, simply called a "Phasor" is a scaled line whose length represents an AC quantity that has both magnitude ("peak amplitude") and direction ("phase") which is "frozen" at some point in time.

A phasor is a vector that has an arrow head at one end which signifies partly the maximum value of the vector quantity (V or I) and partly the end of the vector that rotates.

A complete sine wave can be constructed by a single vector rotating at an angular velocity of ω = 2πƒ, where ƒ is the frequency of the waveform. Then a Phasor is a quantity that has both “Magnitude” and “Direction”. Generally, when constructing a phasor diagram, angular velocity of a sine wave is always assumed to be: ω in rad/s. Consider the phasor diagram below.



Concept of Power Factor

power factor comes into picture in AC circuits only. Mathematically it is cosine of the phase difference between source voltage and current. It refers to the fraction of total power (apparent power) which is utilized to do the useful work called active power.

Need for Power Factor Improvement

· Real power is given by P = VIcos ϕ . To transfer a given amount of power at certain voltage, the electrical current is inversely proportional to cos ϕ . Hence higher the pf lower will be the current flowing. A small current flow requires less cross sectional area of conductor and thus it saves conductor and money.

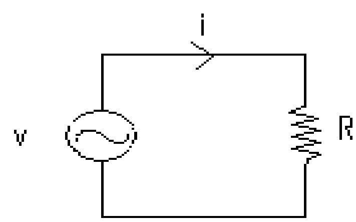
· From above relation we saw having poor power factor increases the current flowing in conductor and thus copper loss increases. Further large voltage drop occurs in alternator, electrical transformer and transmission & distribution lines which gives very poor voltage regulation.

· Further the KVA rating of machines is also reduced by having higher power factor as,Hence, the size and cost of machine also reduced. So, electrical power factor should be maintained close to unity.

Unit-02/Lecture-04

AC circuit containing pure resistance-

AC circuit containing pure resistance gives the relation between voltage and current in the ac circuit.

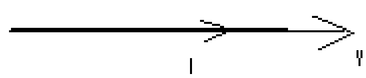


$v = V_m \text{Sin } wt$

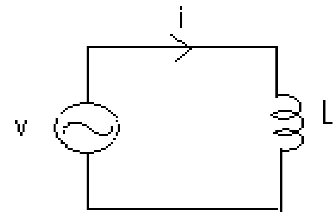
$i = I_m \text{ Sin } wt$

Instantaneous power $p = v*i$

$= V_{rms} I_{rms}$



AC circuit contacting pure inductance-



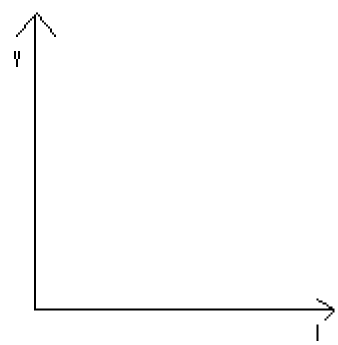
AC circuit containing pure inductance gives the relation between voltage and current in the ac circuit.

$v = V_m \text{Sin } wt$

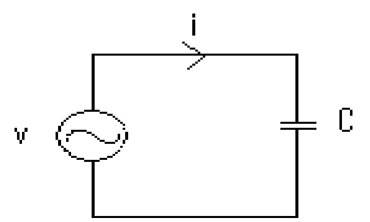
$i = I_m \text{ Sin } (wt - \pi/2)$

Instantaneous power p = v*i

= 0



AC circuit contacting pure Capacitance-



AC circuit containing pure capacitance gives the relation between voltage and current in the ac circuit.

$v = V_m \text{Sin } wt$

$i = I_m \text{ Sin } (wt + \pi/2)$

Instantaneous power p = v*i

= 0

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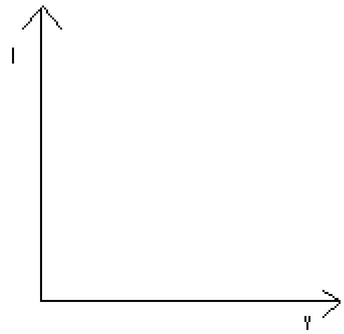
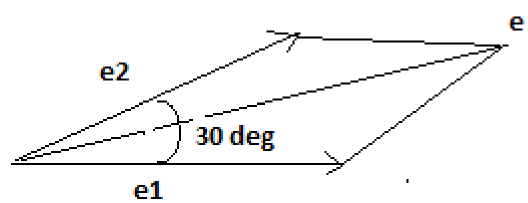


Q. Obtain resultant voltage when two sources of emf having e1=100sinwt and e2 =100sin(wt-pi/6) are connected in series. If the resultant voltage is applied to circuit of impedance (8+3j), calculate the power supplied to the impedance.

Sol^n- Phasor of two voltages



$$e1\ rms = \frac{100}{\sqrt{2}} = 70.72$$

$$e2\ rms = \frac{100}{\sqrt{2}} = 70.72$$

According to law of parallogarm-

$$e = \sqrt{e1^2 + e2^2 + 2e1e2cos\theta}$$

$$e = \sqrt{70.72^2 + 70.72^2 + 270.72 \times 70.72cos30}$$

$$e = 136\ volts$$

Current

$$i = \frac{136}{\sqrt{73}angle - 20}$$

$$i = 16\ angle\ 20deg$$

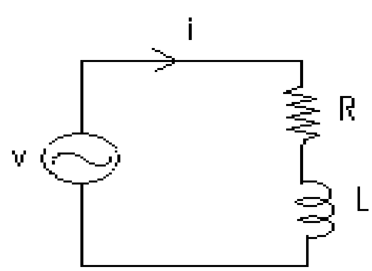
Active power

$$p = vicos\emptyset = 136 \times 16 \times \cos(-20) = 2kw$$

S.NO	RGPV QUESTIONS	Year	Marks
Q.1	obtain resultant voltage when two sources of emf having e1=100sinwt and e2 =100sin(wt-pi/6) are connected in series. If the resultant voltage is applied to circuit of impedance (8+3j), calculate the power supplied to the impedance.	June 2013	7
Q.8	Define the following the following Average value, RMS value , Power Factor, Active Power, Reactive power, Apparent Power	Dec 2013	07

Unit-02/Lecture-05-06

AC circuit contacting resistance and inductance in series



AC circuit containing resistance and inductance gives the relation between voltage and current in the ac circuit.

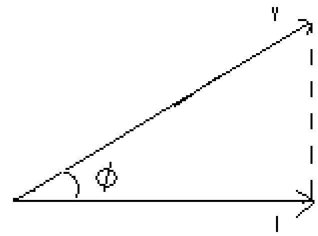
v =V_mSin wt

i =I_m Sin (wt-ϕ)

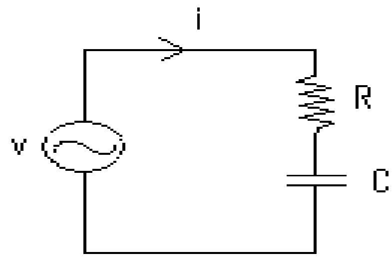
Z = $\sqrt{(R^2 + X_L^2)}$

Instantaneous power p = v*i

= VICosϕ



AC circuit contacting resistance and capacitance in series



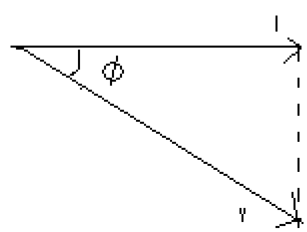
AC circuit containing resistance and capacitance gives the relation between voltage and current in the ac circuit.

$v = V_m \text{Sin } wt$

$i = I_m \text{ Sin } (wt+\phi)$

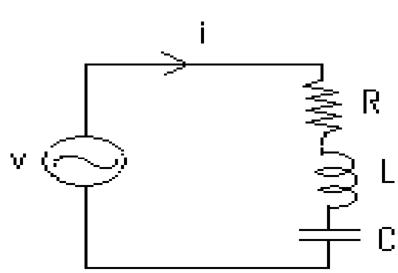
Instantaneous power $p = v*i$

$= VI\text{Cos}\phi$



AC circuit contacting resistance, inductance and capacitance in series

AC circuit containing resistance,inductance and capacitance gives the relation between voltage and current in the ac circuit.



V_r= RMS voltage across resistance

V_l=RMS voltage across inductance

V_c=RMS voltage across capacitance

X_L = inductive reactance

X_C = Capacitive reactance

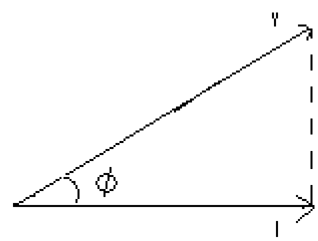
I = V/Z

Z = impedance of the circuit.

CASE 1:

Considering $X_L > X_C$

Z = Sqrt $\{R^2 + (X_L – X_C)^2\}$

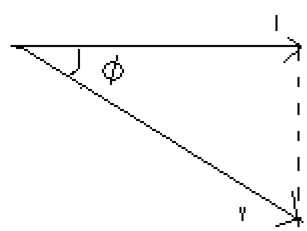


Circuit will behave as RL Ciurcuit.

Case 2

Considering $X_c > X_L$

Z = Sqrt $\{R^2 + (X_c – X_L)^2\}$

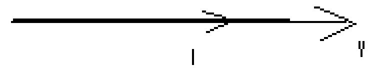


Circuit will behave as RC circuit

Case 3

Considering $X_L = X_C$

Z = R

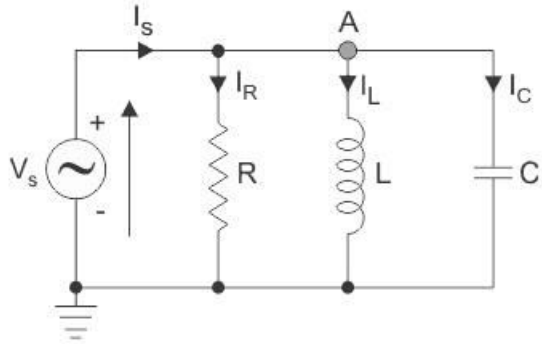


Circuit will behave as resistive circuit.current in the circuit will be maximum.

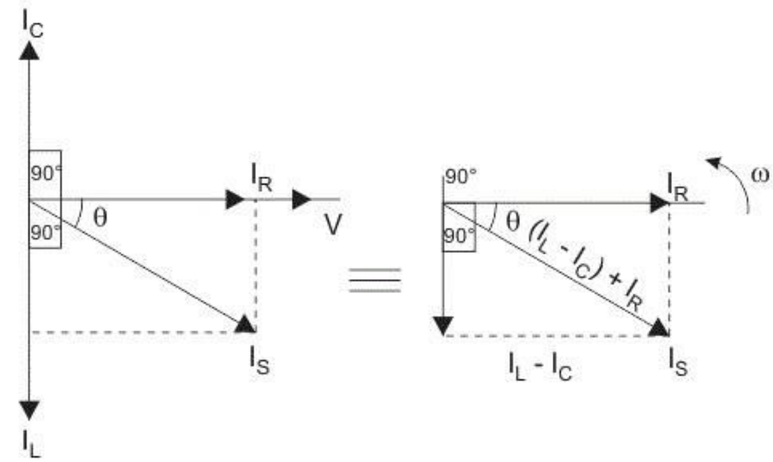
It is also known as resonance condition.

Parallel RLC Circuit

Consider a RLC circuit in which resistor, inductor and capacitor are connected in parallel to each other. This parallel combination is supplied by voltage supply, VS. This parallel RLC circuit is exactly opposite to series RLC circuit. In series RLC circuit, the current flowing through all the three components i.e the resistor, inductor and capacitor remains the same, but in parallel circuit, the voltage across each element remains the same and the current gets divided in each component depending upon the impedance of each component. That is why parallel RLC circuit is said to have dual relationship with series RLC circuit.



Phasor Diagram of Parallel RLC Circuit



$$I_S^2 = I_R^2 + (I_L - I_C)^2$$

$$Now,\ I_R = \frac{V}{R},\ I_C = \frac{V}{X_C},\ and\ I_L = \frac{V}{X_L}$$

$$I_S = \sqrt{\left(\frac{V}{R}\right)^2 + \left(\frac{V}{X_L} - \frac{V}{X_C}\right)^2}$$

$$Addmittance\ \frac{1}{Z} = Y = \frac{I_S}{V}\sqrt{\left(\frac{1}{R}\right)^2 + \left(\frac{1}{X_L} - \frac{1}{X_C}\right)^2}$$

<u>Resonance in Parallel RLC Circuit</u>

Like series RLC circuit, parallel RLC circuit also resonates at particular frequency called resonance frequency i.e. there occurs a frequency at which inductive reactance becomes equal to capacitive

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reactance but unlike series RLC circuit, in parallel RLC circuit the impedance becomes maximum and the circuit behaves like purely resistive circuit leading to unity electrical power factor of the circuit.

UNIT – 3
3-phase AC Circuit
Unit-03/Lecture-01

Advantages of a three phase system

The three phase power system has been adopted universally for transmission of AC power.
The advantages of a three phase system over a single phase system are:-

- Higher power/weight ratio of alternators. A three phase alternator is smaller and lighter that a single phase alternator of the same power output. Hence, it is also cheaper.
- A three phase transmission system requires less copper or aluminium to transmit the same quantity of power of a specific distance than a single phase system.
- Three phase motors are self-starting due to the rotating magnetic field induced by the three phases. On the other hand, a single phase motor is not self starting, it requires a capacitor and an auxilliary winding.
- In Single phase systems, the instanteous power(power delivered at any instant) is not constant and is sinusoidal. This results in vibrations in single phase motors.
- In a three phase power system, though, the instanteous power is always the same.
- Three phase motors have better power factor compared to single phase motors.
- Three phase supply can be rectified into dc supply with a lesser ripple factor

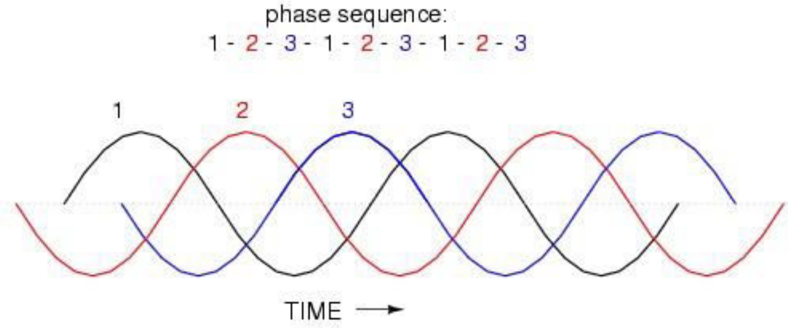
Polyphase circuits

Polyphase systems have three or more energized electrical conductors carrying alternating currents with a definite time offset between the voltage waves in each conductor.

In a polyphase system the phase displacement between the phases is given by ;
Phase difference = $360^{o}/n$
Where n is the no. of phases.
For a three phase system
p.d = 360/3
= 120^{o}

Phase Sequence

Phase rotation, or phase sequence, is the order in which the voltage waveforms of a polyphase AC source reach their respective peaks. For a three-phase system, there are only two possible phase sequences: 1-2-3 and 3-2-1, corresponding to the two possible directions of alternator rotation.



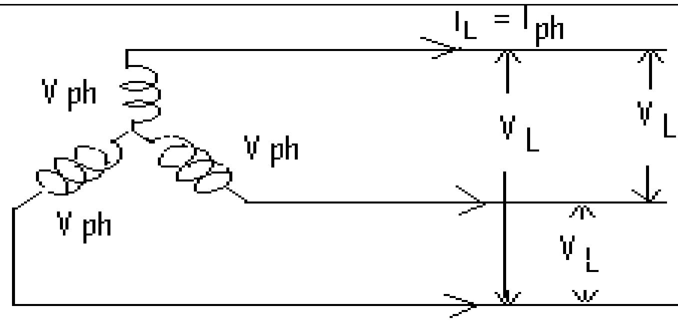
Unit-03/Lecture-02,03&04

3-phase STAR connection

In star connection, there is four wire, three wires are phase wire and fourth is neutral which is taken from the star point. Star connection is preferred for long distance power transmission because it is having the neutral point. In this we need to come to the concept of balanced and unbalanced current in power system.

When equal current will flow through all the three phases, then it is called as **balanced current**. And when the current will not be equal in any of the phase, then it is **unbalanced current**. In this case, during balanced condition there will be no current flowing through the neutral line and hence there is no use of the neutral terminal. But when there will be unbalanced current flowing in the three phase circuit, neutral is having a vital role. It will take the unbalanced current through to the ground and protect the transformer. Unbalanced current affects transformer and it may also cause damage to the transformer and for this star connection is preferred for long distance transmission.

Relation between line voltage and phase voltage, line current and phase current in Star Connection.



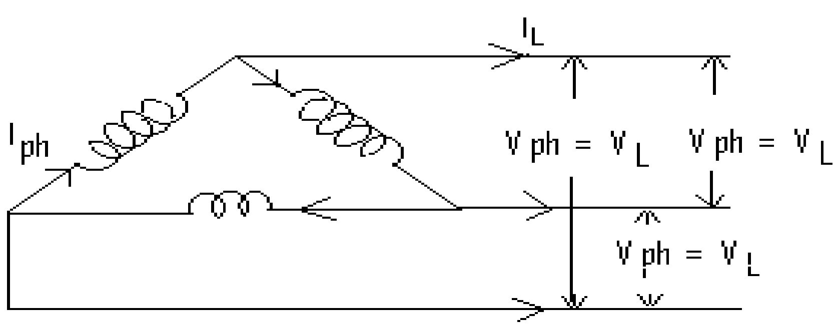
$V_L = \sqrt{3}\ V_{ph}$

$I_L = I_{ph}$

3-phase Delta connection

In delta connection, there is three wires alone and no neutral terminal is taken. Normally delta connection is preferred for short distance due to the problem of unbalanced current in the circuit. The figure is shown below for delta connection.

Relation between line voltage and phase voltage, line current and phase current in Delta Connection



$V_L = V_{ph}$

$I_L = \sqrt{3} I_{ph}$

Power in 3-phase system

The net power in the circuit will be same in both star and delta connection. The power in three phase circuit can be calculated from the equation below,

$P = 3 \times V\text{ph} \quad Iph \;\; cos\emptyset$

Since there is three phases, so the multiple of 3 is made in the normal power equation and the PF is power factor.

Q. Three coils each having resistance of 10 ohm and inductance of 0.02 H are connected in star across 415v, 50Hz, three phase supply. Calculate the line current and total power consumed.

Sol^n-

R=10ohm

$$Xl = 2 \times pi \times f \times L = 2 \times pi \times 50 \times 0.02 = 6.28ohm$$

$$Vph = \frac{Vl}{\sqrt{3}} = \frac{415}{\sqrt{3}} = 239.88\, volts$$

$$Iph = Il = \frac{239.88}{11} = 21A$$

$$Z = \sqrt{10^2 + 6.28^2} = 11ohm$$

Three phase power

$$p = 3 \times VphIphcos\emptyset = 3 \times 239.88 \times 21 \times \frac{10}{11} = 13.73kw$$

S.NO	RGPV QUESTIONS	Year	Marks
Q.1	Q. Three coils each having resistance of 10 ohm and inductance of 0.02 H are connected in star across 415v, 50Hz, three phase supply. Calculate the line current and total power consumed.	Feb. 2010	4
Q.2	Derive the relation for conversion for star and delta connection.	Dec 2014	7

UNIT – 4
Magnetic Circuits
Unit-04/Lecture-01

Magnetic Circuit- [RGPV June 2008]

The path followed by magnetic flux in a magnetic core is known as magnet circuit.

Comparison Between Electric & Magnetic Circuit-

	Electric Circuit	**Magnetic Circuit**
1	Current- I	Flux –Ø
2	Resistance –R	Reluctance –S
3	EMF=I. R	MMF=S. Ø
4	Resistivity	Reluctivity
5	Conductance	Permeance
6	Conductivity	Permeability
7	Current Density	Flux Density
8	Current Actually flows in the circuit.	Flux is imaginary
9	Perfect Dielectric is possible	There is no perfect dielectric

S.NO	RGPV QUESTIONS	Year	Marks
Q.1	Compare Magnetic and Electric Circuit	June 2008	10

Unit-04/Lecture-02-04

Basic Definitions- [June 2013]

1. Flux (Ø)– It is defined as magnetic lines of forces which are set up in a magnetic material.

Ø=MMF / S (Weber)

2. Reluctance(S)- It is defined as the property of magnetic material by which it opposes the flow of magnetic flux in a magnetic circuit. Unit-

$$S = \frac{l}{\mu_0 \mu_r A}$$

3. Magneto motive Force (MMF) – It drives the magnetic flux to set up in a magnetic circuit. MMF can be produced when current flown in a coil of one or more number of turns.

MMF= N. I = Ø. S

4. Permeability (μ) – Permeability is the property of magnetic material.The permeability (m) of a material is a measure of the ease with which magnetic flux lines can be established in the material. It is similar in many respects to conductivity in electric circuits.It is inversely proportional to reluctance.

μ= μo μr

5. Magnetic flux density (B)- It is defined as magnetic flux per unit area of cross section of core.

B= Ø/A (Weber/Meter)

6. Magnetic field intensity (H)- It is defined as the magnetomotive force per unit lengthor strength of a magnetic field. It is also known as magnetic field strength or magnetizing force (H).

H=N.I /L (AT/Meter)

Leakage Flux & Fringing- [RGPV Dec 2014]

There is a tendency of magnetic flux to bulge outward in the air gap due to which area of cross section in the air gap increases and flux density decreases this phenomenon is known as fringing

The flux which is not mutually linked over the core is known as leakage flux. It is not responsible for useful flux.

Total flux = Useful flux + Leakage flux

Q. An iron ring of 40 cm mean diameter and circular cross sectional area of 1 cm sqr is excited by 100 turn coil carrying 1 Amp. A saw cut of 0.4pi mm is made radially in the ring. Assuming the relative permeability of the material of the ring as 10000 determine the flux through the air gap

Sol^n- [RGPV Feb. 2010]

D=40cm=0.4m

l_{total}=pi D =1.25m

l_{steel}=1.25-0.00125m
l_{air}=0.00125m

N=100
μr=10000
A=0.0001msqr
MMF=NI=100*1

$$S = Sair + Ssteel$$

$$S = \frac{l}{\mu o A} + \frac{l}{\mu o \mu r A}$$

$$S = \frac{o.oo125}{4 \times pi \times 10^{-7} \times 1 \times 10^{-4}} + \frac{1.25}{4 \times pi \times 10^{-7} \times 10^{4} \times 1 \times 10^{-4}}$$

$$S = 1094 \times 10^{-4} AT/wb$$

$$NI = \emptyset S$$
$$\emptyset = \frac{NI}{S} = 100 \times \frac{1}{1094} \times 10^{-4} = 0.914 \times 10^{3} wb$$

Q. A cast steel electromagnet has an air gap of length 3 mm and an iron path of length 40 cm. Find the number of ATs necessary to produce a flux density of 0.7wb/m sqr in the air gap. Neglect leakage and fringing. Assume flux density in gap to be equal to flux density in iron. Assume μr=1000. [RGPV June 2009]

Sol^n- MMF=NI=HL
$$l\ iron = 40 \times 10^{-3} m$$

$$l\ air = 3 \times 10^{-3} m$$
$$B = 0.7 wb/msqr$$
$$\mu r = 1000$$
$$AT = \mu o \mu r B L$$
$$AT = 4 \times pi \times 1000 \times 0.7 \times 403 \times 10^{-3}$$
$$AT = 3.5 \times 10^{-4} AT$$

S.NO	RGPV QUESTIONS	Year	Marks
Q.1	Explain following terms- Magnetic Flux Density, Permeability, Magnetic Reluctance , MMF, Flux	June 2008	10
Q.2	An iron ring of 40 cm mean diameter and circular cross sectional area of 1 cm^2 is excited by 100 turn coil carrying 1 Amp. A saw cut of 0.4pi mm is made radially in the ring. Assuming the relative permeability of the material of the ring as 10000 determine the flux through the air gap	Feb. 2010	7
Q.3	A cast steel electromagnet has an air gap of length 3 mm and an iron path of length 40 cm. Find the number of ATs necessary to produce a flux density of 0.7wb/m^2 in the air gap. Neglect leakage and fringing. Assume flux density in gap to be equal to flux density in iron. Assume	June 2009	10

	μr=1000		
Q.4	Define magnetic flux and fringing.	Dec 2014	2

Unit-04/Lecture-05

Magnetization characteristics of ferromagnetic material

The relationship between the flux density, B and the magnetic field strength, H can be defined by the fact that the relative permeability, μ_r is not a constant but a function of the magnetic field intensity thereby giving magnetic flux density as: $B = \mu H$.

Then the magnetic flux density in the material will be increased by a larger factor as a result of its relative permeability for the material compared to the magnetic flux density in vacuum, $\mu_o H$ and for an air-cored coil this relationship is given as:

$$B = \mu H$$

So for ferromagnetic materials the ratio of flux density to field strength (B/H) is not constant but varies with flux density.

By plotting values of flux density, (B) against the field strength, (H) we can produce a set of curves called **Magnetisation Curves**, **Magnetic Hysteresis Curves** or more commonly **B-H Curves** for each type of core material used as shown below.

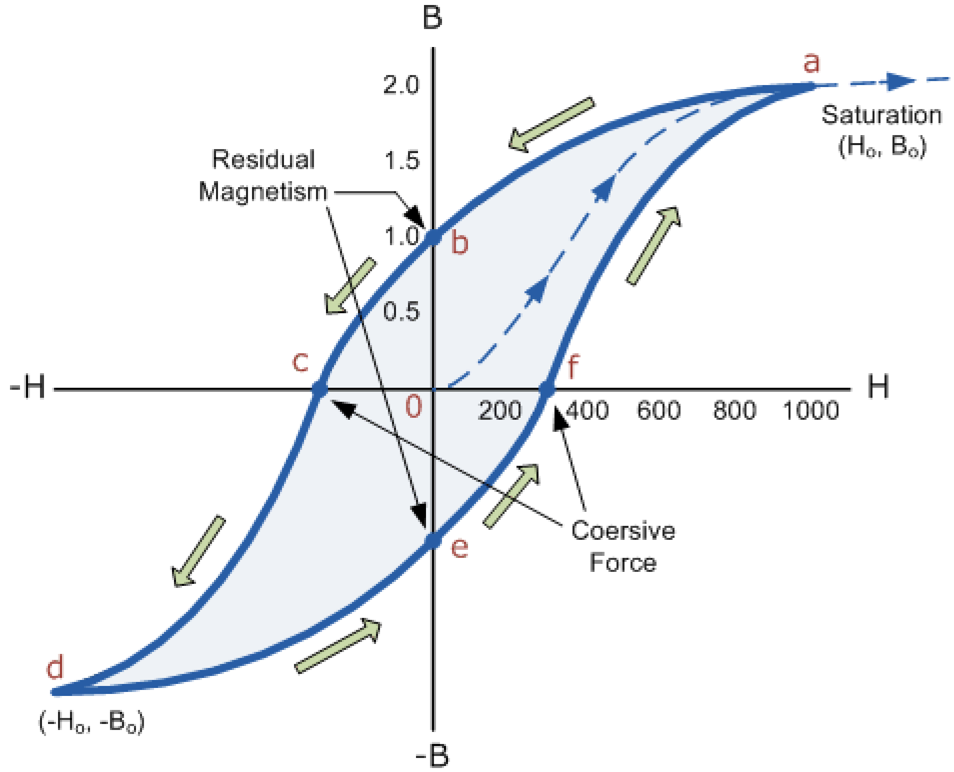
Retentivity

The magnetic flux does not completely disappear as the electromagnetic core material still retains some of its magnetism even when the current has stopped flowing in the coil. This ability for a coil to retain some of its magnetism within the core after the magnetisation process has stopped is called **Retentivity** or remanence, while the amount of flux density still remaining in the core is called **Residual Magnetism**, B_R .

”. Some ferromagnetic materials have a high retentivity (magnetically hard) making them excellent for producing permanent magnets.

While other ferromagnetic materials have low retentivity (magnetically soft) making them ideal for use in electromagnets, solenoids or relays. One way to reduce this residual flux density to zero is by reversing the direction of the current flowing through the coil, thereby making the value of H, the magnetic field strength negative. This effect is called a Coercive Force, H_C .

Magnetic Hysteresis Loop



The **Magnetic Hysteresis** loop above, shows the behaviour of a ferromagnetic core graphically as the relationship between B and H is non-linear. Starting with an unmagnetised core both B and H will be at zero, point 0 on the magnetisation curve.

If the magnetisation current, i is increased in a positive direction to some value the magnetic field strength H increases linearly with i and the flux density B will also increase as shown by the curve from point 0 to point a as it heads towards saturation.

Now if the magnetising current in the coil is reduced to zero, the magnetic field circulating around the core also reduces to zero. However, the coils magnetic flux will not reach zero due to the residual magnetism present within the core and this is shown on the curve from point a to point b.

To reduce the flux density at point b to zero we need to reverse the current flowing through the coil. The magnetising force which must be applied to null the residual flux density is called a "Coercive Force". This coercive force reverses the magnetic field re-arranging the molecular magnets until the core becomes unmagnetised at point c.

An increase in this reverse current causes the core to be magnetised in the opposite direction and increasing this magnetisation current further will cause the core to reach its saturation point but in the opposite direction, point d on the curve.

This point is symmetrical to point b. If the magnetising current is reduced again to zero the residual magnetism present in the core will be equal to the previous value but in reverse at point e.

Again reversing the magnetising current flowing through the coil this time into a positive direction will cause the magnetic flux to reach zero, point f on the curve and as before increasing the magnetisation current further in a positive direction will cause the core to reach saturation at point a.

Then the B-H curve follows the path of a-b-c-d-e-f-a as the magnetising current flowing through the coil alternates between a positive and negative value such as the cycle of an AC voltage. This path is called a **Magnetic Hysteresis Loop**.

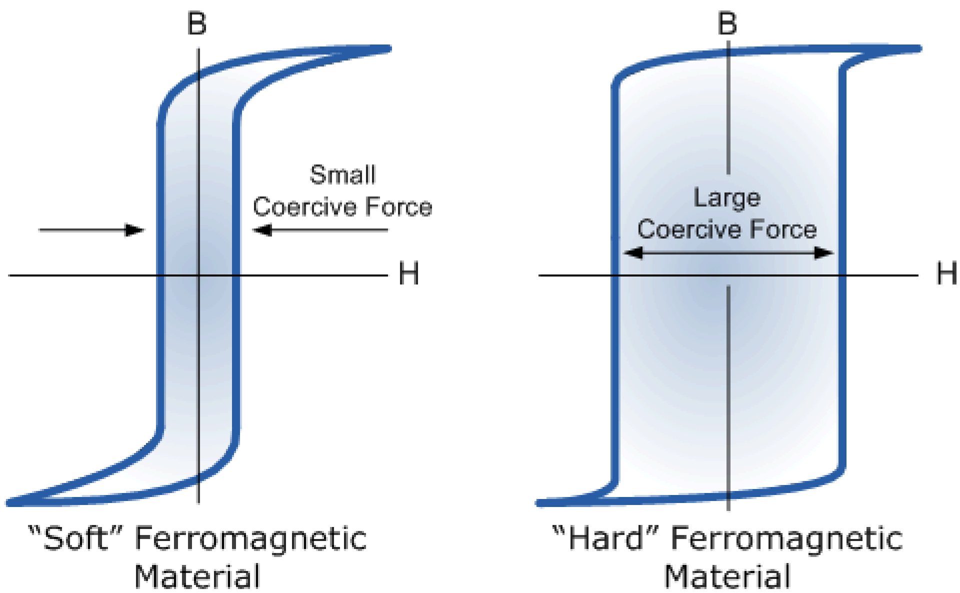
The effect of magnetic hysteresis shows that the magnetisation process of a ferromagnetic core and therefore the flux density depends on which part of the curve the ferromagnetic core is magnetised on as this depends upon the circuits past history giving the core a form of “memory”. Then ferromagnetic materials have memory because they remain magnetised after the external magnetic field has been removed.

However, soft ferromagnetic materials such as iron or silicon steel have very narrow magnetic hysteresis loops resulting in very small amounts of residual magnetism making them ideal for use in relays, solenoids and transformers as they can be easily magnetised and demagnetised.

Since a coercive force must be applied to overcome this residual magnetism, work must be done in closing the hysteresis loop with the energy being used being dissipated as heat in the magnetic material. This heat is known as hysteresis loss, the amount of loss depends on the material’s value of coercive force.

By adding additive’s to the iron metal such as silicon, materials with a very small coercive force can be made that have a very narrow hysteresis loop. Materials with narrow hysteresis loops are easily magnetised and demagnetised and known as soft magnetic materials.

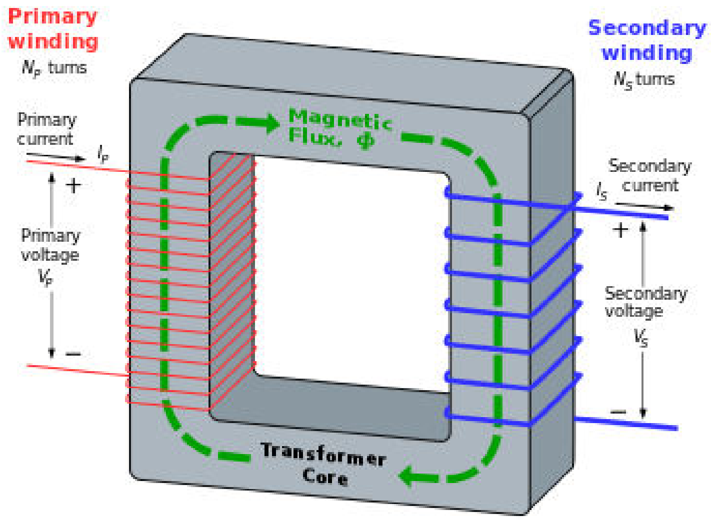
Magnetic Hysteresis Loops for Soft and Hard Materials



Self Inductance
The property of an electrical conductor by which a change in current flowing through it, induces an electromotive force in that conductor itself.

Mutual Inductance
The property of an electrical conductor by which a change in current flowing through it, induces an electromotive force in any nearby conductors.

Single Phase Transformer-



Working Principle-

A transformer can be defined as a static device which helps in the transformation of electric power in one circuit to electric power of the same frequency in another circuit. The voltage can be raised or lowered in a circuit, but with a proportional increase or decrease in the current ratings.

The main principle of operation of a transformer is mutual inductance between two circuits which is linked by a common magnetic flux. A basic transformer consists of two coils that are electrically separate and inductive, but are magnetically linked through a path of reluctance. The working principle of the transformer can be understood from the figure.

As shown above the transformer has primary and secondary windings. The core laminations are joined in the form of strips in between the strips you can see that there are some narrow gaps right through the cross-section of the core. These staggered joints are said to be 'imbricated'. Both the coils have high mutual inductance. A mutual electro-motive force is induced in the transformer from the alternating flux that is set up in the laminated core, due to the coil that is connected to a source of alternating voltage. Most of the alternating flux developed by this coil is linked with the other coil and thus produces the mutual induced electro-motive force. The so produced electro-motive force can be explained with the help of Faraday's laws of Electromagnetic Induction as

$$e=M*dI/dt$$

If the second coil circuit is closed, a current flows in it and thus electrical energy is transferred magnetically from the first to the second coil.

The alternating current supply is given to the first coil and hence it can be called as the primary winding. The energy is drawn out from the second coil and thus can be called as the secondary winding.

In short, a transformer carries the operations shown below:

1. Transfer of electric power from one circuit to another.
2. Transfer of electric power without any change in frequency.
3. Transfer with the principle of electromagnetic induction.
4. The two electrical circuits are linked by mutual induction.

Unit-04/Lecture-07

Construction of Transformer - [RGPV June 2009]

A transformer consists following parts –

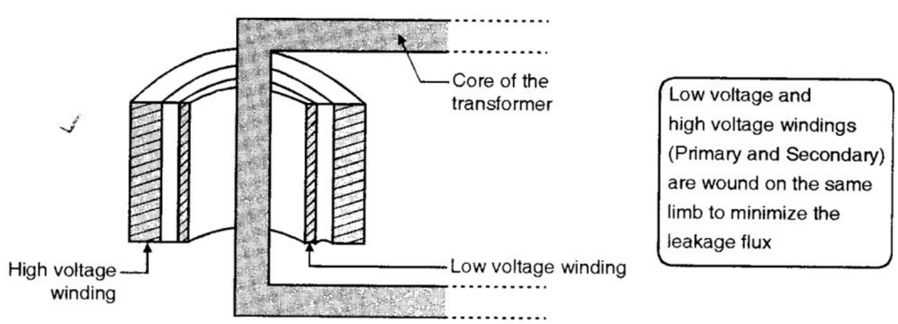
The most important parts of a transformer are the windings (coils) and the core. However for the large capacity transformers, some other parts such as suitable tank, conservator, bushings, breather, explosion vent etc. are also used along with the core and windings.

Laminated steel core

The material used for the construction of the transformer core is silicon steel. It is used for its high permeability and low magnetic reluctance. Due to this the magnetic field produced in the core is very strong. The core is in the form of stacks of laminated thin steels sheet which are electrically isolated from each other. The laminations are typically 0.35 mm thick.

Windings of the transformer

In Figure we have shown the primary and secondary windings to be on two different limbs of the core. But such an arrangement is made practically, then a part of the flux produced in the core will not be linked to the secondary windings at all. This is called as the leakage flux. In order to avoid this, the primary and secondary windings are mounted on the same limb of the core as shown in Fig.



Transformer tank

The whole assembly of large size transformer is placed in a sheet metal tank. Inside the tank the assembly of the transformer is immersed in oil which acts as an insulator as well as a coolant.

The oil will take out the heart produced by the transformer windings and core and transformer it to the surface of the transformer tank.

Conservator

In large transformers, some empty space is always provided above the oil level. This space is essential for letting the oil to expand or contract due to the temperature changes.

When the oil temperature increase, it expands and the air will be expelled out from the conservator. Whereas when the oil cools, it contracts and the outside air gets sucked inside the conservator. This process is called as the breathing of the transformer.

However, the outside air which has being drawn in can have the moisture content. When such an air comes in contact with the oil, the oil will absorb the moisture content and loses its insulating properties, to some extent. This can be prevented by using a conservator.

The conservator is a cylindrical shaped air tight metal drum placed on the transformer tank. The conservator is connected to the tank by a pipe.

The oil level in the conservator is such that, always some empty space is available above the oil. Due to the use of conservator, the main tank will be always full with oil and the surface of oil in the tank will not be exposed directly to the air.

Breather

The apparatus through which breathing of the transformer take place is called as "Breather".

The air goes in or out through the breather. To reduce the moisture content of this air, some drying agent (material that absorbs moisture) such as silica gel or calcium chloride is used in the breather. The dust particles present in the air are also removed by the breather.

Buccholz relay

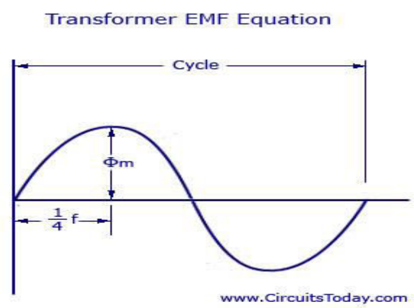
There is a pipe connecting the tank and conservator. On this pipe a protective device called Buccholz is mounted.

When the transformer is about to be faulty and draw large currents, the oil becomes very hot and decomposes. During this process different types of gases are liberated. The Buccholz relay get operated by these gases and given an alarm to the operator. If the fault continues to persist, they the relay will trip off the main circuit breaker to protect the transformer.

S.NO	RGPV QUESTIONS	Year	Marks
Q.4	Explain the construction and function of each parts of transformer	June 2009	10

Unit-04/Lecture-08

EMF Equation of Transformer-[RGPV June 2008] [RGPV Feb 2010]



Transformer EMF Equation
Let,
N_P= Number of turns in primary coil
N_S= Number of turns in secondary coil
$\varnothing_{max}$ = Maximum flux in the core in weber = B_{max}. A
f = Frequency of alternating current input in hertz (H_Z)

As shown in figure above, the core flux increases from its zero value to maximum value $\varnothing_{max}$ in one quarter of the cycle , that is in ¼ frequency second.

Therefore, average rate of change of flux =$\frac{\varnothing max}{1/4f}$ = 4f $\varnothing_{max}$Wb/s
Now, rate of change of flux per turn means induced electro motive force in volts.

Therefore, average electro-motive force induced/turn = 4f $\varnothing_{max}$volt

If flux Ø varies sinusoidally, then r.m.s value of induced e.m.f is obtained by multiplying the average value with form factor.

$$\text{Form Factor} = \frac{\text{r.m.s.value}}{\text{Average value}} = 1.11$$

Therefore, r.m.s value of e.m.f/turn = 1.11 X 4f $\varnothing_{max}$= 4.44f $\varnothing_{max}$
Now, r.m.s value of induced e.m.f in the whole of primary winding
= (induced e.m.f./turn) X Number of primary turns
Therefore,

$$E_A = 4.44f\, N_p\varnothing_{max} = 4.44fN_pB_mA$$

Similarly, r.m.s value of induced e.m.f in secondary is

$$E_B = 4.44f\, N_s\varnothing_{max} = 4.44fN_sB_mA$$

In an ideal transformer on no load,

$V_P = E_P$ and $V_S = E_S$, where $V_S$is the terminal voltage

Voltage Transformation Ratio (K)

From the above equations we get

$$\frac{E_s}{E_p} = \frac{V_s}{V_p} = \frac{N_s}{N_p} = k$$

This constant K is known as voltage transformation ratio.

(1) If $N_S>N_P$, that is K>1 , then transformer is called step-up transformer.

(2) If $N_S< N_P$, that is K<1 , then transformer is known as step-down transformer.

Again for an ideal transformer,

Input V_A = output V_A

$$V_p I_p = V_s I_s$$

$$\frac{I_s}{I_p} = \frac{V_P}{V_S} = k$$

Hence, currents are in the inverse ratio of the (voltage) transformation ratio.

Types of Transformer-

1. Based on construction-

a. Core Type transformer
b. Shell Type transformer

2. Based on phases-

a. Single phase transformer
b. three phasetransformer

3. Based on operation-

a. Step Up transformer
b. Step Downtransformer

4. Based on location-

a. Power transformer
b. Distribution transformer

Q.1 A single phase transformer is connected across 200V 50 Hz supply. Number of turns in primary is 500 while in secondary is 1000. Net cross sectional area of core is 80 cm sqr .Calculate [RGPV Dec. 2013]

I) Transformation ratio

II) Maximum flux density in core

III) EMF induced in secondary winding

Sol^n-

V=200, f=50 HZ, N_1=500, N_2=1000, A=0.008 m^2

I) $K=N_2/N_1=1000/500=2$

II) $E_1=4.44f\phi N_1$

		$200=4.44\times50\times B\times0.008\times500$
		$B=0.22$ wb/msqr
	III)	$E_2=4.44\ f\ \phi N_2$
		$E_2/E_1=N_2/N_1$
		$E_2=400V$

S.NO	RGPV QUESTIONS	Year	Marks
Q.1	Derive EMF Equation of Transformer	June 2008 Feb 2010	10
Q.2	A single phase transformer is connected across 200V 50 Hz supply. Number of turns in primary is 500 while in secondary is 1000 . Net cross sectional area of core is 80 cm sqr .Calculate I) Transformation ratio II) Maximum flux density in core III) EMF induced in secondary winding	Dec. 2013	7

Unit-04/Lecture-09

Transformer Losses- Following losses occurs in a transformer**[June 2013]**

1. Iron Loss-

Hysteresis loss and eddy current loss both depend upon magnetic properties of the materials used to construct the core of transformerand its design. So these **losses in transformer** are fixed and do not depend upon the load current. So **core losses in transformer** which is alternatively known as **iron loss in transformer** can be considered as constant for all range of load.

a. Eddy Current Loss-[RGPV Dec 2014]

b. Hysteresis Loss

Hysteresis loss in transformer is denoted as,

$$W_h = K_h f (B_m)^{1\cdot 6} \; watts$$

Eddy current loss in transformer is denoted as,

$$W_e = K_e f^2 K_f^2 B_m^2 \; watts$$

Where, K_h = Hysteresis constant.
K_e = Eddy current constant.
K_f = form constant.

2. Copper Loss

Copper loss is I^2R loss, in primary side it is $I_1^2R_1$ and in secondary side it is $I_2^2R_2$ loss, where I_1& I_2 are primary & secondary current of transformer and R_1& R_2 are resistances of primary & secondary winding. As the both primary & secondary currents depend upon load of transformer, copper loss in transformervary with load.

<u>**Efficiency of Transformer- [RGPV Dec 2014]**</u>

$$\eta = \frac{xV2\ I2\ Cos\emptyset}{xV2\ I2\ Cos\emptyset + pi + x^2Pc} \times 100$$

Condition for maximum efficiency-

For maximum efficiency of transformer iron loss must be equal to copper loss.

$$Pi = x^2 P_c$$

All Day Efficiency-[June 2013]

η_{all} =Output in KWH/Input in KWH *100

Voltage Regulation- [RGPV Dec 2014]

The voltage regulation is the percentage of voltage difference between no load and full load voltages of a transformer with respect to its full load voltage.

$$Voltage\ regulation(\%) = \frac{E_2 - V_2}{V_2} \times 100\%$$

Q. A single phase transformer rated 570 w has an efficiency of 95% when working at full load and half load both at unity p.f. Calculate its efficiency at 75% of full load. [RGPV June 3013]

$$\eta = \frac{xV2\ I2\ Cos\emptyset}{xV2\ I2\ Cos\emptyset + pi + x^2Pc} \times 100$$

Efficiency at full load

$$\eta = \frac{570}{570 + pi + Pc} \times 100 = 95\%$$

$$pi + Pc = 28.5 \quad (1)$$

Efficiency at half load

$$\eta = \frac{570/2}{570/2 + pi + Pc/4} \times 100 = 95\%$$

$$pi + 0.25Pc = 14.25 \quad (1)$$

Solving eqn 1 and 2

$$pi = 9.5w$$

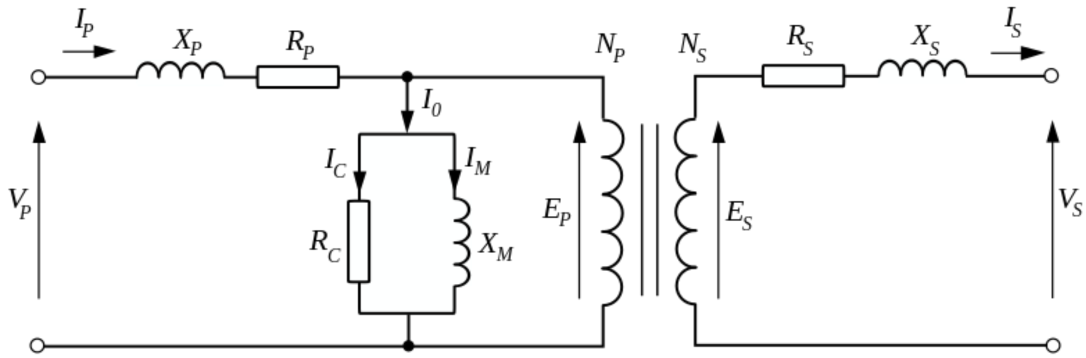
$$pc = 19w$$

Efficiency at 75% load

$$\eta = \frac{570 \times 0.75}{570 \times 0.74 + 19 + 0.75^2 \times 9.5} \times 100 = 94\%$$

S.NO	RGPV QUESTIONS	Year	Marks
Q.1	Define all Day efficiency of transformer	June 2013	4
Q.2	Define losses in transformer	June 2013	3
Q.3	A single phase transformer rated 570 w has an efficiency of 95% when working at full load and half load both at unity p.f. Calculate its efficiency at 75% of full load.	June 2013	7
Q.4	Give the reason of eddy current loss in transformer core.	Dec 2014	2
Q.5	Define voltage regulation and efficiency of a transformer. Give the formula also.	Dec 2014	3

Equivalent Circuit of Transformer-



V_p=Applied Voltage to Primary side

I_p=Primary Current

E_p= Primary Induced EMF

X_p=Primary winding leakage reactance

R_p=Primary resistance

R_c= Core loss resistance

X_m= Magnetising reactance

I_o= No load current

I_c= Core loss component of no load current

I_m = Magnetizing component of no load current

N_p= No. of turns of Primary winding

N_s= No. of turns of Secondary winding

E_s= Secondary Induced EMF

R_s= Secondary resistance

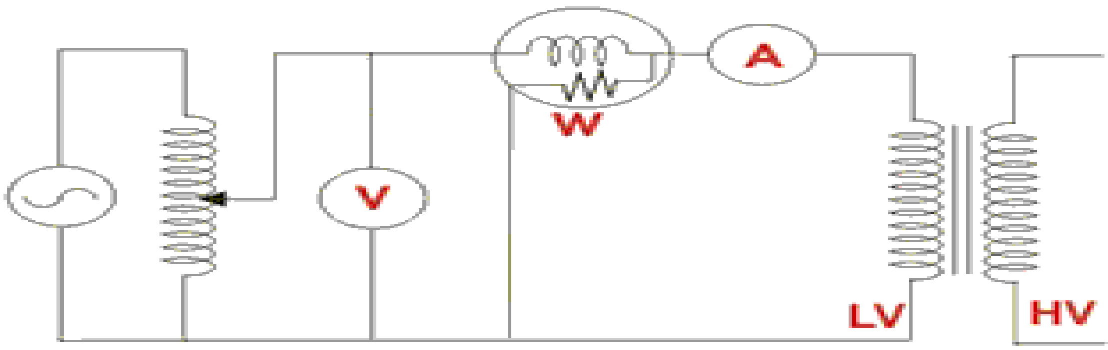
X_s= Secondary winding leakage reactance

V_s= secondary terminal voltage

I_s= secondary current

Testing of Transformer:

1. Open Circuit Test-



Open Circuit Test on Transformer

$$W_0 = V_0 I_0 \mathrm{Cos}\emptyset o$$

$$\mathrm{Cos}\emptyset o = \frac{W_0}{V_0 I_0}$$

$$I_C = I_o \mathrm{Cos}\emptyset_o$$

$$I_m = I_o \mathrm{Sin}\emptyset_o$$

$$R_0 = \frac{V_0}{I_W}$$

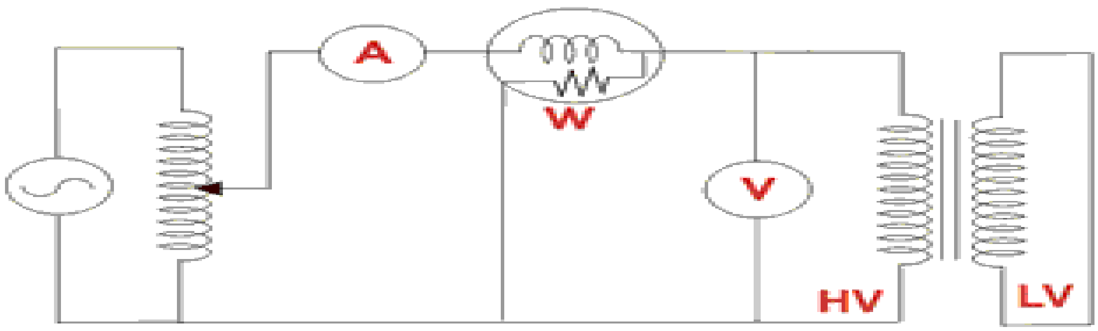
$$X_0 = \frac{V_0}{I_m}$$

$$Z_o = \sqrt{(R^2 + X^2)}$$

Unit-04/Lecture-11

Testing of Transformer:

2. Short Circuit Test-



Short Circuit Test on Transformer

$$Z_{sc} = \frac{V_{sc}}{I_{sc}}$$

$$R_{sc} = \frac{W_{sc}}{I_{sc}^2}$$

$$X_{sc} = \sqrt{(Z^2 - R^2)}$$

Q. The following readings were obtained for O.C. and O.C. tests on 8KVA, 400/120V, 50 Hz transformer. [RGPV Dec. 2010]

O.C. test (LV side) 120V, 4A, 75W

S.C.test (HV side) 9.5V, 20A, 110W

i) Find equivalent circuit par meters referred to H.V. side

ii) Efficiency at half load and 0.8 p.f. lagging

Sol^n-

$$Zsc = \frac{Vsc}{Isc} = \frac{9.5}{20} = 0.475ohm$$

$$Rsc = \frac{Ws}{Isc^2} = \frac{110}{400} = 0.275ohm$$

$$Xc = \sqrt{Zsc^2 - Rsc^2} = 0.387ohm$$

$$\eta = \frac{xV2\ I2\ Cos\emptyset}{xV2\ I2\ Cos\emptyset + pi + x^2Pc} \times 100$$

$$\eta = \frac{8 \times 1000 \times 0.8 \times 0.5}{8 \times 1000 \times 0.8 \times 0.5 + 75 + 0.5^2 \times 110} \times 100 = 96.8\%$$

S.NO	RGPV QUESTIONS	Year	Marks
Q.1	The following readings were obtained for O.C. and O.C. tests on 8KVA, 400/120V, 50 Hz transformer. O.C. test (LV side) 120V, 4A, 75W S.C.test (HV side) 9.5V, 20A, 110W i) Find equivalent circuit par meters referred to H.V. side ii) Efficiency at half load and 0.8 p.f. lagging	Dec. 2010	10
Q.2	The results of test performed on single phase, 20 KVA, 2200/220 volt, 50 Hz Transformer are as follows- O.C. test (LV side) 220V, 4.2A, 148W S.C. test (HV side) 86V, 10.5A, 360W Determine: The regulation and efficiency at 0.8 p.f. lagging at full load.	Dec 2014	7

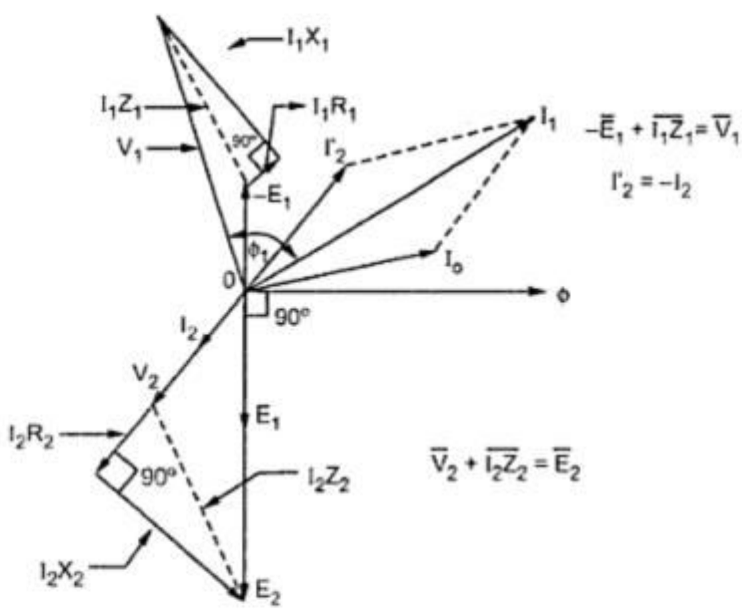
Unit-02/Lecture-12

Phasor Diagrams of Transformer-

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.

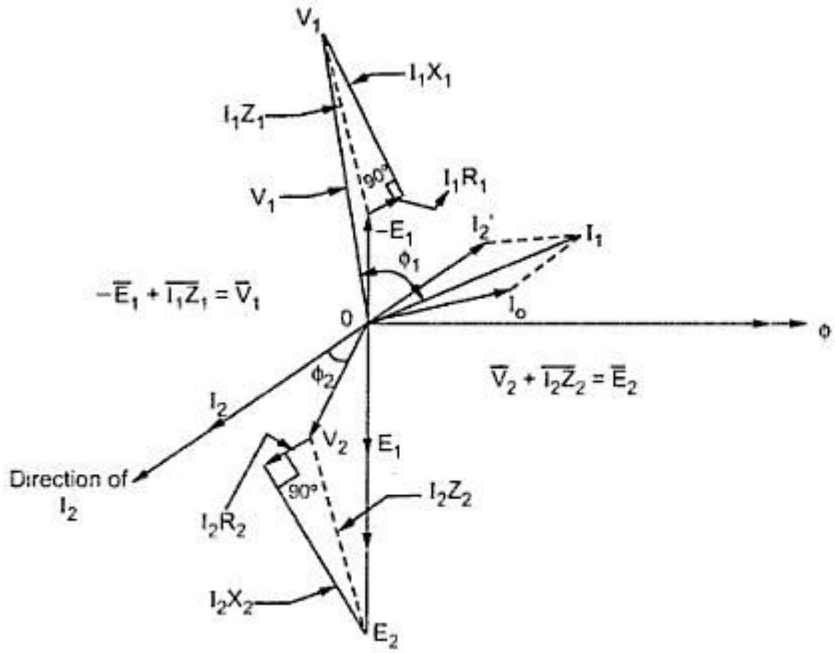
Angle between V_1 and I_1 is Φ_1 and $\cos\Phi_1$ is primary power factor. Remember that I_1X_1 leads I_1 direction by 90^o and $I_2 X_2$ leads I_2 by 90^o as current through inductance lags voltage across inductance by 90^o. The phasor diagram is shown in the Fig. below



Phasor diagram for unity power factor load

Lagging Power Factor Load[RGPV April 2009, Dec 2014]

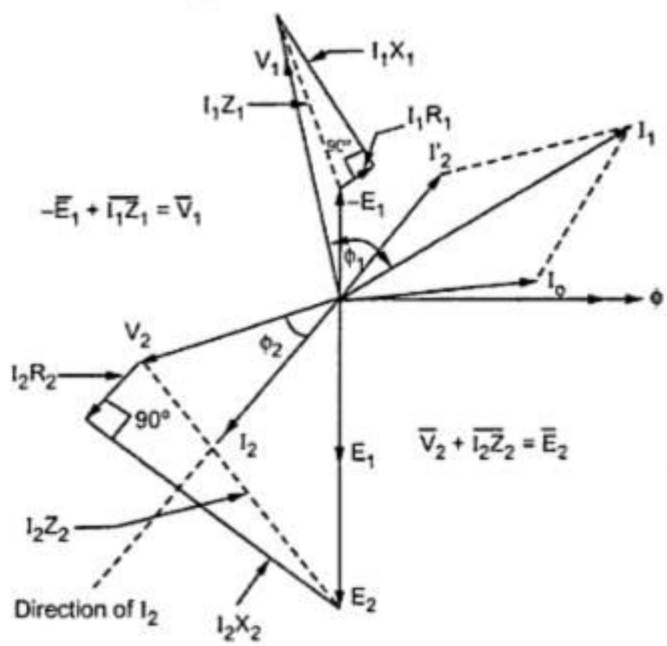
As load power factor is lagging $\cos\Phi_2$, the current I_2 lags V_2 by angle Φ_2. So only changes in drawing the phasor diagram is to draw I_2 lagging V_2 by Φ_2 in step 5 discussed earlier. Accordingly direction of $I_2 R_2$, $I_2 X_2$, I_2', I_1, $I_1 R_1$ and I_1X_1 will change. Remember that whatever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



Phasor diagram for lagging power factor

Leading Power Factor Load

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. The complete phasor diagram is shown in the Fig. below



Phasor diagram for leading power factor

S.NO	RGPV QUESTIONS	Year	Marks
Q.1	Draw the complete phasor diagram of a single phase transformer for an inductive load. Also write the notations used for all voltages and currents used in the phasor diagram.	Dec 2014	3

UNIT – 5

Electrical MACHINES

Unit-05/Lecture-01

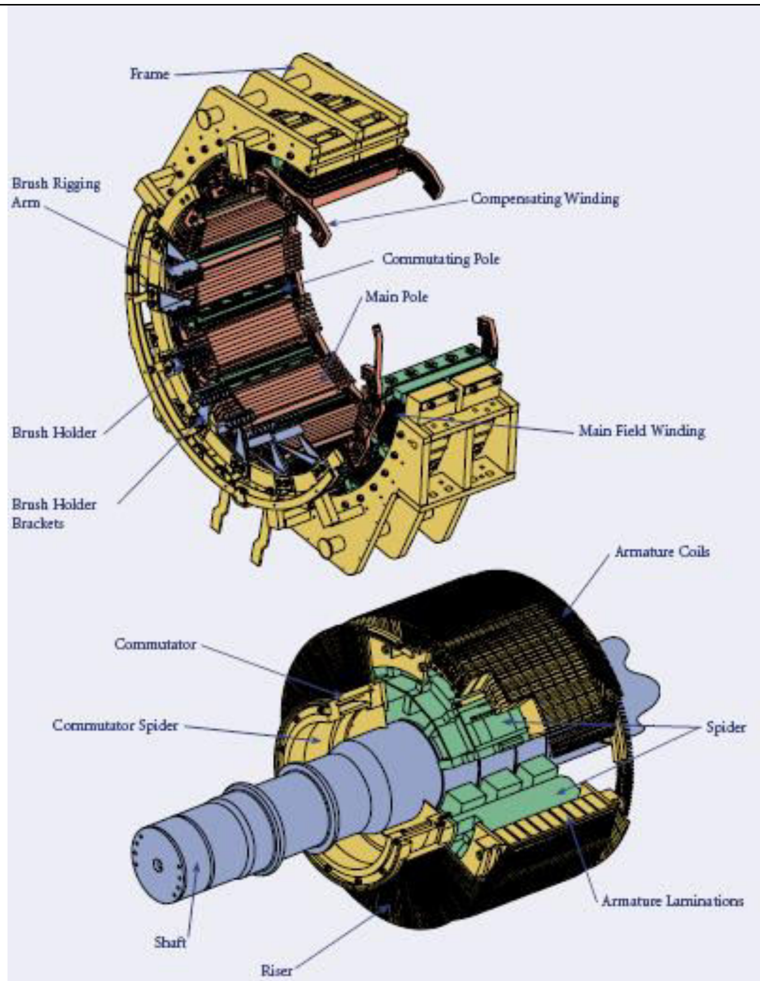
D.C Machines- [RGPV June 2008]

D.C Machine is an electromechanical energy conversion device that converts mechanical energy into electrical energy and vice versa. These are broadly classified into two parts say dc generator and dc motor.

An Electric motor is a machine which converts electric energy into mechanical energy. Its action is based on the principle that when a current-carrying conductor is placed in a magnetic field, it experiences a mechanical force whose direction is given by Fleming's Left-hand Rule and whose magnitude is given by F= *Bil* Newton.

Construction wise, there is no basic difference between a d.c. generator and a d.c. motor. In fact, the same d.c. machine can be used interchangeably as a generator or as a motor. D.C. motors are also like generators, shunt-wound or series-wound or compound-wound.

The same d.c.machine can be used, at least theoretically, interchangeably as a generator or as a motor. When operating as a generator, it is driven by a mechanical machine and it develops voltage which in turn produces a current flow in an electric circuit. When operating as a motor, it is supplied by electric current and it develops torque which in turn produces mechanical rotation.Commutator converts ac into dc in dc generator and dc to ac in dc motor.



Classification of D.C. Machines-

1. DC Generator
   a) Separately excited dc Generator
   b) Self-excited dc Generator
      i) DC Series Generator
      ii) DC Shunt Generator
      iii) DC Compound Generator

2. DC Motor
   a) Separately excited dc Motor
   b) Self-excited dc Motor
      i) DC Series Motor
      ii) DC Shunt Motor
      iii) DC Compound Motor

EMF Equation-

$$Eg = \frac{P\emptyset NZ}{60A}$$

Φ = flux/pole in weber

Z = total number of armature conductors

= No. of slots $\times$ No. of conductors/slot

P = No. of generator poles

A = No. of parallel paths in armature

N = armature rotation in revolutions per minute (r.p.m.)

E = e.m.f. induced in any parallel path in armature.

S.NO	RGPV QUESTIONS	Year	Marks
Q.1	Write the principle of operation of DC motor.	June 2008	10

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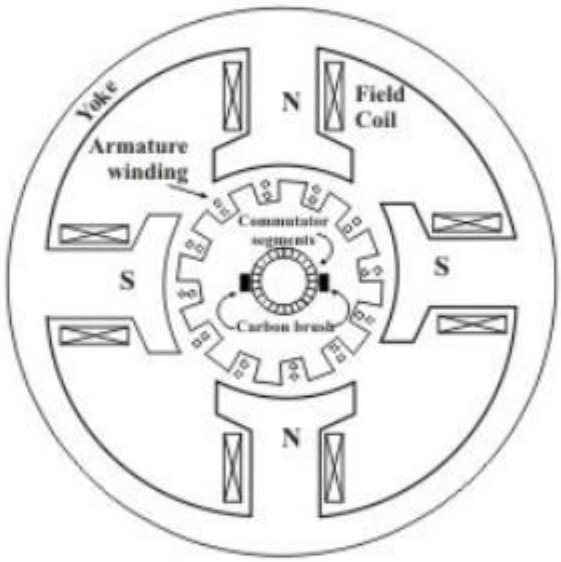
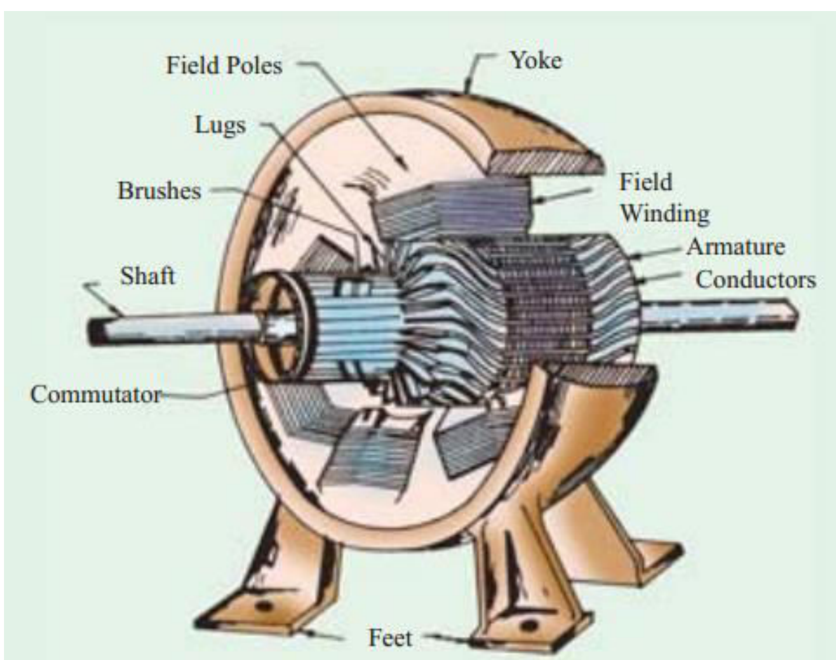
Unit-05/Lecture-02- 03

Construction of DC Motor-[June 2008]



Sectional Diagram of a DC Machine

Figure shows a sectional view of a 4-pole D.C machine. The length of the machine is perpendicular to the paper. Stator has got 4 numbers of projected poles with coils wound over it. These coils may be connected in series in order that consecutive poles produce opposite polarities (i.e., N-S-N-S) when excited from a source.



1) **Yoke of DC Motor-**

The magnetic frame or the yoke of dc motor made up of cast iron or steel and forms an integral part of the stator or the static part of the motor. The outer frame or yoke serves double purpose :

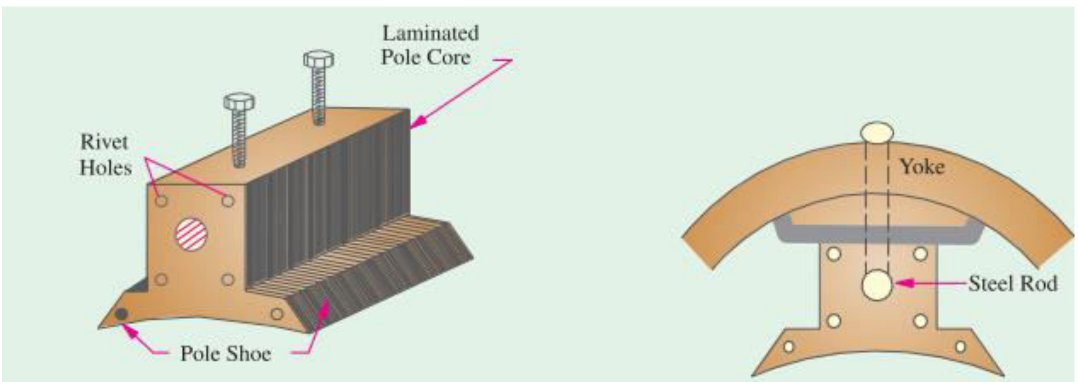
i) It provides mechanical support for the poles and acts as a protecting cover for the whole machine.

ii) It carries the magnetic flux produced by the poles.

In small generators where cheapness rather than weight is the main consideration, yokes are made of cast iron. But for large machines usually cast steel or rolled steel is employed.

2) Poles of DC Motor-

The magnetic poles of DC motor are structures fitted onto the inner wall of the yoke with screws. The construction of magnetic poles basically comprises of two parts namely, the pole core and the pole shoe stacked together under hydraulic pressure and then attached to the yoke. These two structures are assigned for different purposes, the pole core is of small cross sectional area and its function is to just hold the pole shoe over the yoke, whereas the pole shoe having a relatively larger cross-sectional area spreads the flux produced over the air gap between the stator and rotor to reduce the loss due to reluctance.

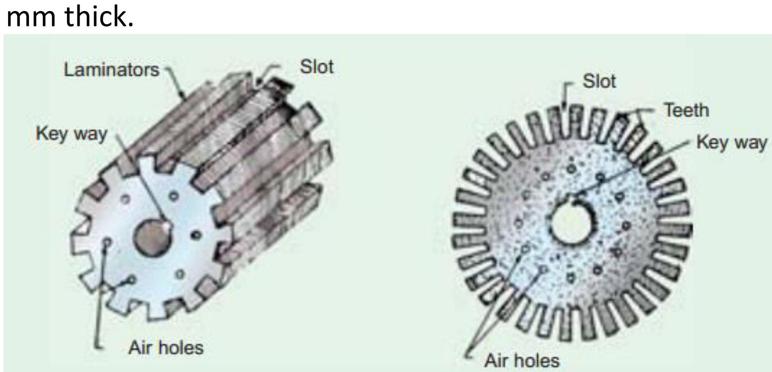


3) Field Winding of DC Motor-

The field winding of dc motor are made with field coils (copper wire) wound over the slots of the pole shoes in such a manner that when field current flows through it, then adjacent poles have opposite polarity are produced.When current is passed through these coils, they electro-magnetise the poles which produce the necessary flux that is cut by revolving armature conductors

4) Armature Core –

It houses the armature conductors or coils and causes them to rotate and hence cut the magnetic flux of the field magnets. In addition to this, its most important function is to provide a path of very low reluctance to the flux through the armature from a N-pole to a S-pole. It is cylindrical or drum-shaped and is built up of usually circular sheet steel discs or laminations approximately 0.5 mm thick.



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5) ArmatureWinding of DC Motor-

The armature winding of dc motor is attached to the rotor, or the rotating part of the machine, and as a result is subjected to altering magnetic field in the path of its rotation which directly results in magnetic losses. For this reason the rotor is made of armature core, that's made with several low-hysteresis silicon steel laminations, to reduce the magnetic losses like hysteresis and eddy current loss respectively. These laminated steel sheets are stacked together to form the cylindrical structure of the armature core.

6) Commutator of DC Motor- [RGPV Dec 2014]

The commutator of dc motor is a cylindrical structure made up of copper segments stacked together, but insulated from each other by mica. The function of the commutator is to facilitate collection of current from the armature conductors; it rectified i.e. converts the alternating current induced in the armature conductors into unidirectional current in the external load circuit. It is of cylindrical structure and is built up of wedge-shaped segments of high-conductivity hard-drawn or drop forged copper. The number of segments is equal to the number of armature coils. Each commutator segment is connected to the armature conductor by means of a copper lug or strip. As far as the dc motor is concerned, Its main function is to commute or relay the supply current from the mains to the armature winding housed over a rotating structure through the brushes of dc motor.

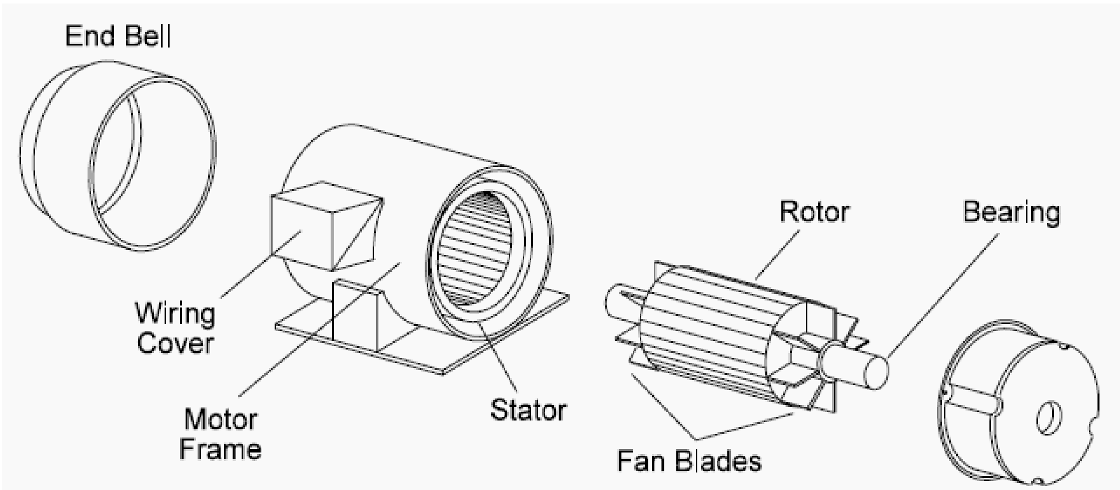
7) Brushes of DC Motor-[RGPV Dec 2014]

The brushes of dc motor whose function is to collect current from commutator are made with carbon or graphite structures, making sliding contact over the rotating commutator. The brushes are used to relay the electric current from external circuit to the rotating commutator form where it flows into the armature winding. So, the commutator and brush unit of the dc motor is concerned with transmitting the power from the static electrical circuit to the mechanically rotating region or the rotor.The number of brushes per spindle depends on the magnitude of the current to be collected from the commutator

S.NO	RGPV QUESTIONS	Year	Marks
Q.1	Write the constructional details of DC motor	June 2008	10
Q.2	Write the necessity and material used for the following in a d.c. machine i) Commutator ii) Brush	Dec 2014	2

Unit-05/Lecture-04

Induction Machine- [June 2009] [June 2008]



The three phase induction motor is the most widely used electrical motor. Almost 80% of the mechanical power used by industries is provided by three phase induction motors because of its simple and rugged construction, low cost, good operating characteristics, absence of commutator and good speed regulation. In three phase induction motor the power is transferred from stator to rotor winding through induction. The Induction motor is also called asynchronous motor as it runs at a speed other than the synchronous speed.

Construction of Induction Machine-

Like any other electrical motor induction motor also have two main parts namely rotor and stator

1. Stator: As its name indicates stator is a stationary part of induction motor. A stator winding is placed in the stator of induction motor and the three phase supply is given to it.
2. Rotor: The rotor is a rotating part of induction motor. The rotor is connected to the mechanical load through the shaft.

The rotor of the three phase induction motor are further classified as

1. Squirrel cage rotor,
2. Slip ring rotor or wound rotor or phase wound rotor.

Depending upon the type of rotor construction used the three phase induction motor are classified as:

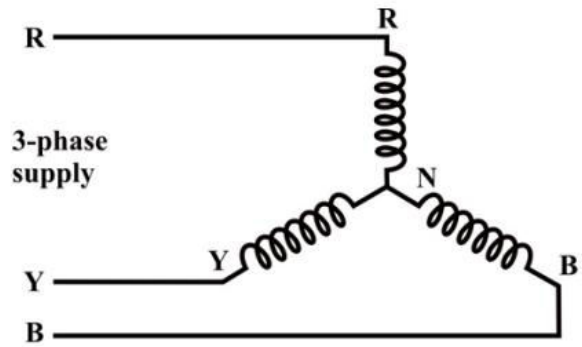
1. Squirrel cage induction motor,
2. Slip ring induction motor or wound induction motor or phase wound induction motor.

S.NO	RGPV QUESTIONS	Year	Marks
Q.1	Explain working principle of three phase induction motor	June 2009	10

Unit-05/Lecture-05-06

Rotating Magnetic field in an Induction Machine- [June 2007] [June 2009][Dec. 2010]

The principle of operation of the induction machine is based on the generation of a rotating magnetic field.A three-phase balanced winding in the stator of the Induction motor (IM) is shown in Fig. (schematic form). In a three-phase balanced winding, the number of turns in three windings, is equal, with the angle between the adjacent phases, say R & Y, is 120^0 (electrical). Same angle of 120^0 (elec.) is also between the phases, Y & B.



A three-phase balanced voltage, with the phase sequence as R-Y-B, is applied to the above winding. In a balanced voltage, the magnitude of the voltage in each phase,
assumed to be in star in this case, is equal, with the phase angle of the voltage between the adjacent phases, say R & Y, being 120^0
The three phases of the stator winding (balanced) carry balanced alternating (sinusoidal) currents as shown

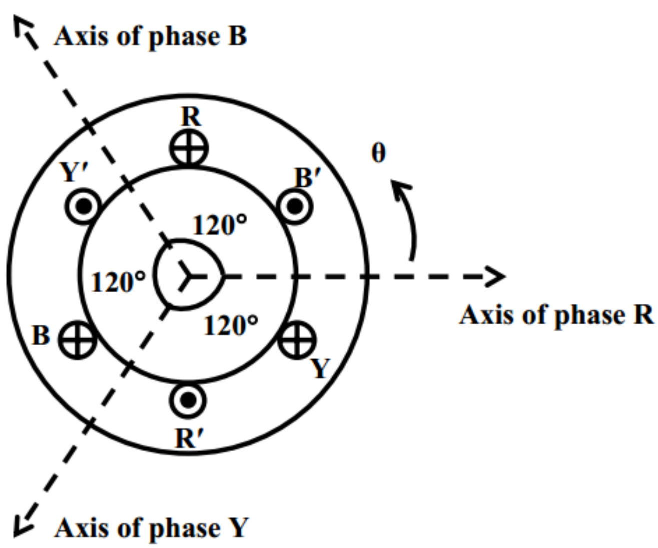
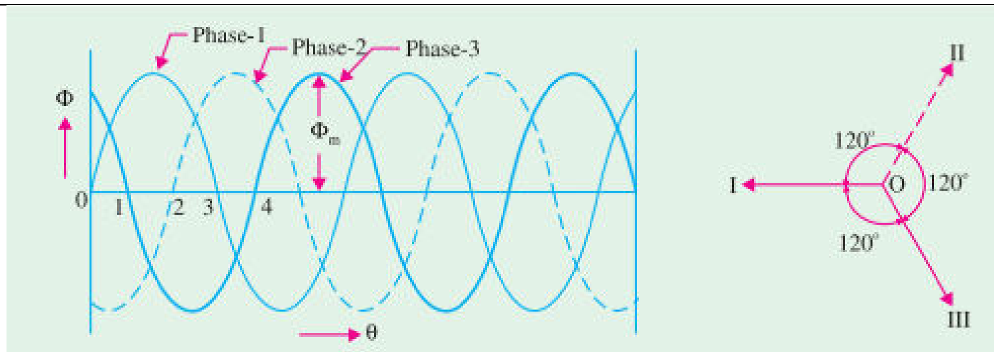


Fig.: The relative location of the magnetic axis of three phases

Let the maximum value of flux due to any one of the three phases be Φ_m. The resultant flux Φ_r, at any instant, is given by the vector sum of the individual fluxes, Φ_A, $\Phi_B$and $\Phi_C$due to three phases.
The resultant is $1.5\Phi_m$ and has rotated clockwise through an additional angle 60^O or through an angle of 180^0 from the start.



Hence, the resultant flux is of constant value = 1.5 Φm i.e. 1.5 times the maximum value of the flux due to any phase. The resultant flux rotates around the stator at synchronous speed given by Ns = 120 f/P.

Principle of operation of Induction motor:

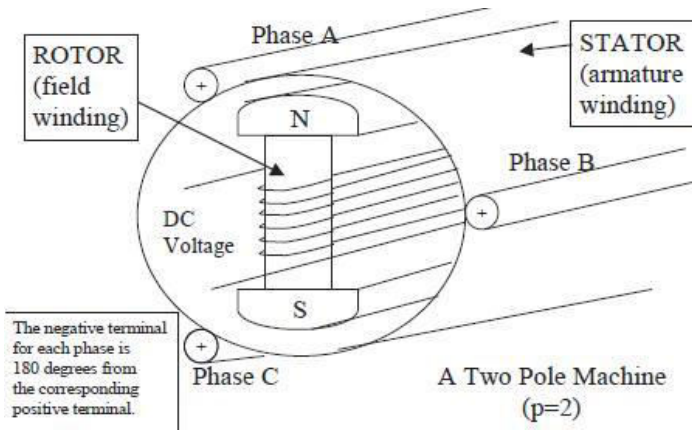
The balanced three-phase winding of the stator is supplied with a balanced three phase voltage. The current inthe stator winding produces a rotating magnetic field, the magnitudeof which remains constant. The axis of the magnetic field rotates at a synchronous speed, a function of the supply frequency (f), and number of poles (p) in the stator winding. The magnetic flux lines in the air gap cut both stator and rotor (being stationary, as the motor speed is zero) conductors at the same speed. The emfs in both stator and rotor conductors are induced at the same frequency, i.e. line or supply frequency, with No. of poles for both stator and rotor windings (assuming wound one) being same. The stator conductors are always stationary, with the frequency in the stator winding being same as line frequency. As the rotor winding is short-circuited at the slip-rings, current flows in the rotor windings. The electromagnetic torque in the motor is in the same direction as that of the rotating magnetic field, due to the interaction between the rotating flux produced in the air gap by the current in the stator winding, and the current in the rotor winding. This is as per Lenz's law, as the developed torque is in such direction that it will oppose the cause, which results in the current flowing in the rotor winding. This is irrespective of the rotortype used −cage or wound one, with the cage rotor, with the bars short-circuited by two end-rings, is considered equivalent to a wound one The current in the rotor bars interacts with the air-gap flux to develop the torque, irrespective of the no. of poles for which the winding in the stator is designed. Thus, the cage rotor may be termed as universal one.

The induced emf and the current in the rotor are due to the relative velocity between the rotor conductors and the rotating flux in the air-gap, which is maximum, when the rotor is stationary. As the rotor starts rotating in the same direction, as that of the rotating magnetic field due to production of the torque as stated earlier, the relative velocity decreases, along with lower values ofinduced emf and current in the rotor. If the rotor speed is equal that of the rotating magnetic field, which is termed as synchronous speed, and also in the same direction, the relative velocity is zero, which causes both the induced emf and current in the rotor to be reduced to zero. Under this condition, torque will notbe produced. So, for production of positive (motoring) torque, the rotor speed must always be lower than the synchronous speed. The rotor speed is never equal to the synchronous speed in an IM.

S.NO	RGPV QUESTIONS	Year	Marks
Q.1	Explain rotating magnetic field in a three phase induction motor	June 2009 June 2007	10
Q.2	Derive the e.m.f. equation of a 3 phase Induction motor.	Dec 2014	7

Unit-05/Lecture-07

Synchronous Machine-[RGPV Dec 2014]



A synchronous electric motor is an AC motor in which, at steady state, the rotation of the shaft is synchronized with the frequency of the supply current; the rotation period is exactly equal to an integral number of AC cycles. Synchronous motors contain electromagnets on the stator of the motor that create a magnetic field which rotates in time with the oscillations of the line current. The rotor turns in step with this field, at the same rate. The synchronous motor and induction motor are the most widely used types of AC motor. The difference between the two types is that the synchronous motor rotates in exact synchronism with the line frequency.
Some characteristic features of a synchronous motor are

i) It runs either at synchronous speedor not at all i.e.while running it maintains a constant speed. The only way tochange its speed is to vary the supplyfrequency.
ii) It is not inherently self-starting. It has to be run up to synchronous (or near synchronous) speed by some means, before it can be synchronized to thesupply.
iii) It is capable of being operated undera wide range of power factors, both lagging and leading. Hence, it can be usedfor power correction purposes, in addition to supplying torque to drive loads.

Construction of Synchronous Machine-

Stator-

The exterior frame, made of steel, either cast or a weldment, supports the laminated stator core and has feet, or flanges, for mounting to the foundation. Frame vibration from core magnetic forcing or rotor unbalance is minimized by resilient mounting the core anor by designing to avoid frame resonance with forcing frequencies. If bracket type bearings are employed, the frame must support the bearings, oil seals, and gas seals when cooled with hydrogen or gas other than air.

Rotor-

Synchronous rotors are designed primarily for applications requiring highly efficient motors. Each pole assembly is made from high strength steel laminations with a DC field winding encircling the pole body. The field winding consists of a rectangular section of insulated copper wire wound directly on an insulated pole body and bonded by a high temperature, high strength insulating epoxy resin.

EMF Equation-

$$E=\sqrt{2} \times pi \times fN \times Kw$$

Q) Calculate the no load terminal voltage of a 3- phase 4 pole star connected alternator running at 1500rpm having the following data:[RGPV Feb. 2010]

Sinusoidally distributed two per pole=66mwb,
Total no of armature slots=72
No.of conductors per slot=10
Distribution factor =0.96
Assume full pitch winding.
Sol^n-

$$P=4$$
$$N_s=1500$$
$$\emptyset = 66 \times 10^{-3}\, wb$$
$$K_d=0.96$$

Conductor per slot=10
Total no. Of conductors=72$\times 10 = 720$

$$N_s=120f/P$$
$$1500=120f/4$$
$$F=50\text{ Hz}$$
$$N=720/2$$
$$E = \sqrt{2} \times pi \times f \times \emptyset \times N \times kw$$
$$E = \sqrt{2} \times 3.14 \times 50 \times 66 \times 10^{-3} \times 360 \times 0.96$$
$$E = 62.02$$

S.NO	RGPV QUESTIONS	Year	Marks
Q.1	Q) Calculate the no load terminal voltage of a 3- phase 4 pole star connected alternator running at 1500rpm having the following data: Sinusoidally distributed two per pole=66mwb, Total no of armature slots=72 No.of conductors per slot=10 Distribution factor =0.96 Assume full pitch winding.	Feb. 2010	7
Q.2	Why synchronous machine is called as synchronous. Define synchronous speed.	Dec 2014	2

Unit-05/Lecture-08

INDUCTION-MOTOR EQUIVALENT CIRCUIT

The equivalent circuit representing stator phenomena is exactly like that used to represent the primary of a transformer.

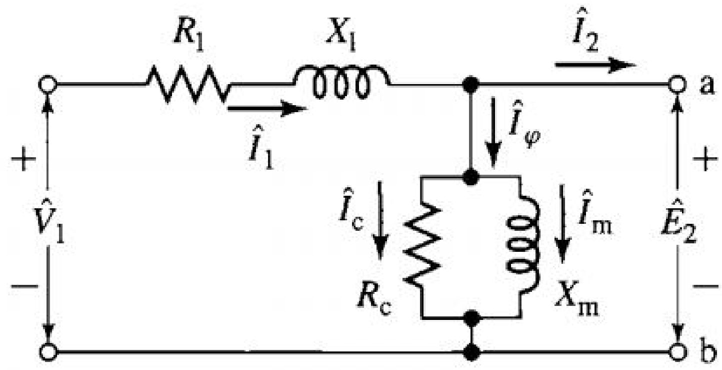


Fig: Stator equivalent circuit for a polyphase induction motor.

The slip-frequency equivalent circuit of one phase of the referred rotor is shown in Figure below. Note that here X2 has been defined as the referred rotor leakage reactance at stator frequency f. Since the actual rotor frequency f_r = Sf, it has been converted to the slip-frequency reactance simply by multiplying by the slip s. This is the equivalent circuit of the rotor as seen in the slip-frequency rotor reference frame.

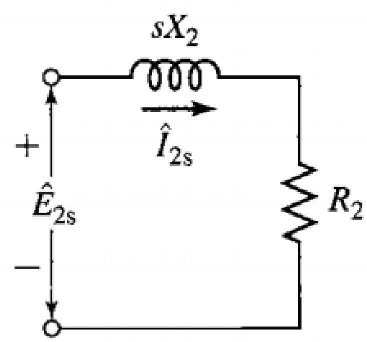


Fig: Rotor equivalent circuit for a polyphase induction motor at slip frequency.

Concept of slip in 3-Phase induction motor-

The difference between the synchronous speed N_s of the rotating stator field and the actual rotor speed N is called slip. It is usually expressed as a percentage of Synchronous speed.Three phase induction motor is a particular form of transformer which has secondary winding rotating. In transformer, the frequency of primary and secondary winding is same but in induction motor the frequency of emf induced in rotor depends on slip.

$$\%\, Slip = \frac{N_s - N}{N_s} \times 100$$

The quantity N_s - N is sometimes called slip speed. When the rotor is stationary (i.e., N = 0), slip, s = 1 or 100 %. In an induction motor, the change in slip from no-load to full-load is hardly 0.1% to 3% so that it is essentially a constant-speed motor.

Unit-05/Lecture-09

Torque-Slip Characteristics-[RGPV Dec 2014]

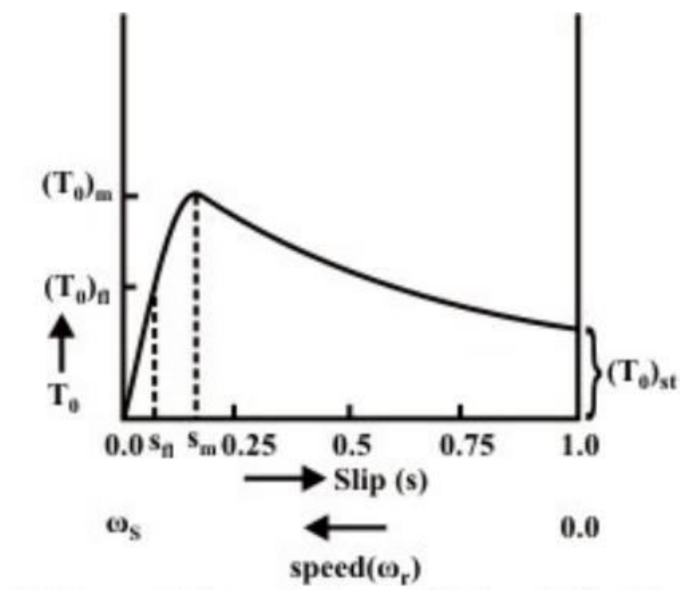
If a curve is drawn between the torque and slip for a particular value of rotorresistance R2, the graph thus obtained is called torque-slip characteristic.

$$T = \frac{k\emptyset s E_2 R_2}{R_2^2 + (sX_2)^2}$$

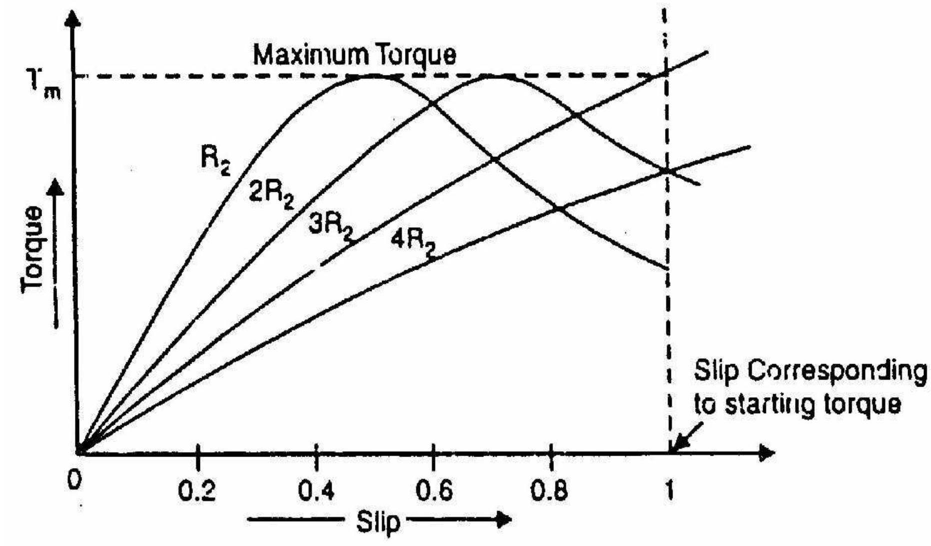
The torque-slip or torque-speed characteristic, as per the equation of torque, is shown in Figure below. The slip is

$$s = \frac{n_s - n_r}{n_s} = 1 - \frac{n_r}{n_s}$$

The range of speedn_s is between 0.0 (standstill) and (synchronous speed). The range of slip is between 0.0 ($n_r = n_s$) and 1.0 ($n_r = 0$)



It may be observed from the torque-slip characteristic (Fig. 32.1), or described earlier, that the output torque developed increases, if the slip increases from 0.0 to s_m , or the motor speed decreases from n_s to n_rThis ensures stable operation of IM in this region (0.0 < s <s_m), for constant load torque. But the output torque developed decreases, if the slip increases from$s_m$to 1.0, or the motor speed decreases from n_r to zero (0.0). This results in unstable operation of IM in this region (s_m< s <1.0), for constant load torque. However, for fan type loads with the torque as ( ), stable operation of IM is achieved in this region (s_m< s < 1.0)



The following points may be noted carefully:

1. At s = 0, T = 0 so that torque-slip curve starts from the origin.
2. At normal speeds, close to synchronism, slip is small so that the term ($s.X_2$) is negligible as compared toR_2.Hence, for low values of slip, the torque/slip curve is approximately a straight line.
3. As slip increases (forincreasing load on the motor) beyond full-load slip, the torque increases and becomes maximum at $s = R_2/X_2$. This maximum torque in an induction motor is called pull-out torque or break-down torque. Its value is at least twice the full-load value when the motor is operated at rated voltage and frequency.
4. As the slip further increases (i.e. motor speed falls) with further increase in motor load then R2 becomes negligible as compared to (sX_2). Therefore, for large values of slip

$$\boldsymbol{T} \propto \frac{s}{(sX_2)^2} \propto \frac{1}{s}$$

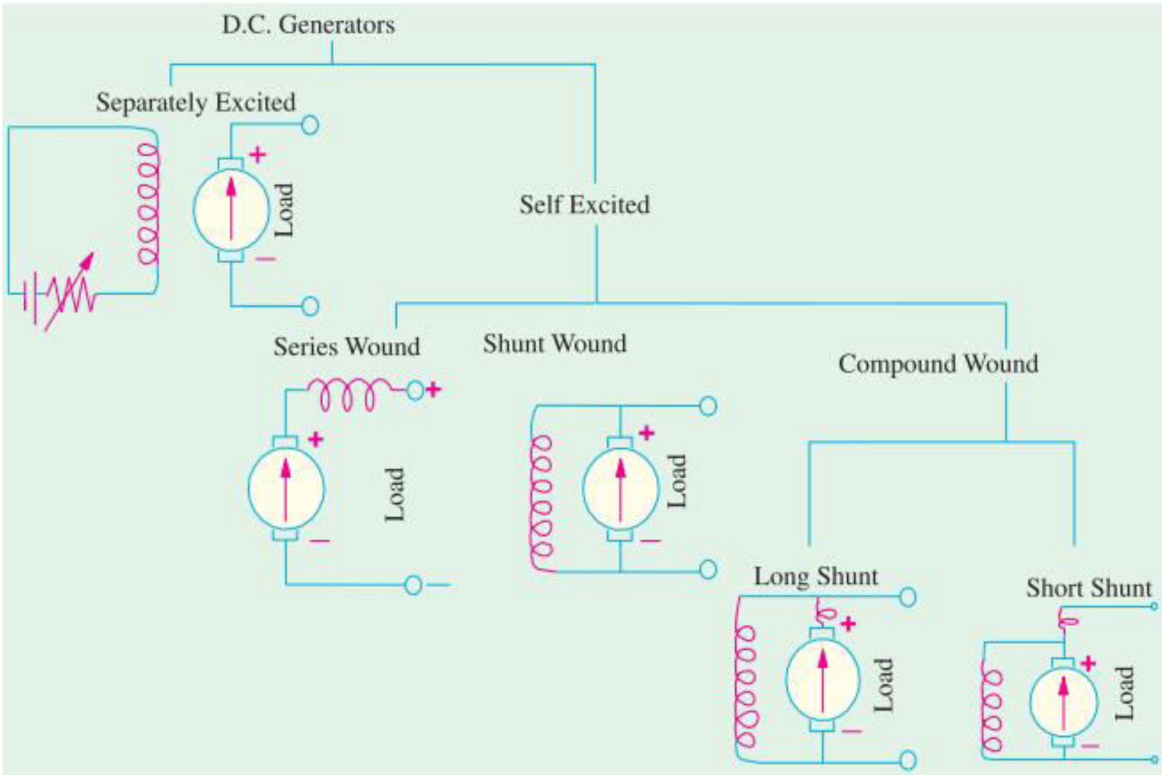
Hence, the torque/slip curve is a rectangular hyperbola. So, we see that beyond the point of maximum torque, any further increase in motor load results in decrease of torque developed by the motor. The result is that the motor slows down and eventually stops.

S.NO	RGPV QUESTIONS	Year	Marks
Q.1	Draw and explain the complete Torque–slip characteristics of 3 phase induction motor.	Dec 2014	7

Unit-03/Lecture-10

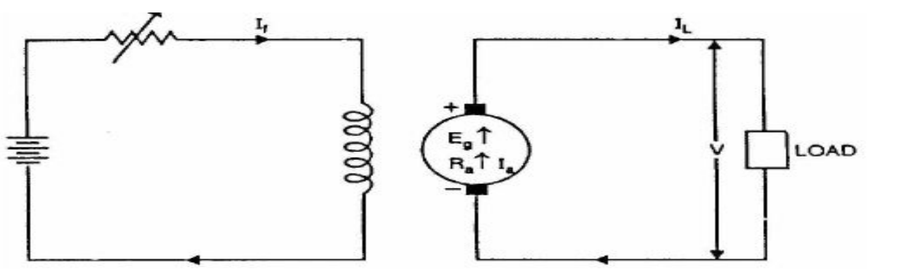
Classification of D.C. Generator-

Generators are usually classified according to the way in which their fields are excited. Generators may be divided into



1. **Separately excited D.C. Generator-**

Separately-excited generators are those whose field magnets are energised from an independent external source of d.c.current.

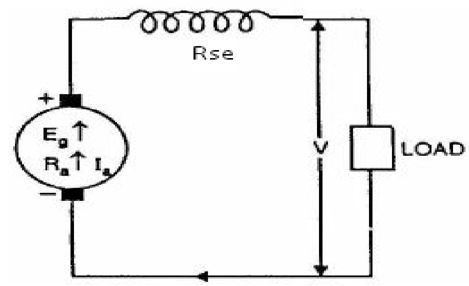


Armature current, $I_a = I_L + I_{sh}$
Terminal voltage, $V = E_g - I_aR_a$
Electric power developed $= E_gI_a$
Power delivered to load $= E_gI_a - I_a^2R_a = I_a(E_g - I_aR_a) = VI_a$

2. **Self-excited D.C. Generator-**

Self-excited generators are those whose field magnets are energised by the current produced by the generators themselves. Due to residual magnetism, there is always present some flux in the poles. When the armature is rotated, some e.m.f. and hence some induced current is produced which is partly or fully passed through the field coils thereby strengthening the residual pole flux. There are three types of self-excited generators named according to the manner in which their field coils (or windings) are connected to the armature

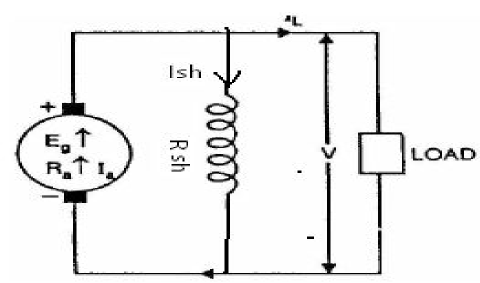
i) D.C. Series Generator –In this case, the field windings are joined in series with the armature conductors.



Armature current, $I_a = I_L$

Terminal voltage, $V = E_g - I_aR_a - I_aR_{se}$

ii) D.C. Shunt Generator –The field windings are connected across or in parallel with the armature conductors and have the full voltage of the generator applied across them



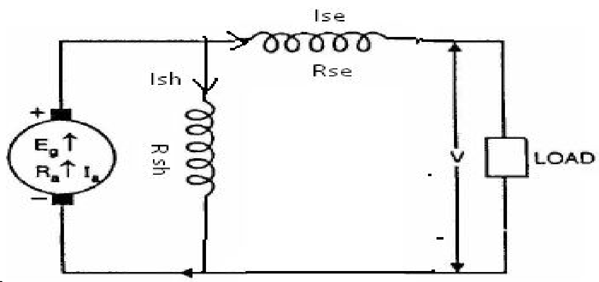
Armature current, $I_a = I_L + I_{sh}$

Terminal voltage, $V = E_g - I_aR_a$

Unit-05/Lecture-11

iii) D.C. Compound Generator –

It is a combination of a few series and a few shunt windings and can be either short-shunt. In a compound generator, the shunt field is stronger than the series field. When series field aids the shunt field, generator is said to be commutatively-compounded. On the other hand if series field opposes the shunt field, the generator is said to be differentially compounded.



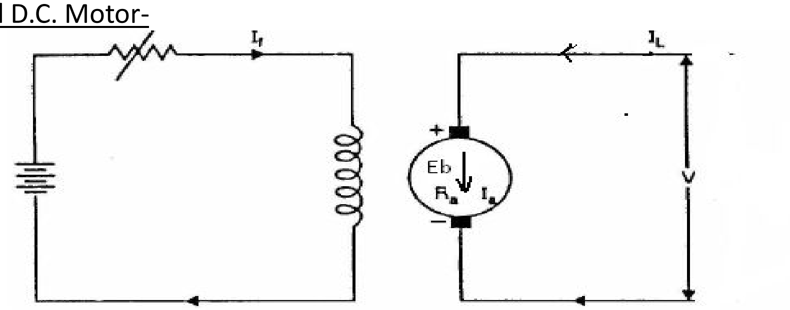
or long-shunt

Armature current, $I_a = I_L + I_{sh}$

Terminal Voltage, $V = E_g - I_a R_a - I_{se} R_{se}$

Classification of D.C. Motor-

1) Separately excited D.C. Motor-

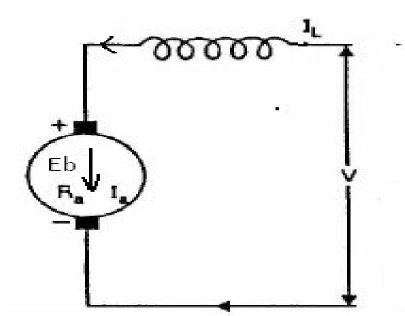


Armature current, $I_a = I_L$

Terminal voltage, $V = E_b + I_a R_a$

2)Self excited D.C.Motor-**[RGPV Dec 2014]**

i) D.C. Series Motor –



Armature current, $I_a = I_L$

Terminal Voltage, $V = E_b + I_a R_a$

Unit-05/Lecture-12

Q. A 4 pole wave connected D.C generator has 900 armature conductors and flux per pole of 0.04wb. At what speed it must be run to generate 500 V. [RGPV Dec. 2010]

Sol^{n-}

$$P = 8$$
$$\emptyset = 0.04$$
$$Z = 900$$
$$Eg = 500$$

For wave winding

A=2

$$\boldsymbol{Eg = \frac{P\emptyset NZ}{60A}}$$

$$500 = 8 \times 0.04 \times N \times 900/(60 \times 2)$$
$$N = 208\, rpm$$

Q. A 4 pole d.c. shunt generator with a lap o wound armature having 390 conductors has to supplya load of 500 lamps each of 100w at 250v,Allowing 10v for the voltage drop in the connecting leads between the generator and the load and brush drop of 2v calculate the speed at which the generator should be driven .$\emptyset perpole$=30mwb,R_a=0.05ohm R_{sh}=65ohm.

Sol^n- [RGPV Feb 2010]

V=250V

Lamp load

Load Power=500*100 = kW

$$I_L = \frac{P_L}{V}$$
$$= \frac{50000}{250} = 200A$$
$$I_{sh} = \frac{V}{R_{sh}}$$
$$= \frac{250 + 10}{65} = 4A$$

$$I_a=I_l+I_{sh} = 200+4 = 204A$$

$$E_g=V+I_ar_a+V_b+V_{load}$$

$$Eg=250+204\times0.05+2+10=272.72Volts$$

$$\boldsymbol{Eg = \frac{P\emptyset NZ}{60A}}$$

$$N = 272.72 \times 60 \times 4/4 \times 30 \times 10^{-3} \times 390$$
$$N = 1396\, rpm$$

S.NO	RGPV QUESTIONS	Year	Marks
Q.1	What do you mean by separately excited and self-excited generator, Sketch following Shunt Wound, Series Wound, Compound wound	Dec 2013	7
Q.2	A 4 pole wave connected D.C generator has 900 armature conductors and flux per pole of 0.04wb. At what speed it must be run to generate 500 V	Dec. 2010	7

Q.3	A 4 pole d.c. shunt generator with a lap o wound armature having 390 conductors has to supply a load of 500 lamps each of 100w at 250v,Allowing 10v for the voltage drop in the connecting leads between the generator and the load and brush drop of 2v calculate the speed at which the generator should be driven .$\emptyset\ per pole$=30mwb,R_a=0.05ohm R_{sh}=65ohm.	Feb 2010	10
Q.4	Classify self excited D.C. motor.	Dec 2014	3

Unit-05/Lecture-13

Losses in a Electrical Machine

1) **Copper losses-** These losses are the losses due to armature and field copper windings. Thus copper losses consists of Armature copper loss, Field copper loss and loss due to brush contact resistance

a) **Armature Cu loss-** Armature copper loss = Ia^2Ra (Where Ia is Armature current and Ra is Armature resistance)

This loss is about 30 to 40% of full load losses.

b) **Field Cu loss-** Field copper loss = If^2Rf (where If is field current and Rf is field resistance)

In case of shunt wounded field, this loss is practically constant.

Field copper loss is about 20 to 30% of full load losses.

c) **Loss due to brush contact resistance-** Brush contact resistance also contributes to this type of loss. Generally this loss is included into armature copper loss.

2) **Iron Losses-** As iron core of the armature is continuously rotating in a magnetic field, there are some losses taking place in the core. Therefore iron losses are also known as Core losses. This loss consists of Hysteresis loss and Eddy current loss.

a) **Hysteresis loss-** Hysteresis loss is due to reversal of magnetization of the armature core. When the core passes under one pair of poles, it undergoes one complete cycle of magnetic reversal.

b) **Eddy current loss-** When the armature core rotates in the magnetic field, an emf is also induced in the core (just like it induces in armature conductors), according to the Faraday's law of electromagnetic induction. Though this induced emf is small, it causes a large current to flow in the body due to low resistance of the core. This current is known as eddy current. The power loss due to this current is known as eddy current loss.

3) **Mechanical losses-** Mechanical losses consist of the losses due to friction in bearings and commutator. Air friction loss of rotating armature also contributes.
These losses are about 10 to 20% of full load losses.

a) Friction losses
b) Windage losses