SKP Engineering College

Tiruvannamalai – 606611

A Course Material

on

Electrical Engineering and Instrumentation

By

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Assistant Professor

Electrical and Electronics Engineering Department

Quality Certificate

This is to Certify that the Electronic Study Material

Subject Code: EE6352

Subject Name: Electrical Engineering and Instrumentation

Year/Sem: II/III

Being prepared by me and it meets the knowledge requirement of the University curriculum.

Signature of the Author

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This is to certify that the course material being prepared by Mr.M. Thanigaivelraja & Mr. G. Nithiyanandham is of the adequate quality. They had referred more than five books and one among them is from abroad author.

Signature of HD

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Signature of the Principal

Name: Dr.V.Subramania Bharathi

Seal:

EE6352 ELECTRICAL ENGINEERING AND INSTRUMENTATION L T P C 3 1 0 4

UNIT I DC MACHINES 9

Three phase circuits, a review. Construction of DC machines – Theory of operation of DC generators – Characteristics of DC generators- Operating principle of DC motors – Types of DC motors and their characteristics – Speed control of DC motors- Applications.

UNIT II TRANSFORME **9**

Introduction – Single phase transformer construction and principle of operation – EMF equation of transformer-Transformer no–load phasor diagram - Transformer on–load phasor diagram - Equivalent circuit of transformer – Regulation of transformer –Transformer losses and efficiency-
All day efficiency –auto transformers.

UNIT III INDUCTION MACHINES AND SYNCHRONOUS MACHINES **9**

Principle of operation of three-phase induction motors – Construction –Types – Equivalent circuit –Construction of single-phase induction motors – Types of single phase induction motors – Double revolving field theory – starting methods - Principles of alternator – Construction details – Types –Equation of induced EMF – Voltage regulation. Methods of starting of synchronous motors – Torque equation – V curves – Synchronous motors.

UNIT IV BASICS OF MEASUREMENT AND INSTRUMENTATION **9**

Static and Dynamic Characteristics of Measurement – Errors in Measurement - Classification of Transducers – Variable resistive – Strainguage, thermistor RTD – transducer - Variable Capacitive
Transducer – Capacitor Microphone - Piezo Electric Transducer – Variable Inductive transducer –
LVDT, RVDT

UNIT V ANALOG AND DIGITAL INSTRUMENTS **9**

DVM, DMM – Storage Oscilloscope. Comparison of Analog and Digital Modes of operation, Application of measurement system, Errors. Measurement of R, L and C, Wheatstone, Kelvin, Maxwell, Anderson, Schering and Wien bridges Measurement of Inductance, Capacitance, Effective resistance at high frequency, Q-Meter.

TOTAL (L:45+T:15): 60 PERIODS

TEXT BOOKS:

1. I.J Nagarath and Kothari DP, “Electrical Machines”, McGraw-Hill Education (India) Pvt Ltd 4 th Edition ,2010
2. A.K.Sawhney, “A Course in Electrical & Electronic Measurements and Instrumentation”, Dhanpat Rai and Co, 2004.

REFERENCES:

1. Del Toro, “Electrical Engineering Fundamentals” Pearson Education, New Delhi, 2007.
2. W.D.Cooper & A.D.Helfrick, “Modern Electronic Instrumentation and Measurement Techniques”, 5 th Edition, PHI, 2002.
3. John Bird, “Electrical Circuit Theory and Technology”, Elsevier, First Indian Edition, 2006.
4. Thereja .B.L, “Fundamentals of Electrical Engineering and Electronics”, S Chand & Co Ltd, 2008.
5. H.S.Kalsi, “Electronic Instrumentation”, Tata Mc Graw-Hill Education, 2004.
J.B.Gupta, “Measurements and Instrumentation”, S K Kataria & Sons, Delhi, 2003.

CONTENTS

UNIT - I
DC MACHINES

PART A

1. Give advantages of three phase system over single phase system. [CO1-L1]

- Output of three phase machine is greater than single phase machine of same size.
- Three phase transmission system is more economical than single phase transmission system as less copper or aluminum is required.
- Three phase motors are normally self starting as against single phase motors.

2. Define stalling current of DC motor. [CO1-L1-Nov 2007]

Armature current, $I_a = V - E_b/R_a$
At starting; $E_b = 0$.
Stalling current = V/R_a

3. List the essential parts of a DC generator. [CO1-L1-May 2008]
Yoke, Poles, Brushes, Bearings, Shaft, Commutator, Pole shoes, commutator poles and armature windings.

4. Why yoke is required in a DC machine? [CO1-L1-Nov 2005]

It gives a protective cover to the machine and is a mechanical support for poles.

5. Why is the core of the armature laminated? [CO1-L1-Nov 2008]

It helps in reducing eddy current losses.

6. Give the emf equation of a DC generator. [CO1-L1-Nov 2005]

Generated emf, $E = P\Phi ZN/60A$
Where, P- No. of poles, Φ – flux per pole, Z - No. of conductors, N – Speed of the armature and A - No. of parallel paths.

7. Give the type of armature windings used in DC machines. [CO1-L1-Apr 2007]

i. Wave winding

ii. Lap winding

8. Give the conditions to build up voltage in shunt generator. [CO1-L1-Nov 2003]

i. Residual magnetism should be there in the poles.
ii. The field winding should be connected with armature in proper way.
iii. The shunt field resistance should be less than the critical resistance under no load conditions.

9. List the main parts of stator of DC machine. [CO1-L1-Nov 2006]

i. Yoke
ii. Field winding
iii. Main poles
iv. Commutator poles

10. What is the Commutator pitch of a 4 pole DC armature having 49 Commutator bars? [CO1-L1-Apr 2006]

Commutator pitch, yc = (No. of Commutator bars (+/-) 1)/No. of pairs of poles
= 49(+/-) 1/2 = 24 or 25

11. State Faraday's law of Electromagnetic induction. [CO1-L1-Nov 2010]

Whenever there is a change in the magnetic flux linked with a circuit, an emf is induced in the circuit. The magnitude of the induced emf is proportional to the rate of change of flux linkages.

12. Give an application of a differentially compounded generator. [CO1-L1-Nov 2007]

It is mainly used in arc welding where larger voltage drop is desirable with increasing in current.

13. Why series motor cannot be started without any load? [CO1-L1-Nov 2007]

In series motor, Φ is directly proportional to I_a under no load conditions, the armature
current is extremely low and flux is also less.
By N is inversely proportional to Φ, it is clear that; low Φ will result in extremely high motor speed. Hence series motor should always be started with some load on shaft.

14. What is the significance of back emf? [CO1-L1-Nov 2012, May 2013]

In motoring mode, armature induced emf is known as the back emf to stress the fact that it opposes armature emf. It plays the rule of a regulator.

15. Give the reason for high starting current in a DC motor. [CO1-L1-May 2014]

For large motors the armature resistance may be 0.01 pu or less. Thus in full voltage starting of a DC motor, the armature current can be several times (100 times of large motors) the rated value.

16. List the methods of speed control of DC shunt motor. [CO1-L1-Nov 2009]

i. Field control
ii. Armature control
iii. Armature resistance control
iv. Ward-Leonard control

17. What are the different methods of excitation of generator? [CO1-L1-Nov 2012]

i. Separate excitation
ii. Shunt excitation
iii. Series excitation
iv. Compound excitation

18. Define the term armature reaction? [CO1-L1]

The interaction between the flux setup by the current carrying conductors with the main field flux is defined as armature reaction.

19. Define critical resistance of a DC shunt generator. [CO1-L1]

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

20. Mention the applications of DC series motor. [CO1-L1-May 2013]

i. Electric traction
ii. Hoists
iii. Cranes
iv. Battery powered vehicles

21. What are the functions of interpoles and how are the interpole windings connected? [CO1-L1-May 2010]

Commutating winding is placed on interpoles to aid commutation process by inducing emf in commutating coils to cancel reactance emf. So interpoles are located the interpolar region along MNA of main poles in just above the brushes where the coils undergo commutation.

22. What is the importance of residual emf in self excited DC generator? [CO1-L1]

The residual emf in self excited DC generator is used to develop emf in an armature.

23. A DC motor operates from a 240V supply; the armature resistance is 0.2 ohm. Determine the back emf when the armature current is 50A. [CO1-L2]

Given Data: V = 240V, R_a = 0.2 ohm, I_a = 50A.
Solution:
Back emf, $E_b = V - I_a \times R_a$
$= 240 - 50 \times 0.2 = 230V$.

24. An 8 pole, wave wounded armature has 600 conductors and is driven at 625 rpm. If the flux per pole is 20 mWb, determine the generated emf. [CO1-L2]

Given Data: P = 8, Z = 600, N = 625 rpm, Φ =20 mWb.
Wave winding, A = 2
Solution:
Generated emf, $E = P\Phi ZN/60A$
$= 8 \times 20 \times 10^{-3} \times 600 \times 625/60 \times 2 = 500V$.

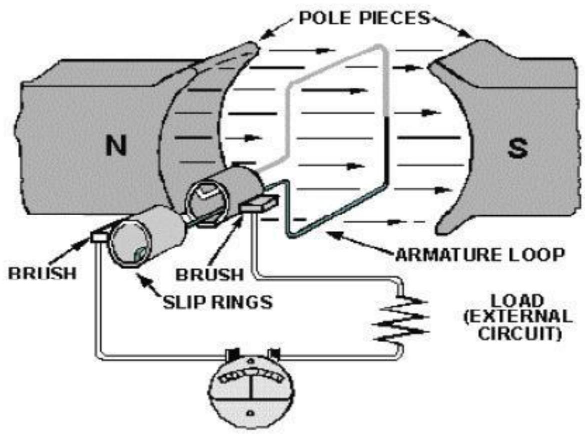
PART - B

1. Explain the theory and principle of operation and working of DC Generator. [CO1-H1-Nov 15]

Theory of Operation Of DC Generators

A generator works on the principles of **Faraday's law of electromagnetic induction**.

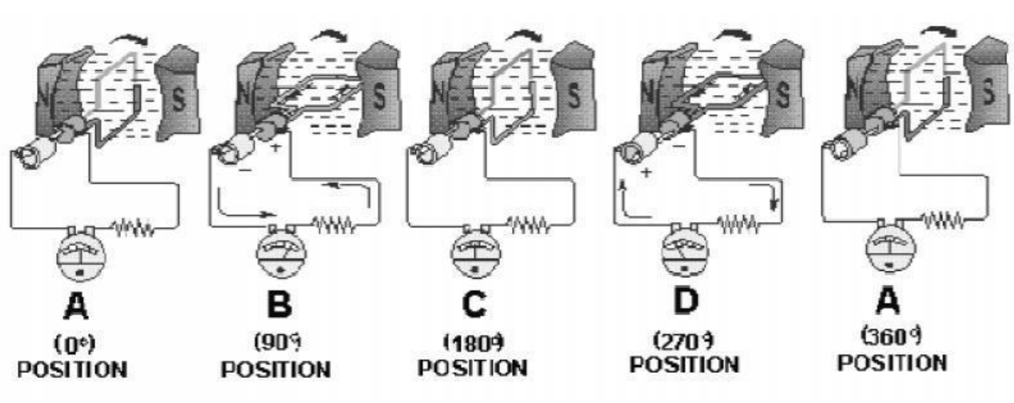
It states that "**Whenever a conductor is moved in the magnetic field, an emf is induced and the magnitude of the induced emf is directly proportional to the rate of change of flux linkage**". This emf causes a current flow if the conductor circuit is closed.



Elementary Generator

The pole pieces (marked N and S) provide the magnetic field. The pole pieces are shaped and positioned as shown above to concentrate the magnetic field as close as possible to the wire loop. The loop of wire that rotates through the field is called the ARMATURE. The ends of the armature loop are connected to rings called SLIP RINGS. They rotate with the armature. The brushes, usually made of carbon, with wires attached to them, ride against the rings. The generated voltage appears across these brushes.

The elementary generator produces a voltage in the following manner.



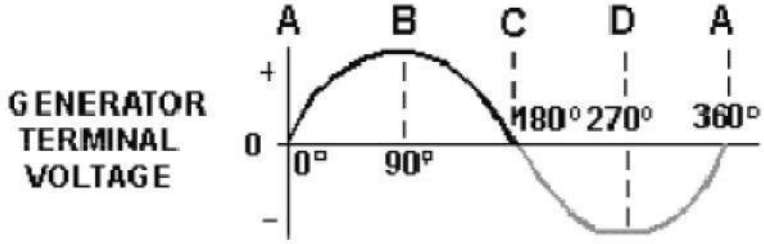
EMF Generation

The armature loop is rotated in a clockwise direction. The initial or starting point is shown at position A. (This will be considered the zero-degree position.) At 0º the armature loop is perpendicular to the magnetic field. The black and white conductors of the loop are moving parallel to the field. The instant the conductors are moving parallel to the magnetic field, they do not cut any lines of flux. Therefore, no emf is induced in the conductors, and the meter at position A indicates zero. This position is called the NEUTRAL PLANE.

As the armature loop rotates from position A (0º) to position B (90º), the conductors cut through more and more lines of flux, at a continually increasing angle. At 90º they are cutting through a maximum number of lines of flux and at maximum angle. The result is that between 0º and 90º the induced emf in the conductors builds up from zero to a maximum value. Observe that from 0º to 90º the black conductor cuts DOWN through the field. At the same time the white conductor cuts UP through the field. The induced emfs in the conductors are series-adding. This means the resultant voltage across the brushes (the terminal voltage) is the sum of the two induced voltages. The meter at position B reads maximum value.

As the armature loop continues rotating from 90º (position B) to 180º (position C), the conductors which were cutting through a maximum number of lines of flux at position B now cut through fewer lines. They are again moving parallel to the magnetic field at position C. They no longer cut through any lines of flux. As the armature rotates from 90º to 180º, the induced voltage will decrease to zero in the same manner that it increased during the rotation from 0º to 90º. The meter again reads zero. From 0º to 180º the conductors of the armature loop have been moving in the same direction through the magnetic field. Therefore, the polarity of the induced voltage has remained the same. This is shown by points A through C on the graph.

As the loop rotates beyond 180º (position C), through 270º (position D), and back to the initial or starting point (position A), the direction of the cutting action of the conductors through the magnetic field reverses. Now the black conductor cuts UP through the field while the white conductor cuts DOWN through the field. As a result, the polarity of the induced voltage reverses. Following the sequence shown by graph points C, D, and back to A, the voltage will be in the direction opposite to that shown from points A, B, and C. The terminal voltage will be the same as it was from A to C except that the polarity is reversed (as shown by the meter deflection at position D). The voltage output waveform for the complete revolution of the loop is shown in FIG.



Output voltage waveform

2. Obtain the mathematical expression for the Generated EMF or EMF Equation of a Generator [CO1-H1-Nov 14]

EMF Equation of Gene rator

Let

Φ = flux/pole in webers

Z = total number of armature connductors

= No. of slots x No. of

conductors/slot P = No. of poles

A = No. of parallel paths in arma ture

N = Armature rotation in revolutions per minute

(r.p.m) E = e.m.f induced in any parallel path in

armature

Average e.m.f generated /conduc tor = **dΦ/dt** volt (n=1)

Now, flux cut/conductor in one revolution **dΦ = ΦP** Wb

No. of revolutions/second = N/6 0

Time for one revolution, **dt = 60/N** second

According to Faraday's Laws of Electromagnetic Induction,

E.M.F generated/conductor is

$$\frac{d\varnothing}{dt} = \frac{\varnothing PN}{60}$$

For a simplex wave-wound gen erator

No. of parallel paths = 2

No. of conductors (in series) in o ne path = Z/2

E.M.F. generated/path is

$$\frac{\varnothing PN}{60} \times \frac{Z}{2} = \frac{\varnothing ZPN}{120} \text{ volt}$$

For a simplex lap-wound gener ator

No. of parallel paths = P

No. of conductors (in series) in o ne path = Z/P

E.M.F.generated/path $\frac{\varnothing PN}{60} \times \frac{Z}{P} = \frac{\varnothing ZN}{60}$ volt

In general generated e.m.f

$$E_g = \frac{\varnothing ZN}{60} \times \left(\frac{P}{A}\right) \text{ volt}$$

Where, A = 2 for simplex wave- winding.
A = P for simplex lap-w inding.

3. Explain the following characteristics (i)No Load Saturation characteristics (ii) Internal or Total Characteristics (iii) External Characteristics [CO1-H1-Nov 14]

Characteristics of DC Generators

The magnetic field in a d.c. g enerator is normally produced by electromag nets rather than permanent magnets. Generators are generally classified according to their methods of field excitation. On this basis, d.c. gen erators are divided into the following two class es:

(i) Separately excited d.c. generators
(ii) Self-excited d.c. generators

The behavior of a d.c. generator on load depends upon the method of field excita tion adopted.

There are two characteristics

1. Magnetic (no load or open ciircuit) characteristics

This curve shows the relation b etween the generated e.m.f. at no-load (E_0) and the field current (I_f) at constant speed. It is also k nown as magnetic characteristic or no-load saturation curve. Its shape is practically the same fo r all generators whether separately or self-excited. The data for O.C.C. curve are obtained expe rimentally by operating the generator at no l oad and constant speed and recording the change in terminal voltage as the field current is varied.

2. Internal and External characteristics Internal characteristics

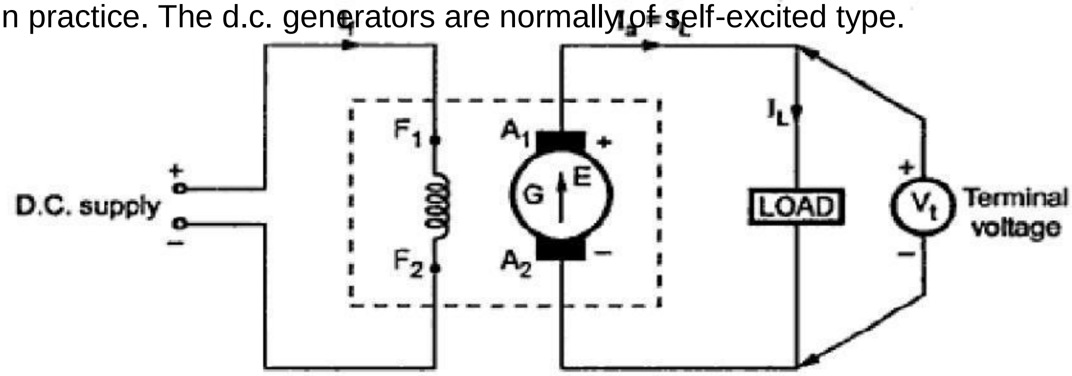
This curve shows the relation b etween the generated e.m.f. on load (E or E_g) and the armature current (Ia).The e.m.f. E is les s than E_0 due to the demagnetizing effect of armature reaction. Therefore, this curve will lie below the open circuit characteristic (O.C.C .). The internal characteristic is of interest chiefly to the designer. It cannot be obtained directly by experiment. It is because a voltmeter cannot read the e.m.f. generated on load due to the voltage drop in armature resistance. The internaal characteristic can be obtained from external characteristic if winding resistances are know n because armature reaction effect is in cluded in both characteristics

External characteristics

This curve shows the relation between the terminal voltage (V_t) and load current (I_L). The terminal voltage V_t will be less than E due to voltage drop in the armature circu it. Therefore, this curve will lie below the inte rnal characteristic. This characteristic is very important in determining the suitability of a generator for a given purpose. It can be obt ained by making simultaneous

(i) Separately Excited D.C. Ge nerators

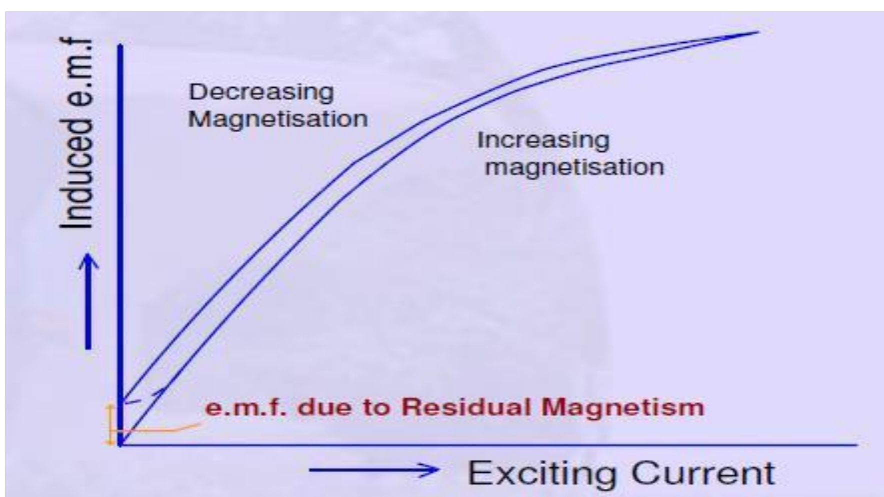
A d.c. generator whose field m agnet winding is supplied from an independent external d.c. source (e.g., a battery etc.) is called a separately excited generator. The c onnections of a separately excited generator are shown below. The voltage output depends u pon the speed of rotation of armature and the field current. The greater the speed and field curreent, greater is the
generated e.m.f. It may be noted that separately excited d.c. generators are rarely used in practice. The d.c. generators are normally of self-excited type.



Separately Excited DC Generator

Armature current, $I_a = I_L$ Terminal voltage, $V_t = E_g - I_aR_a$ Electric power developed = E_gI_a Power delivered to load = VI_L

Magnetic characteristics (E_0 versus I_f)

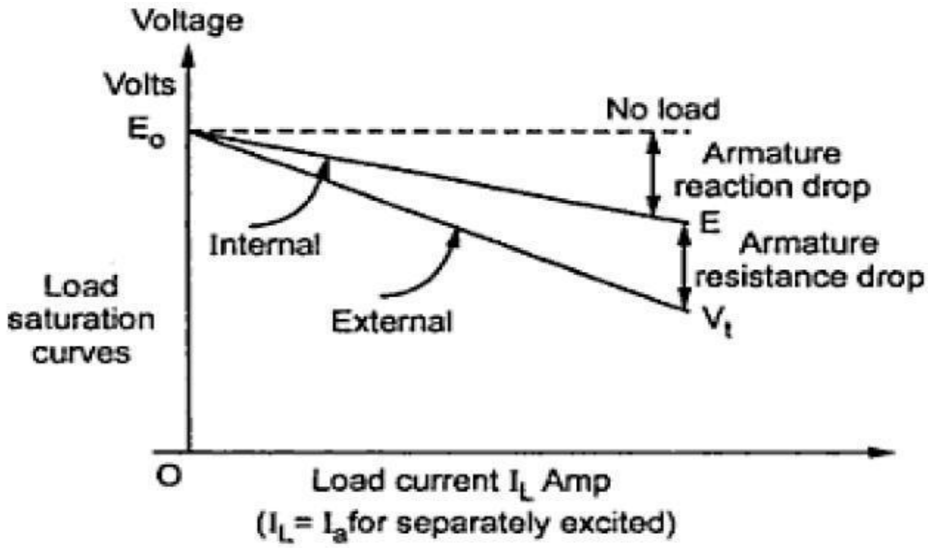


Magnetic Characteristics

A separate excitation is normally used for testing of d.c. generators to determine their open circuit or magnetization characteristic. The excitation current is increased monotonically to a maximum value and then decreased in the same manner, while noting the terminal voltage of the armature. The load current is kept zero. The speed of the generator is held at a constant value.

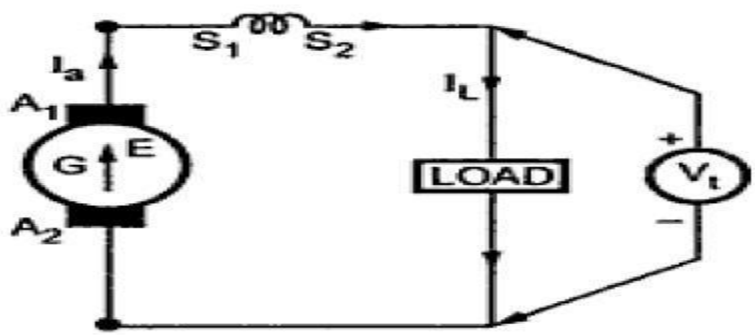
The graph showing the nature of variation of the induced emf as a function of the excitation current is called as open circuit characteristic (occ), or no-load magnetization curve or no-load saturation characteristic.

Internal and External characteristics



Internal and External Characteristics

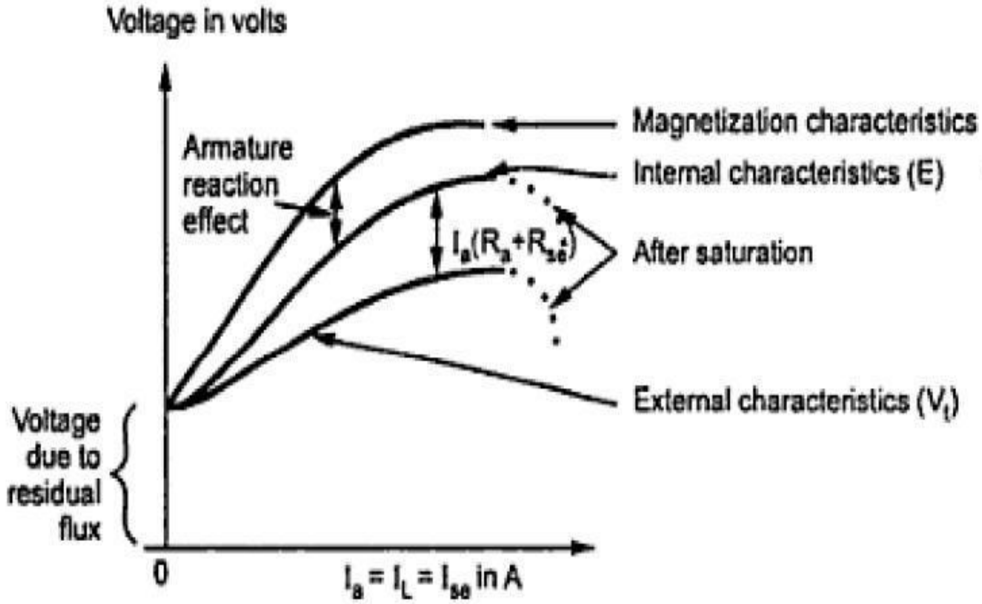
(ii) Self-excited D.C. Generators a). D.C. Series Generator



DC Series Generator

Armature current, $I_a = I_{se} = I_L$ Terminal voltage, $V_t = E_g - I_a(R_a + R_{se})$
Power developed in armature = $E_g I_a$
Power delivered to load = VI_a or VI_L

No load and Load Characteristics



Load and Load Characteristics

b). D.C. Shunt Generator

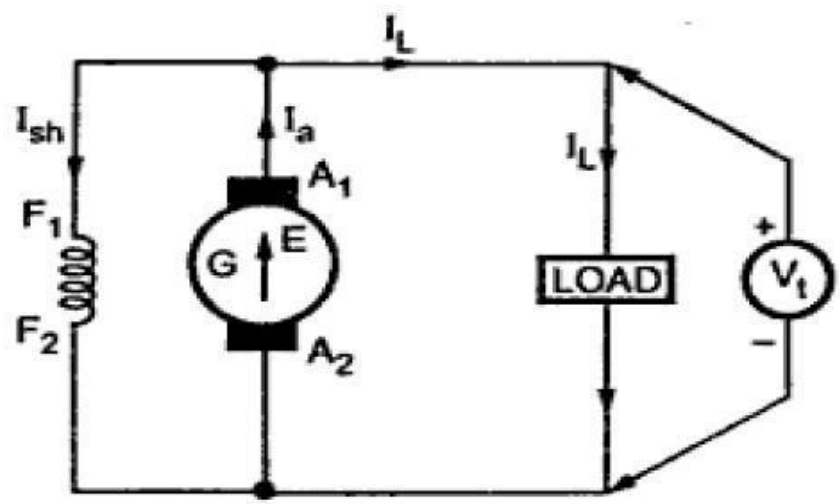


Fig. 1.22 DC shunt generator

Shunt field current, $I_{sh} = V/R_{sh}$ Armature current, $I_a = I_L + I_{sh}$ Terminal voltage, $V_t = E_g - I_aR_a$ Power developed in armature = E_gI_a
Power delivered to load = V_tI_L

Internal and External Characteristics

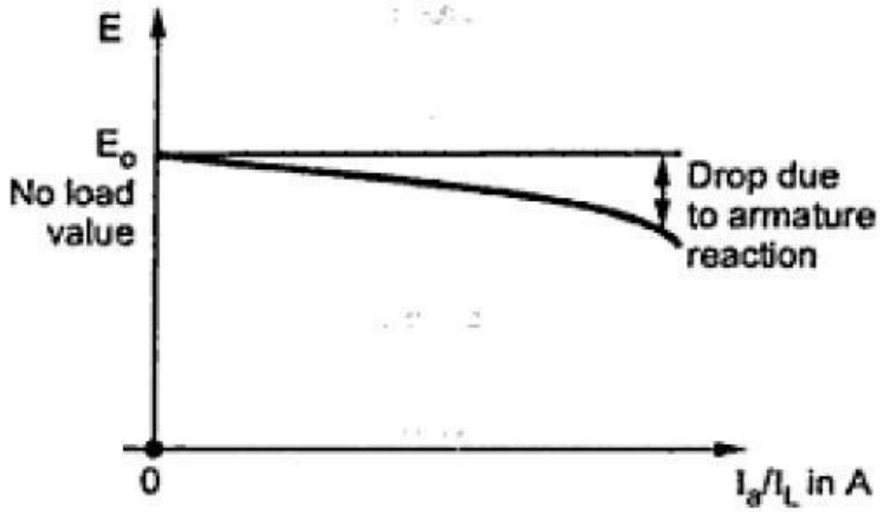
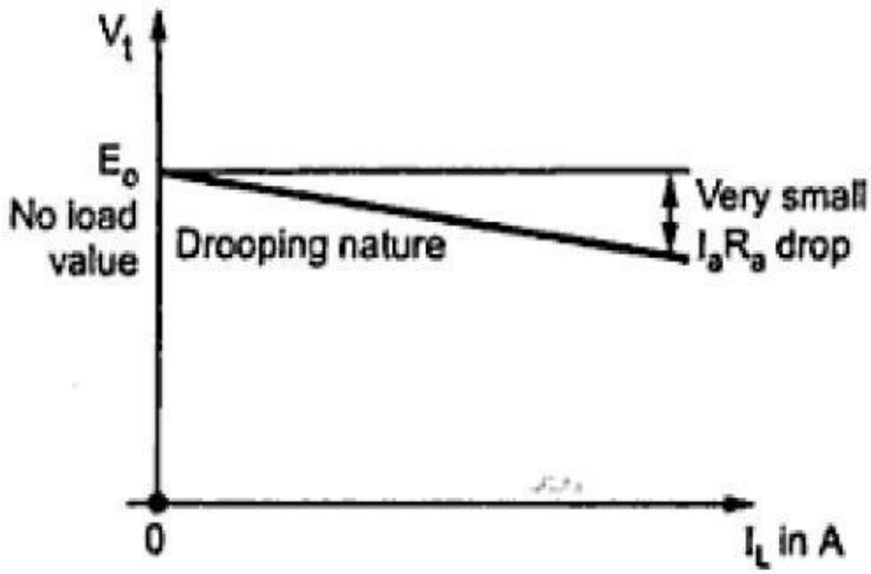


Fig. 1.23 Internal Characteristics

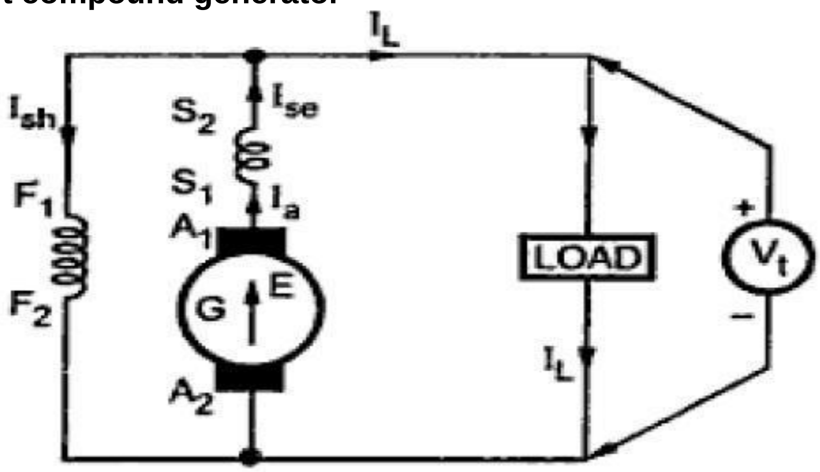


External Characteristics

c). D.C. Compound Generator

In a compound-wound generator, there are two sets of field windings on each pole one is in series and the other in parallel with the armature. A compound wound generator may be: Short Shunt in which only shunt field winding is in parallel with the armature winding. Long Shunt in which shunt field winding is in parallel with both series field and armature winding

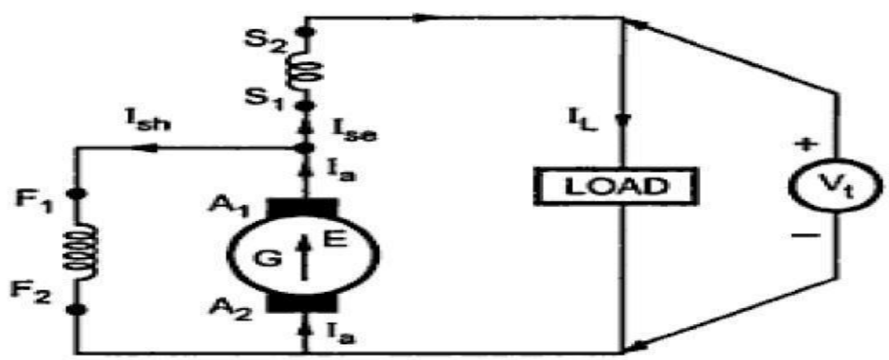
1. Long shunt compound generator



Long Shunt Compound Generator

Series field current, $I_{se} = I_a = I_L + I_{sh}$ Shunt field current, $I_{sh} = V/R_{sh}$
Terminal voltage, $V_t = E_g - I_a(R_a+R_{se})$
Power developed in armature = $E_g I_a$
Power delivered to load = $V_t I_L$

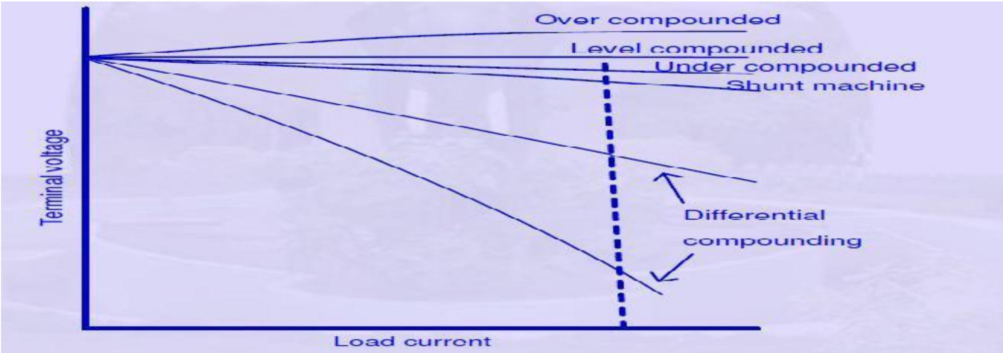
2. Short shunt compound generator



Short Shunt Compound Generator

Series field current, $I_{se} = I_L$ Shunt field current, $I_{sh} = V+I_{se}R_{se}/R_{sh}$ Terminal voltage, $V_t = E_g - I_aR_a+I_{se}R_{se}$ Power developed in armature = $E_g I_a$ Power delivered to load = $V_t I_L$

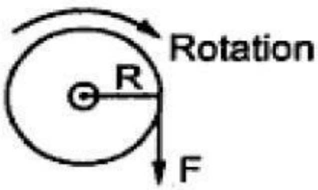
External Characteristics



External Characteristics

4. Derive the expression for Torque Equation of a DC motor. [CO1-H1]

Turning or twisting force about an axis is called torque.



Consider a wheel of radius R meters acted upon by a circumferential force F Newton's as shown in above figure. The wheel is rotating at a speed of N rpm.

The angular speed of the wheel $\omega = 2\pi N/60$ rad/sec

Work done in one revolution W= Force x distanced travelled in one revolution

$$W = F X 2\pi R \text{ joules}$$

Power developed, P = Work done/time = W/Time for 1 rev.

$$P = FX2\pi R/(60/N) = (FXR)(2\pi N/60)$$

$P = T \times \omega$ watts

Power in armature = armature torque x ω

$E_b I_a = T_a \times (2\Pi N/60)$

Where, T_a = Armature torque.

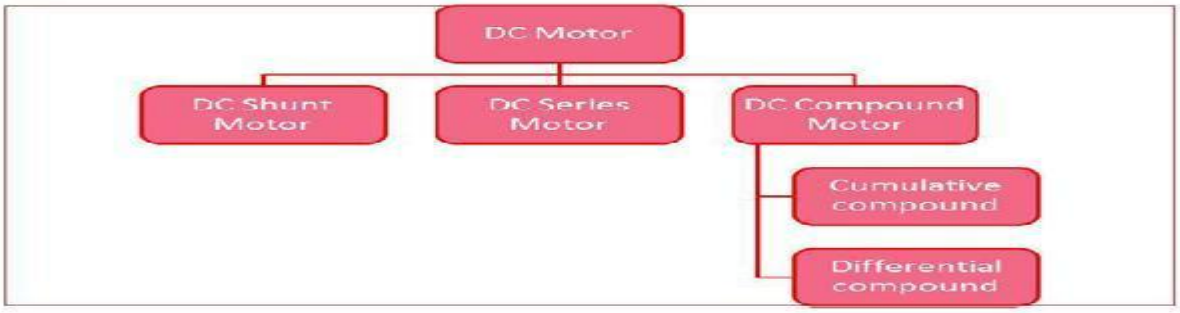
$E_b = P\Phi ZN/60A$

Substituting E_b values, we get,

$Ta = 0.159\Phi I_a\ (PZ/A)$ N-m

5. Explain in detail about the Types of DC Motors and their Characteristics [CO1-H1-Nov 13]

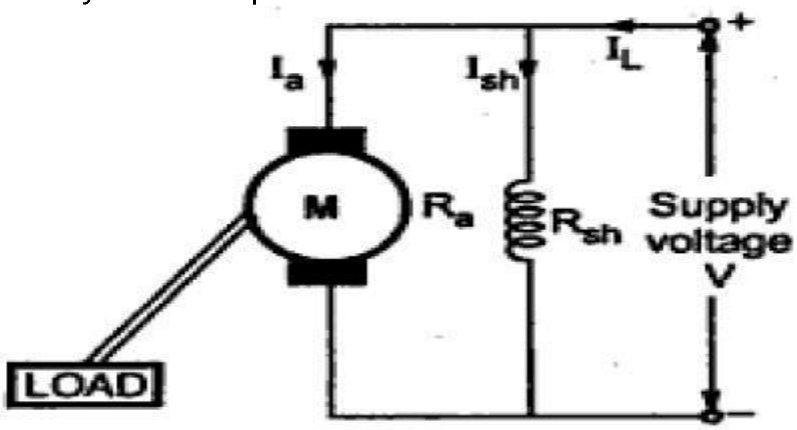
Types of DC Motors



Motor Classification

1. D.C Shunt Motor

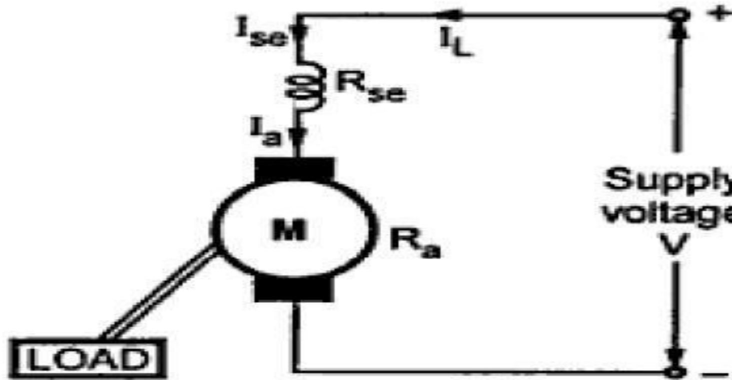
In shunt wound motor the field winding is connected in parallel with armature. The current through the shunt field winding is not the same as the armature current. Shunt field windings are designed to produce the necessary m.m.f. by means of a relatively large number of turns of wire having high resistance.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



DC Shunt Motor

2. D.C Series Motor

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



DC Series Motor

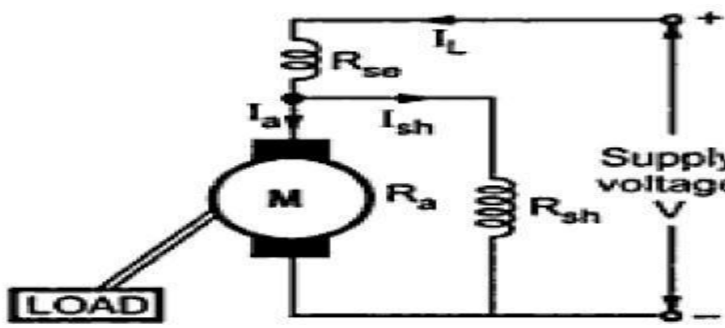
3. D.C Compound Motor

Compound wound motor has two field windings; one connected in parallel with the armature and the other in series with it. There are two types of compound motor connections

1) Short-shunt connection
2) Long shunt connection

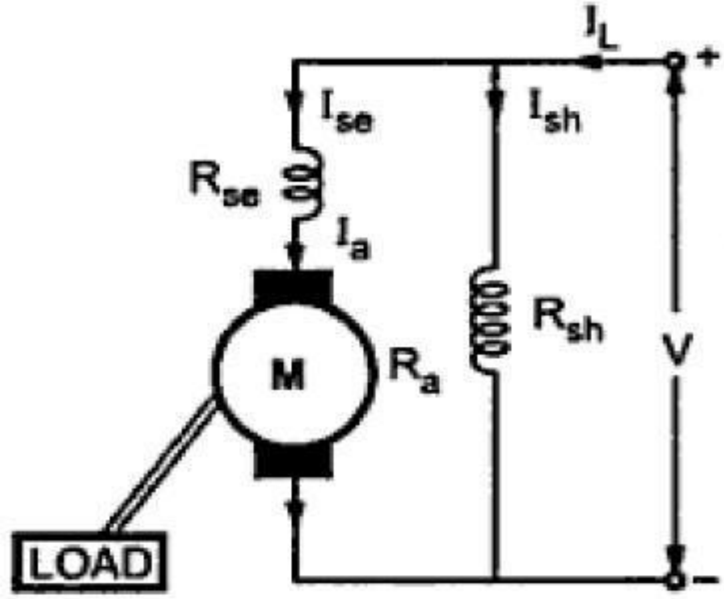
1) Short-shunt connection

When the shunt field winding is directly connected across the armature terminals it is called short-shunt connection.



2) Long shunt connection

When the shunt winding is so connected that it shunts the series combination of armature and series field it is called long-shunt connection.



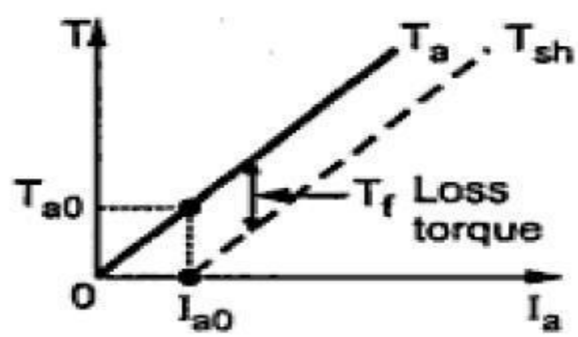
DC Compound Motor (Long shunt)

D.C Motor Characteristics

1. D.C Shunt Motor

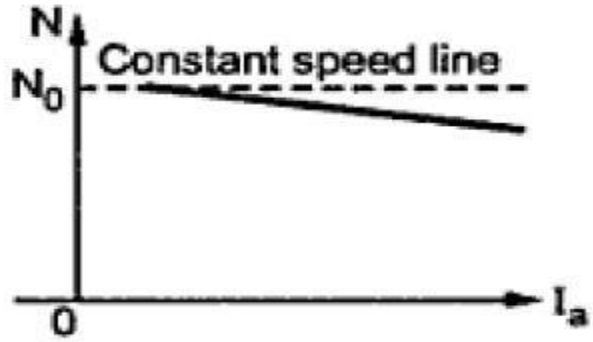
a. Torque versus Armature current

T_a is proportional to I_a



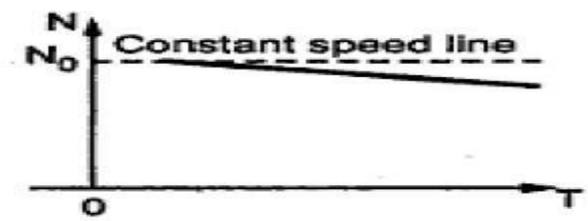
Torque Vs Armature Current

b. Speed versus Armature current



Speed Vs Armature Current

c. Speed versus Torque

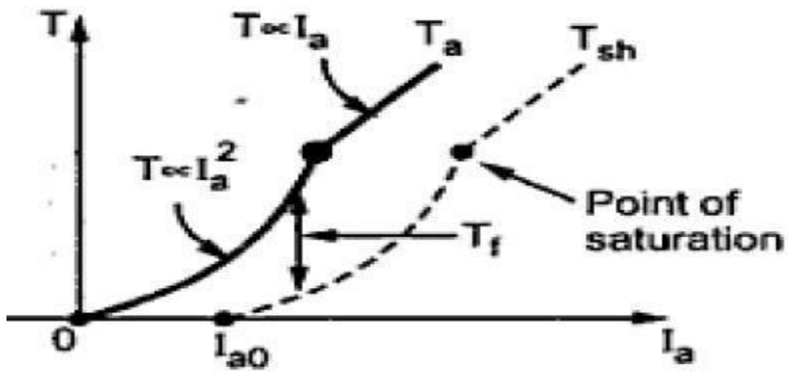


Speed Vs Torque

2. D.C Series Motor

a. Torque versus Armature current

T_a is proportional to I_a^2

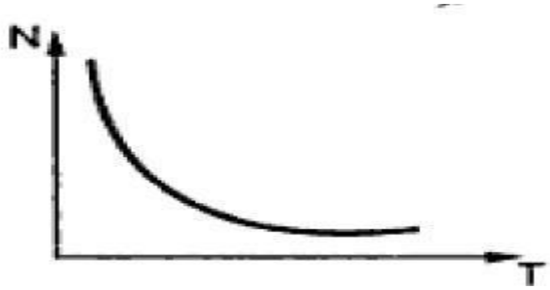


Torque Vs Armature Current

b. Speed versus Armature current

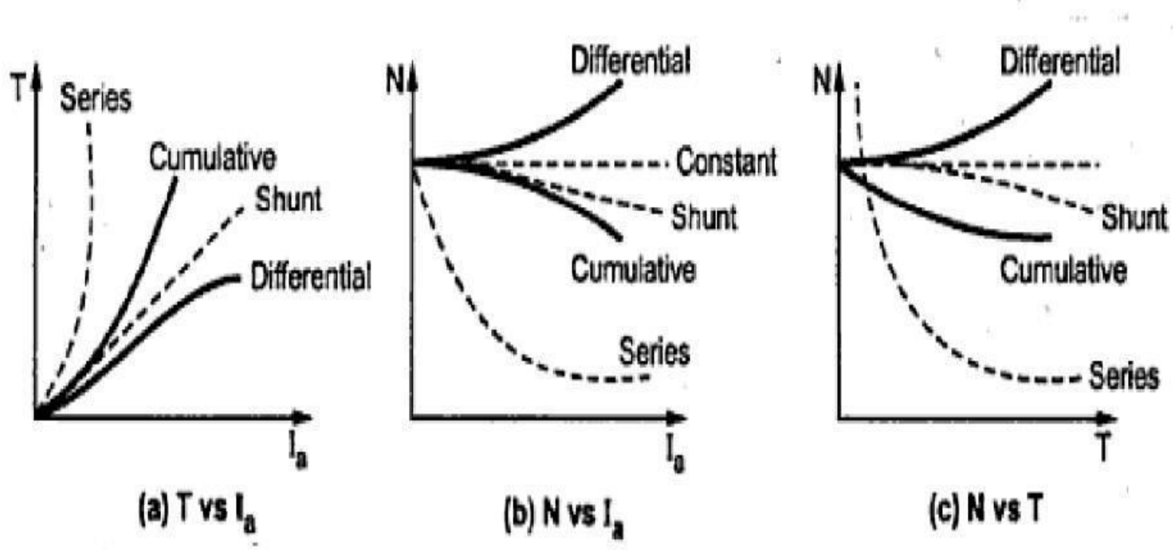
Speed Vs Armature Current

c. Speed versus Torque



Speed Vs Torque

3. D.C Compound Motor

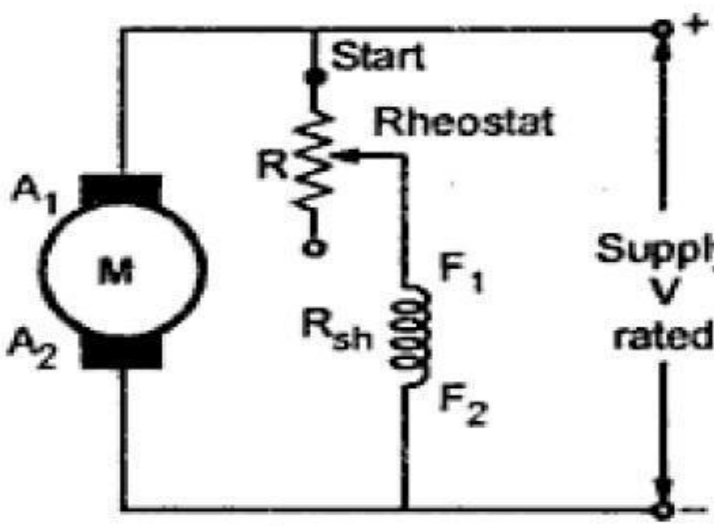


DC Compound Motor Characteristics

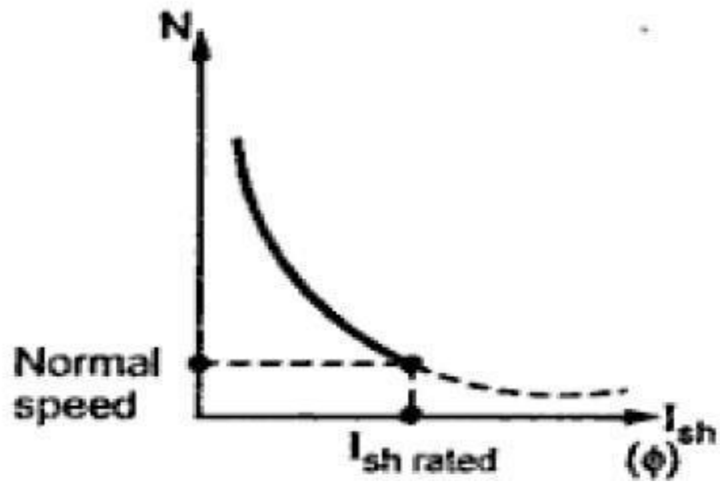
6. Explain the various methods for speed control of DC Motor [CO1-H1-Nov 12]

Speed Control of DC Motors DC shunt motor

i. Flux control



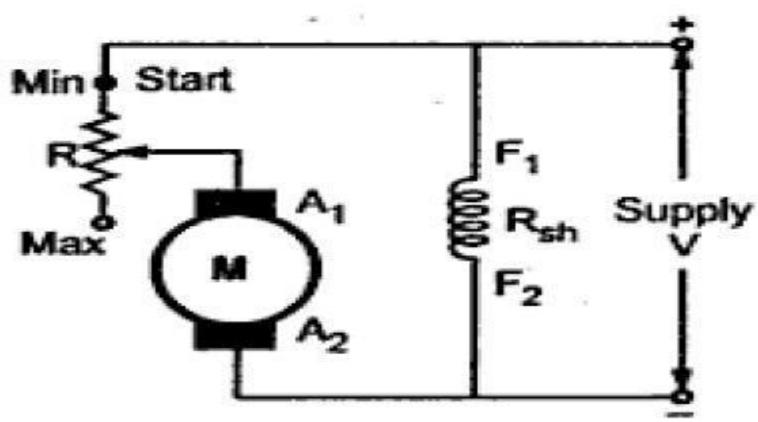
Flux Control



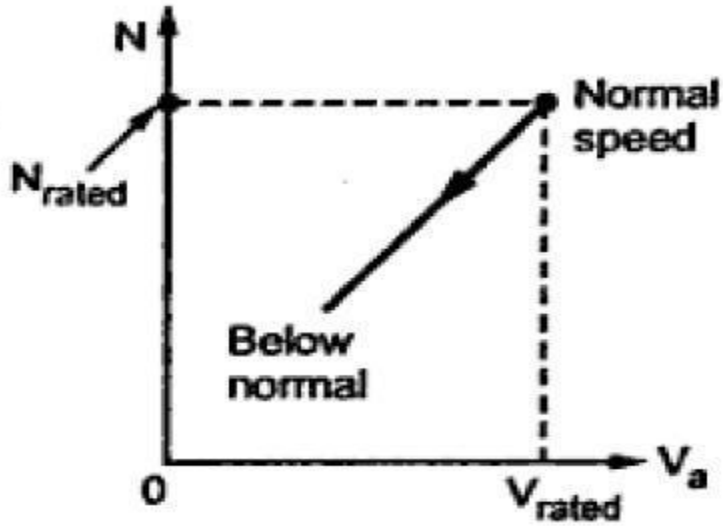
Speed Vs Shunt Field Current

- As speed is inversely proportional to the flux.
- The flux is dependent on the current through the shunt field winding. Thus flux can be controlled by adding a rheostat (variable resistance in series with the shunt field winding as shown in above figure.
- At the beginning the rheostat is kept at minimum.
- The supply voltage is at rated value. So current through the shunt field winding is also its rated value. Hence the speed is also the rated value.
- Resistance is increased, shunt field current is reduced (flux is reduced) and speed is increased beyond its rated value.

ii. Armature voltage control or rheostatic control



Rheostatic Control.



Speed Vs Voltage across Armature

- The speed is directly proportional to the voltage applied across the armature.
- As the supply voltage is normally constant, the voltage across the armature can be controlled by adding a variable resistance in series with the armature as shown in figure above.

iii. Applied voltage control

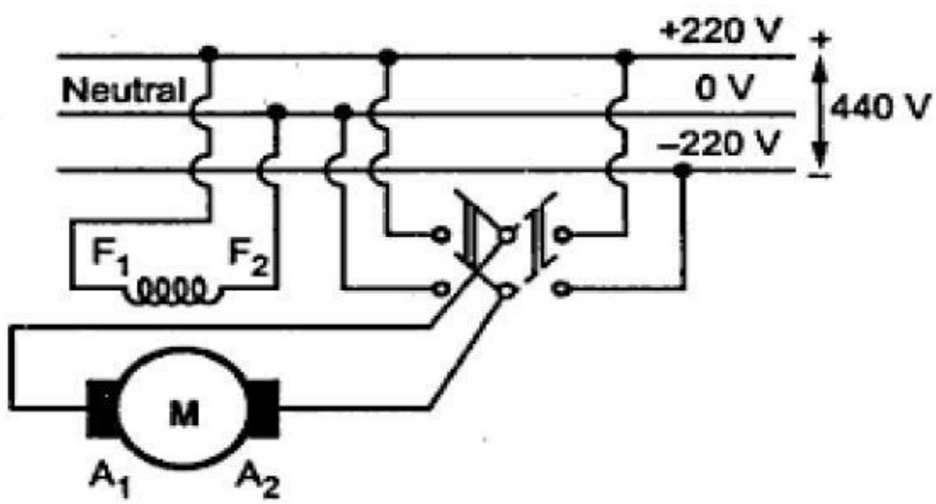
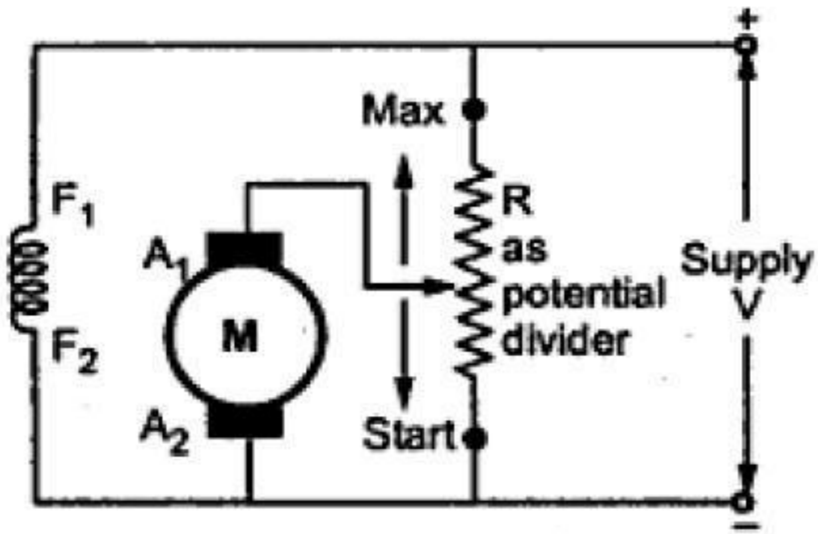


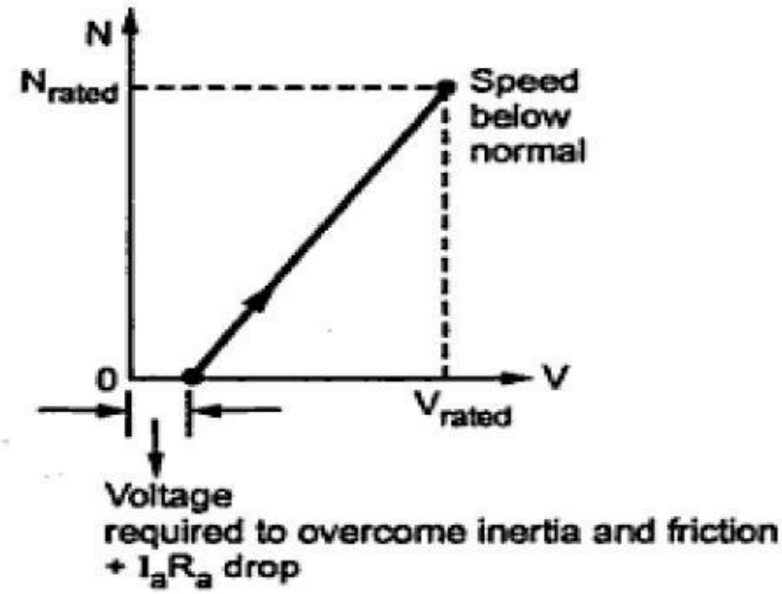
Fig. 1.45 Multiple Voltage Control

- Shunt field of the motor is permanently connected to the fixed voltage supply.
- Armature is supplied with various voltages by means of suitable switchgear arrange

iv. Potential divider control



Potential Divider Arrangement



Speed Vs Voltage

- When the variable rheostat position is at start point shown, voltage across the armature is zero.
- As rheostat is moved towards minimum point shown, the voltage across the armature increases, increasing the speed.
- At maximum point the voltage is maximum and speed is rated value.

7. A 4 pole generator with wave wound armature has 51 slots each having 24 conductors. The flux per pole is 10 mWb. At what speed must the armature rotate to give an induced emf of 0.24 kV. What will be the voltage developed, if the winding is lap connected and the armature rotates at the same speed? [CO1-H2]

Given data

P = 4
No.of slots = 51
No.of conductors/slot = 20
Eg= 0.24 Kv = 240 V
Φ = 10 mW= 10/1000 Web

Find N & Eg at same N?

Solution

Total no. of conductors, Z = 51x20 = 1224

Wave winding, A=2

From EMF equation,

N= Eg60A / ΦZP = (240x60x2)/(10/1000x1224x4) = 612.75 rpm

Lap winding, A=P=4

Eg = PΦZN/60A = (4x10/1000x1224x612.75)/(60x4) = 0.125 kV

8. A 250 volt DC shunt motor has armature resistance of 0.25 ohm on load it takes an armature current of 50A and runs at 750rpm. If the flux of the motor is reduced by 10% without changing the load torque, find the new speed of the motor.
Given data[CO1-H2]

V = 250
R_a =
0.25 I_a =
50
N_1 = 750
$\Phi_2 = 90\%\Phi_1$

Find N_2?

Solution

$$\frac{N_2}{N_1} = \frac{E_{b2}}{E_{b1}} \times \frac{\phi_1}{\phi_2}$$

$E_{b1} = V - I_{a1}R_a = 250-(50x0.25) = 237.5V$

$E_{b2} = V - I_{a2}R_a$

Load torque is constant

Ta1 = Ta2

$\Phi_1 I_{a1} = \Phi_2 I_{a2}$

$I_{a2} = 55.55A$

$E_{b2} = 250-55.55X0.25 = 236.12V$

N_2 = 828 rpm

UNIT- II
TRANSFORMERS

PART A

1. Distinguish between core and shell type transformer. [CO2-L2-April 2015]

In core type, the windings surround the core considerably and in shell type the core surround the winding.

2. What is an ideal transformer and how does it differ from a practical transformer. [CO2-L1-April 2015]

- An ideal transformer is one which does not involve any power loss and does not have any change in frequency. It decreases or increases the input voltage.
- Practical transformer is one which involves power loss and does not have any change in frequency. It decreases or increases the input voltage.

3. Define voltage regulation in a transformer. [CO2-L1-April 2014]

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

% regulation down = $\dfrac{V2_{NL} - V2_{FL}}{V2_{NL}} X\ 100$

% regulation up = $\dfrac{V2_{NL} - V2_{FL}}{V2_{FL}} X\ 100$

4. **Write down the emf equatio n of a transformer. [CO2-L1-Nov 2012]**

Emf induced in primary coil E1 = 4.44 fΦ mN1 volt
Emf induced in secondary coil E2 = 4.44fΦ mN2
volt
Where f is the frequency of AC input Φ m is the maximum value of flux in the core N1, N2 are the number of primary and secon dary turns.

5. Define a transformer. [CO2-L1]

The transformer is a static piece of apparatus by means of which electrical power is transformed from one alternating current circuit to another with desired change in voltage and current without any change in the frequency. It w orks on the principle of mutual induction.

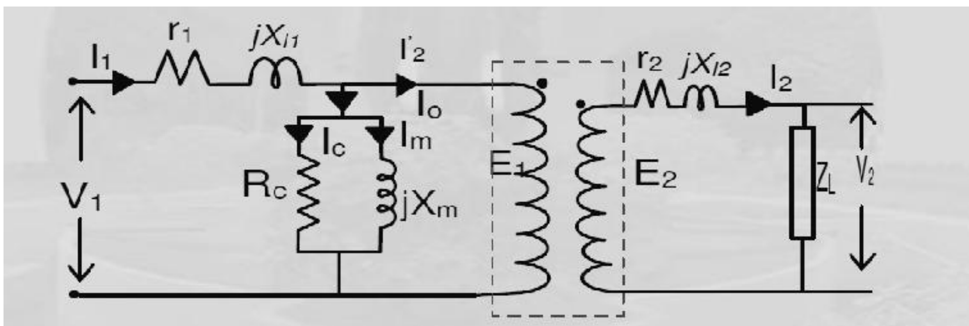
6. Why transformers are rated in kVA? [CO2-L1-April 2010]

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

7. Why the core of a transformer is is laminated? [CO2-L1]

The purpose of laminating the co re in a transformer is to reduce eddy current loss.

8. Draw the equivalent circuit of a transformer. [CO2-L1]



9. An 1100/400 V, 50 Hz single phase transformer has 100 turns on the seco ndary winding. Calculate the number of turns on its primary. [CO2-L2]

We know V1 / V2 = k = N2 / N1
Substituting 400/1100 = 100/N1
N1 = 100/400 x 1100 = 275 turns.

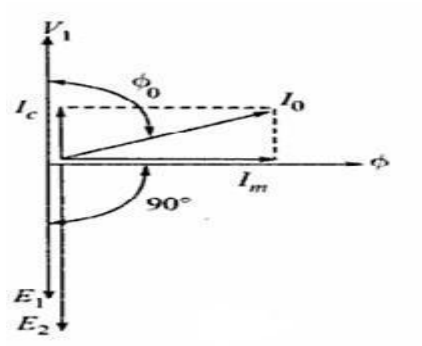
10. What are the advantages of a transformer? [CO2-L1]

- Less I2R loss in the transmission line
- Less voltage drop in the line
- Efficiency of the transmission line is increased
- Volume of the conductor required is less.

11. Define voltage transformation ratio of transformer. [CO2-L1-Nov 2012]
The ratio of secondary induced emf to primary induced emf is called as voltage regulation ratio devoted by K.

$$\frac{E_2}{E_1} = \frac{N_2}{N_1} = K$$

12. Draw the no load phasor diagram of a transformer. [CO2-L1-Nov 2014]



13. Define all day efficiency. [CO2-L1]

All day efficiency is the ratio energy (in kwh) delivered in a 24 hours period to the energy (in kwh) input for the same length of time.

All day efficiency = Output in kwh/Input in kwh (for 24 hrs)

14. Give the factors that determine the thickness of the lamination or stampings. [CO2-L1]

i. Iron loss
ii. Frequency

15. What are the properties of ideal transformer? [CO2-L1]

It has no loss
ii) Its winding has zero resistance.
iii) Leakage flux is zero i.e 100% flux produced by primary links with the secondary
iv) Permeability of core is so high that negligible current is required to establish the flues is it.

16. What are the losses occurring in a transformer? [CO2-L1]

i) Core losses
ii) Copper losses

17. What is meant by core or iron losses? [CO2-L1]

Core or iron losses are caused as the core gets subjected to an alternating flux.

18. What is meant by copper loss? [CO2-L1]

The copper losses are due to the power wasted in the form of I2R due to the resistances of the primary and secondary windings.

19. What is meant by eddy current loss? [CO2-L1]

The induced emf in the core tries to set up eddy currents in the core and hence responsible for the eddy current losses.

20. What is meant by hysteresis losses? [CO2-L1]

Due to alternating flux set up in the magnetic core of the transformer, it undergoes a cycle of magnetization and demagnetization.
Due to hysteresis effect there is loss of energy in this process which is called hysteresis loss.

21. What do you mean by step down transformer? [CO2-L1-May 2013]

If the secondary voltage is greater than primary value, the transformer is called step down transformer.

22. What are the functions of no-load current in a transformer? [CO2-L1]

No-load current produces flux and supplies iron loss and copper loss on no-load.

23. What are the typical uses of auto transformer? [CO2-L1]

- To give small boost to a distribution cable to correct for the voltage drop
- As induction motor starters
- As furnace transformers
- As interconnecting transformers
- In control equipment for single phase and 3 phase elective locomotives

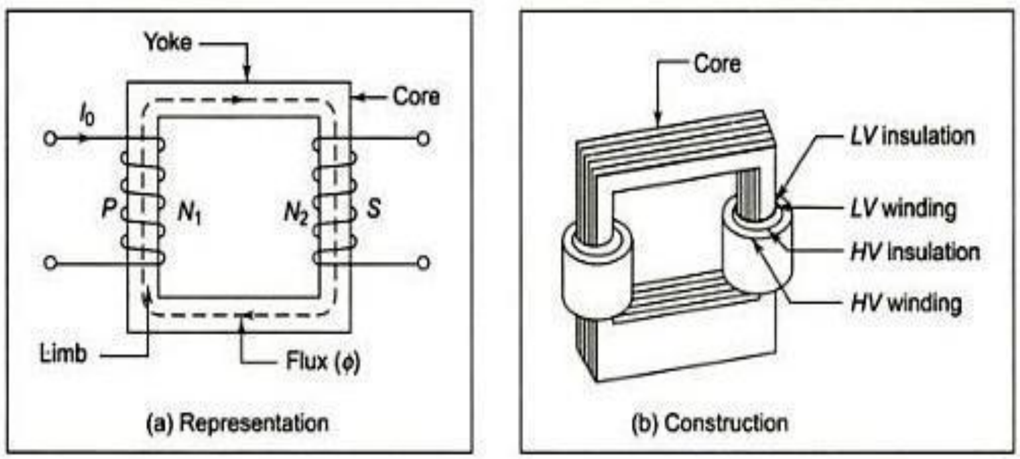
PART-B

1. Describe the construction and also explain the principle of operation of single phase transformer. [CO2-H1-Nov 2012]

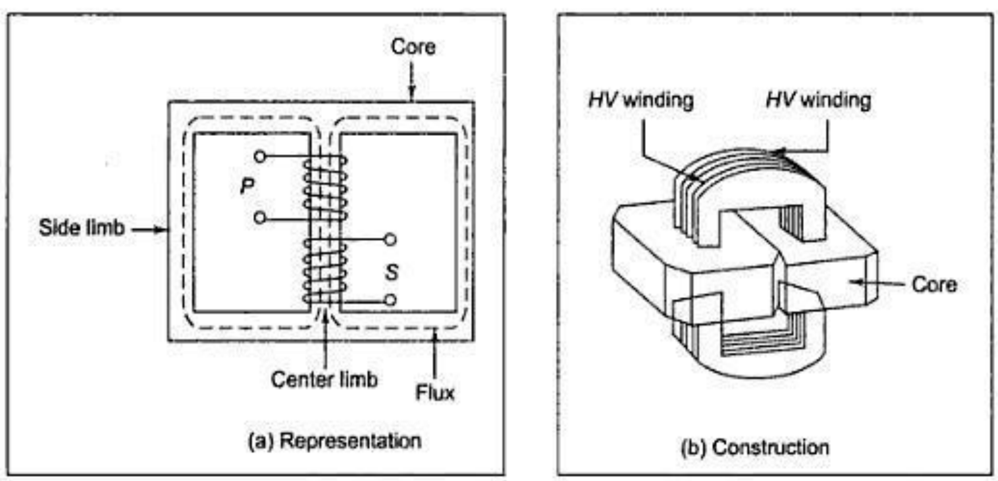
Single Phase Transformer Construction and Principle of Operation

Construction

- It consisted of two electric circuits linked by a common magnetic circuit helped the voltage and current levels to be changed keeping the power invariant.
- It has two types such as core type and shell type which is shown below.



Core Type



Shell Type

- Core type construction the windings are wound around the two legs of a rectangular magnetic core.
- Shell type construction the windings are wound on the central leg of a three legged core.
- There are two basic parts of a transformer i) Magnetic core ii) Winding or coils.
- The core of the transformer is either square or rectangular in size.

- The vertical portion on which coils are wound is called limb.
- The top and bottom horizontal portion is called yoke of the core.
- There are two winding in a transformer such as primary and secondary.
- This excitation winding is called a primary and the output winding is called a secondary.
- The primary and secondary windings are wound with copper (sometimes aluminium in small transformers) conductors.
- As a magnetic medium forms the link between the primary and the secondary windings there is no conductive connection between the two electric circuits.

Principle of operation

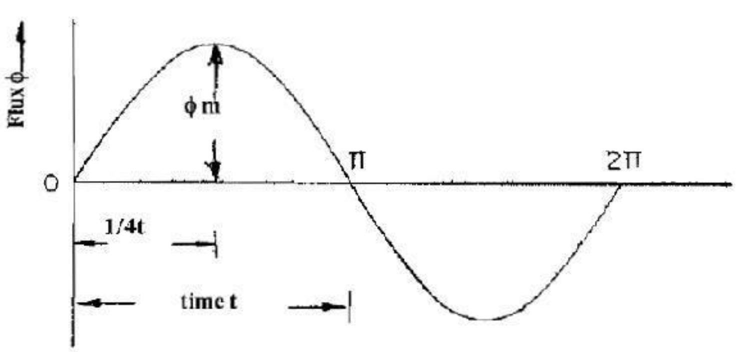
- It operates on the principle of mutual induction between two inductively coupled coils. It consists of two inductive coils which are electrically separated but magnetically coupled to a core. If the coil is connected to a source of alternating voltage an alternating flux is produced in the laminated core. Most of the flux is linked with the coil. Thus flux is called mutual flux.
- As per faraday's laws of electromagnetic induction, an emf is induced in the secondary coil. If the secondary coil circuit is closed, a current flow in it and thus electrical energy is transferred from the first coil to the second coil.

2. **Obtain the mathematical EMF Equation of a transformer and explain each terms [CO2-H1-Apr 2012]**

EMF Equation of Transformer

Let, N_1=Primary number of turns N_2 =Secondary number of turns f = Frequency of supply in Hz

The flux in the core will be sinusoidally as shown below.



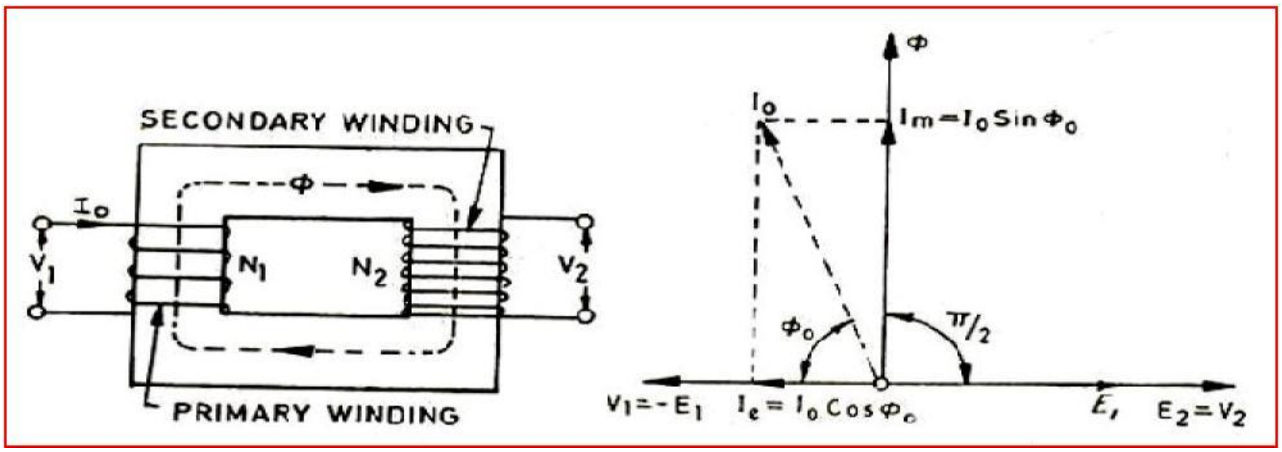
Flux in the Core

The flux in the core increases from zero to Φ_m in one quarter cycle (1/4 second) Therefore, average rate of change of flux = $\Phi_m/(1/4f)$ = 4f Φ_m
Average emf induced per turn = Average rate change of flux x 1 =4f Φ_m Volts
RMS value of induced emf per turn = 1.11 x 4f Φ_m = 4.44f Φ_m
Volts RMS value of induced emf in primary, E_1 = 4.44f Φ_m N_1 Volts
RMS value of induced emf in secondary, E_2 = 4.44f Φ_m N_2 Volts In an ideal transformer on no load, $V_1 = E_1$, $V_2 = E_2$

3. **Explain in detail about the Transformer on No–Load and On-Load with neat phasor diagram. [CO2-H1-Nov 2014]**

Transformer on No–Load

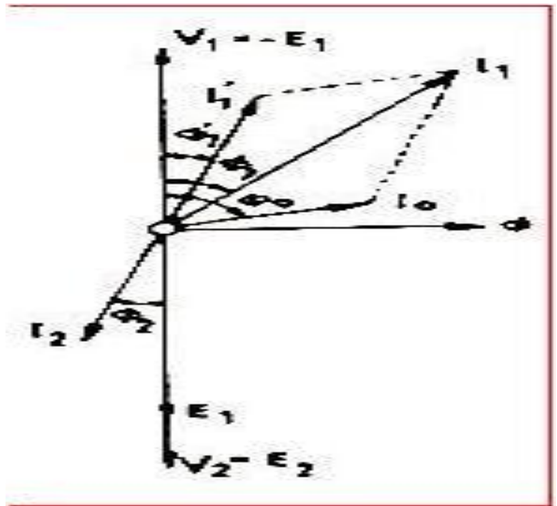
When the primary of a transformer is connected to the source of an ac supply and the secondary is open circuited as shown below, the transformer is said to be on no load. The Transformer on no load alternating applied voltage will cause flow of an alternating current I_0 in the primary winding, which will create alternating flux Φ. No-load current I_0, also known as excitation or exciting current, has two components the magnetizing component Im and the energy component Ie as shown in phasor diagram . Im is used to create the flux in the core and Ie is used to overcome the hysteresis and e ddy current losses occurring in the core in a ddition to small amount of copper losses occurring in the primary only (no copper loss occurs in the secondary, because it carries no current, bei ng open circuited.)



Transformer on No Load

Transformer on Load

The transformer is said to be loaded, when its secondary circuit is compl eted through an impedance or load. The magnitu de and phase of secondary current (i.e. current flowing through secondary) I_2 with respect to secondary terminals depends upon the characteristic of the load i.e. current I_2 will be in phase, lag behind and lead the terminal voltage V_2 respectively when the load is non-inductive, inductive and capacitive. The net flux passing through the core remains almost constant from no-load to full load irrespective of load conditions and so core losses remain almost constant from n o-load to full load. Vector diagram for an ideal transformer supplying inductive load which is shown below.



Phasor Diagram - Transformer on Load

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

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

The self induced emf divided by the primary current gives the reactance of primary and is denoted by

E = 2fπ

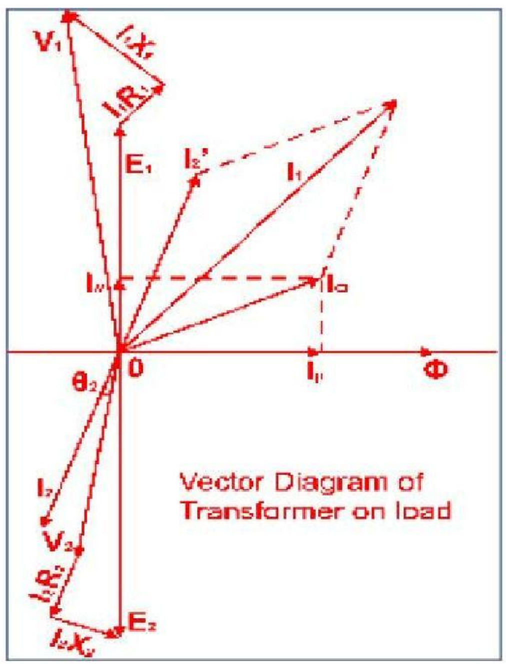
4. **Explain in detail about the Equivalent Circuit of Transformer with neat sketch. [CO2-H1-Nov 2013]**

Equivalent Circuit of Transformer

Equivalent impedance of transformer is essential to be calculated because the electrical power transformer is an electrical power system equipment for estimating different parameters of electrical power system which may be required to calculate total internal impedance of an electrical power transformer, viewing from primary side or secondary side as per requirement. This calculation requires **equivalent circuit of transformer referred to primary** or **equivalent circuit of transformer referred to secondary** sides respectively. Percentage impedance is also very essential parameter of transformer. Special attention is to be given to this parameter during installing a transformer in an existing electrical power system. Percentage impedance of different power transformers should be properly matched during parallel operation of power transformers. The percentage impedance can be derived from equivalent **impedance of transformer** so, it can be said that **equivalent circuit of transformer** is also required during calculation of % impedance.

Equivalent Circuit of Transformer Referred to Primary

For drawing **equivalent circuit of transformer referred to primary**, first we have to establish general **equivalent circuit of transformer** then; we will modify it for referring from primary side. For doing this, first we need to recall the complete vector diagram of a transformer as shown in figure



Vector Diagram

Let us consider the transformatio n ratio be,

$$K = \frac{N_1}{N_2} = \frac{E_1}{E_1}$$

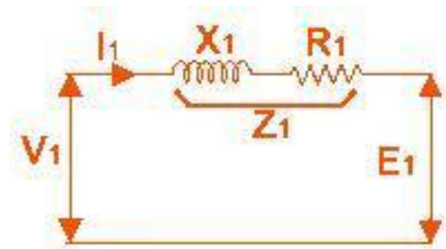
In figure, the applied voltag e to the primary is V_1 and voltage across the primary winding is E_1. Total current supplied to pr imary is I_1. So the voltage V_1 applied to the primary is partly dropped by I_1Z_1 or I_1R_1 + j.I_1X_1 before it appears across primary winding. The voltage appeared across winding is countered by primary induced emf E_1.

$$V_1 - (I_1R_1 + jI_1X_1) = E_1$$

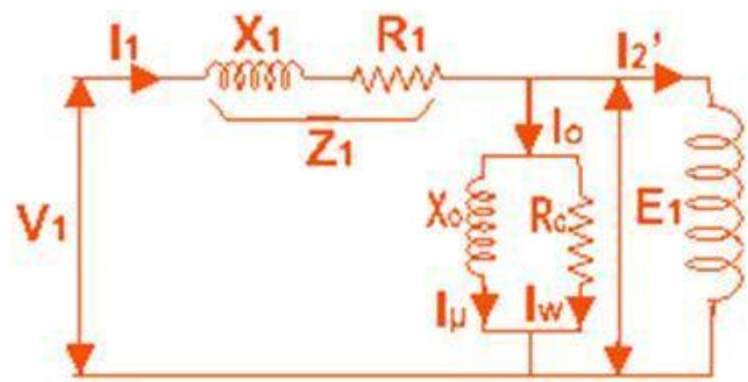
From the vector diagram above, it is found that the total primary current I_1 has two components, one is no - load component I_o and the other is load component I_2'. As this pr imary current has
two a component or branches, so there must be a parallel path with pri mary winding of transformer. This parallel path o f current is known as excitation branch of equivalent circuit of transformer. The resistive and reactive branches of the excitation circuit can be represented as,

$$R_0 = \frac{E_1}{I_w} \ and \ X_0 = \frac{E_1}{I_\mu}$$

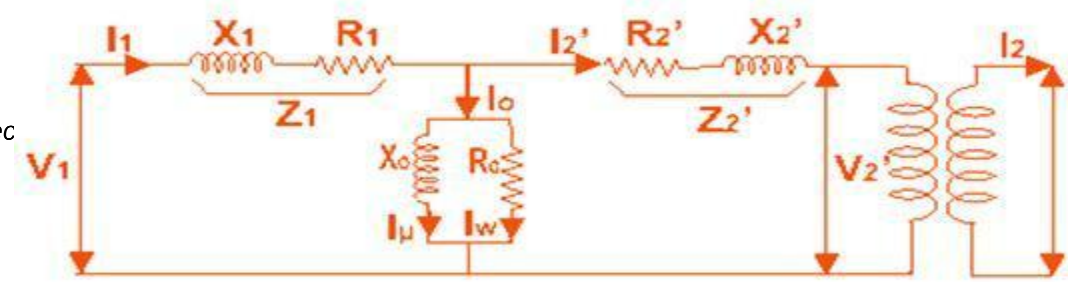
The equivalent circuit for that equation can be drawn as below,



Equivalent Circuit



Equivalent Circuit of Primary Side



Equivalent Circuit of Transformer Referred to Primary

Again $I_2'.N_1 = I_2.N_2$

$$\Rightarrow I_2 = I_2' \frac{N_1}{N_2}$$
$$\Rightarrow I_2 = KI_2'$$

Therefore,

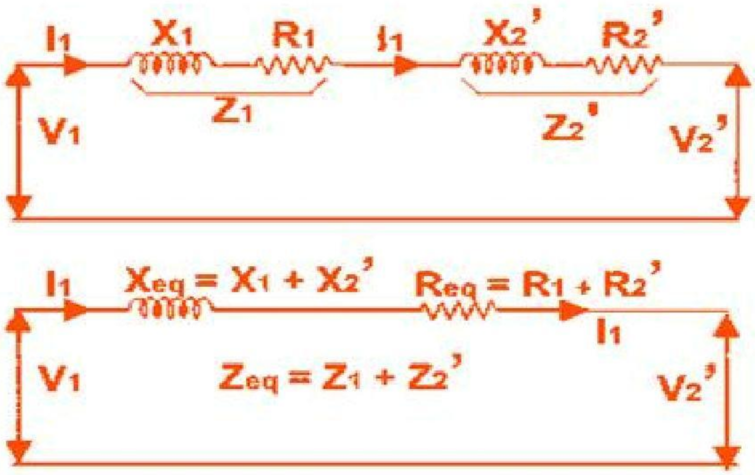
$$KZ_2I_2 = KZ_2KI_2' = K^2Z_2I_2'$$

From above equation, secondary impedance of transformer referred to primary is,
Approximate Equivalent Circuit of Transformer

$$Z_2' = K^2Z_2$$
$$Hence,\ R_2' = K^2R_2 \ \ and\ X_2 = K^2X_2$$

Since I_o is very small compared to I_1, it is less than 5% of full load primary c urrent, I_o changes the voltage drop insignificantly. Hence, it is good approximation to ignore the excitation circuit in approximate equivalent circui t of transformer. The winding resistance and r eactance being in series can now be combined int o equivalent resistance and reactance of transfo rmer, referred to any particular side. In this case it is side 1 or primary side.

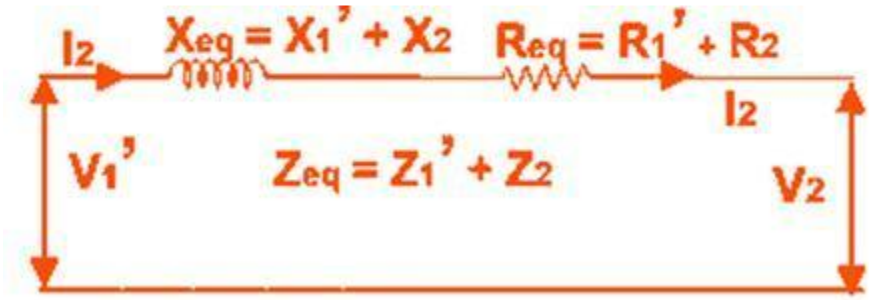
$$Here\ V_2' = KV_2$$



Approximate Equivalent Circuit of Transformer Referred to Primary

Equivalent Circuit of Tra nsformer Referred to Secondary

In similar way, approximate e quivalent circuit of transformer referred to s econdary can be drawn. Where equivalent impeda nce of transformer referred to secondary, can b e derived as,



$$Z_1 = \frac{Z_1}{K^2}$$

$$Therefore,\ R_1' = \frac{R_1}{K^2}$$

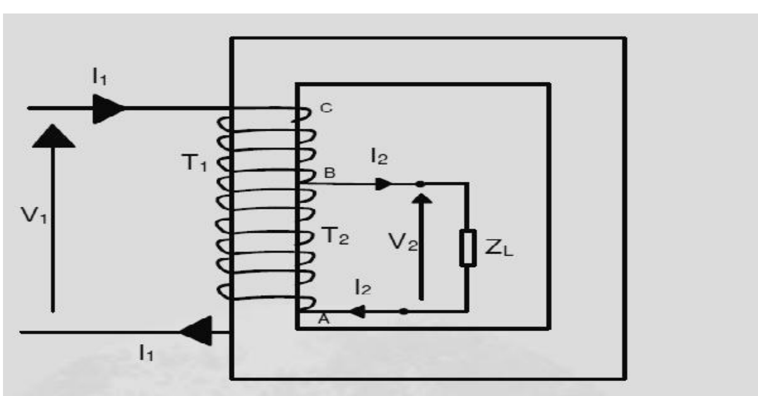
$$X_1' = \frac{X_1}{K^2}$$

Approximate Equivalent Circuit of Transformer Referred to Secondary

$$Here,\ V_1' = \frac{V_1}{K}$$

5.Describe about Auto Transformer with neat sketch. [CO2-H1]

- It is a one winding transf ormer. It works on the principle of self inductio n.
- Physical arrangement of auto transformer is shown below.
- Total number of turns bettween A and C are T1.
- At point B a connection is taken. Section AB has T2 turns. As the volts p er turn, which is proportional to the flux inn the machine, is the same for the whole windin g,
  V1: V2 = T1: T2



Physical Arrangement

- For simplifying analysis, the magnetizing current of the transformer is ne glected.
- When the secondary wi nding delivers a load current of I2 ampere th e demagnetizing ampere turns is I2T2.
- This will be countered by a current I1 owing from the source through the
- T1 turns such that, I1T1 = I2T2
- A current of I1 ampere sh ows through the winding between B and C . The current in the winding between A and B is (I2 -I1) ampere.
- The cross section of the wire to be selected for AB is proportional to this current assuming a constant curr ent density for the whole winding.
- Thus some amount of material saving can be achieved compared to a two winding transformer. To quantify the saving the total quantity of copper used in an auto transformer is expressed as a fraction of that used in a two winding trans former as,

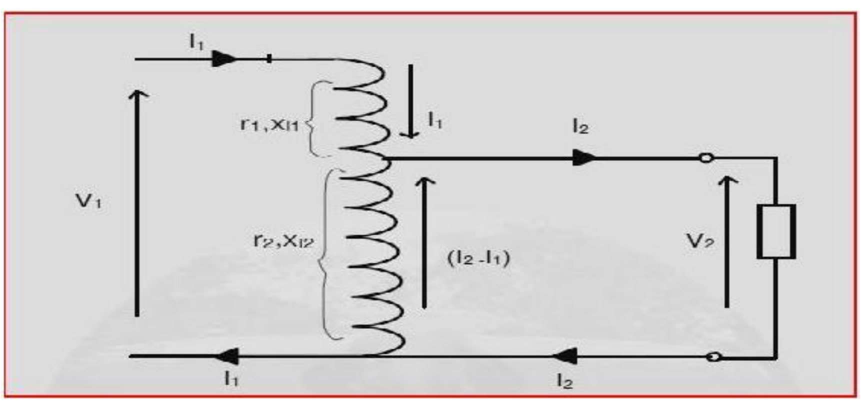
$$\frac{copper\ in\ autotransformer}{copper\ in\ two\ winding\ transformer} = \frac{(T_1 - T_2)I_1 + T_2(I_2 - I_1)}{T_1 I_1 + T_2 I_2}$$

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

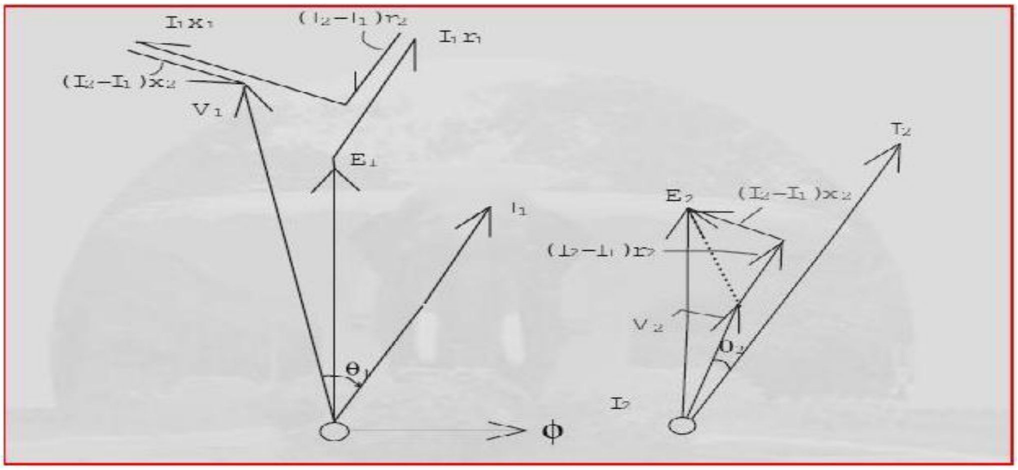
$$\text{But} T_1 I_1 \quad T_2 I_2$$

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

- This means that an auto transformer requires the use of lesser quantity of copper given by the ratio of turns. This rattio therefore denotes the savings in copper.
- The equivalent circuit an d phasor diagram of autotransformer are shown in figures



Equivalent Circuit



Phasor Diagram

- Auto transformers are u sed in applications where electrical isolation is not a critical requirement.
- The wide spread applica tion of auto transformer type of arrangement is in obtaining a variable a.c. voltage from a fixed a.c. voltage supply.
- The secondary voltage is tapped by a brush whose position and hence t he output voltage is variable.

7. A 400 kVA transformer has a primary winding resistance of 0.5 ohm and a secondary winding resistance of 0.001 ohm. The iron loss is 2.5 Kw and the primary and secondary voltages are 5 kV and 320 V respectively. If the power factor of the load is 0.85, determine the efficiency of the transformer (i) on full load and (ii) on half load. [CO2-H2-Nov 2013]

Solution

Rated output = 400 kVA = 400×10^3 kVA

Full load secondary current, I_2 = Rated output/V_2 = 1250 A

Total resistance referred to secondary, $r_{e2} = r_2 + r_1(V_2/V_1)^2$ = 0.033 ohm Full load copper loss, $P_c = I_2^2 r_{e2}$ = 51.5625 Kw

Iron loss, Pi = 2.5 $\times 10^3$ watts

(i) Transformer efficiency at full load and 0.85 pf

$$\eta = \frac{x.V_2 I_2 \cos\phi_2}{xV_2 x_2 \cos\phi_2 + P_i + P_c} x100$$

= 86.2%

(ii) Transformer efficiency at half load and 0.85 pf

x=1/2

$$\eta = \frac{1/2 . V_2 I_2 \cos\phi_2}{1/2 . V_2 x_2 \cos\phi_2 + P_i + P_c} x100$$

= 91.69%

UNIT III INDUCTION MACHINES AND SYNCHRONOUS MACHINES

PART A

1. Write the principle of operation of 3 phase induction motor. [CO3-L1-Nov 2014]

Induction motor works on the principle of faraday's laws of electromagnetic induction. It consists of stator and rotor windings. As these rotor windings or bars rotate within the magnetic field created by the stator magnetizing currents, voltages are induced in them. If the rotor were to stand still, then the induced voltages would be very similar to those induced in the stator windings.

2. Name the types of alternators. [CO3-L1-Nov 2014]

i. Salient pole or projected type
ii. Cylindrical or non salient pole type

3. Compare slip ring and squirrel cage type rotor. [CO3-L1-Apr 2015]

Slip ring rotor: It has windings
Squirrel cage rotor: It has copper bars and shorted through end rings

4. Mention the characteristic features of synchronous motor. [CO3-L1-Apr 2015]

1. Synchronous motors are inherently not self starting. They require some external means to bring their speed close to synchronous speed to before they are synchronized.
2. The speed of operation of is in synchronism with the supply frequency and hence for constant supply frequency they behave as constant speed motor irrespective of load condition
3. This motor has the unique characteristics of operating under any electrical power factor. This makes it being used in electrical power factor improvement.

5. Mention some applications of synchronous motor. [CO3-L1-May 2013]

1) used in machine tools
2) motor generator sets
3) synchronous clocks
4) belt driven reciprocating compressors
5) fans and blowers

6. Why synchronous motor is called so? [CO3-L1-May 2013]

Since the motor is always run with the synchronous speed.

7. Define slip of an induction motor. [CO3-L1-May 2013]

It is the ratio between slip speed to synchronous speed.
Slip = $(N_S - N_r)/N_S$
Where, N_S = Synchronous speed, N_r = Rotor speed

8. Name any four types of single phase induction motors based on method of starting. [CO3-L1-May 2014]

1. Split phase induction motor.
2. Capacitor start induction motor.
3. Capacitor start and capacitor run motor.
4. Shaded pole induction motor.

9.Find the speed at which a 6 pole alternator is to be driven to obtain the frequency of emf induced to be 50 Hz. [CO3-L2-May 2014]

Speed, Ns=120f/p= 120X50/6= 1000 rpm.

10. Write down the relation between speed and frequency. [CO3-L1-Nov 2012]

Synchronous speed, Ns=120f/p
Where, f = Frequency of supply in Hz, p = Number of poles in the stator.

11. What are the two types of 3 phase induction motor? [CO3-L1]

There are two types of 3-phase induction motor based on the type of rotor used:
(i) Squirrel cage induction motor.
(ii) Slip ring induction motor.

12. What are the losses present in the Induction motor? [CO3-L1]

1. Stator copper loss.
2. Stator iron loss.
3. Rotor copper loss.
4. Windage loss & friction loss.

13. Why induction motors are called asynchronous? [CO3-L1]

Because their rotors can never run with the synchronous speed.

14. What is synchronous speed? [CO3-L1]

The speed at which the stator field rotates is called synchronous speed and it depends upon the frequency of supply and number of poles for which the stator is wound.

Ns = synchronous speed in rpm.
= 120 f / p.
f = frequency of supply.
p = Number of poles in the stator.

15. What are the advantages of the slip-ring induction motor over squirrel cage Induction motor? [CO3-L1]

Advantages:

- It is possible to speed control by regulating rotor resistance.
- High starting torque of 200 to 250% of full load voltage.
- Low starting current of the order of 250 to 300% of the full load current.

Hence slip ring induction motors are used where one or more of the above requirements are to be met.

16. What is the function of slip-rings in 3-phase induction motor? [CO3-L1]

The function of slip rings in the case of slip ring induction motor is to add external resistance in the Rotor circuit. If External resistances are added in the rotor circuit, it can be used for speed control operation.

17. What is the use of shading coil in the shaded pole motor? [CO3-L1]

In shaded pole motors, the necessary phase-splitting is produced by induction. These motors have salient poles on stator and a squirrel cage type rotor. The poles are shaded i.e.; each pole carries a copper band one of its unequally divided part called shading band.
When single phase A.C. supply is given to the stator winding, due to shading provided to the poles, a rotating magnetic field is generated.

18. What are the methods of starting of synchronous motor? [CO3-L1]

The various methods of starting of synchronous motor are:

i) Using pony motors
ii) Using damper winding
iii) As a slip ring induction motor
iv) Using small D.C. machine coupled to it.

19. What is meant by synchronous motor? [CO3-L1]

A motor having a speed directly proportional to the frequency of the AC power that operates it.

20. Write the use of damper winding? [CO3-L1]

Damper windings help the synchronous motor to start on its own (self starting machine) by providing starting torque.

21. Compare salient pole rotor and cylindrical rotor. Salient Pole Synchronous [CO3-L1]

Alternator:

- Salient pole Generators will have large diameter and short axial length
- Pole shoes cover 2/3 of the pitch
- Salient Poles are laminated in order to reduce eddy currents

Non-Salient pole Synchronous Alternator:

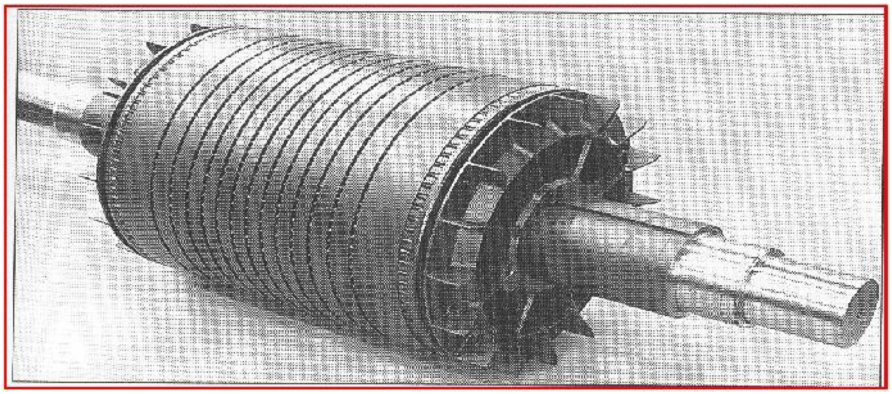
- Non-Salient pole generators will have smaller diameter and longer axial length
- They are used for High speed operation (typically speed will be 1500 and 3000 rpm)
- Better in dynamic balancing because of absence of salient poles.

PART – B

1. **Explain the construction, working of an 3-phase induction motor. And also explain the following rotors (i) Squirrel cage Induction Motor (ii) Phase wound Rotor. [CO3-H1-Nov 2013]**

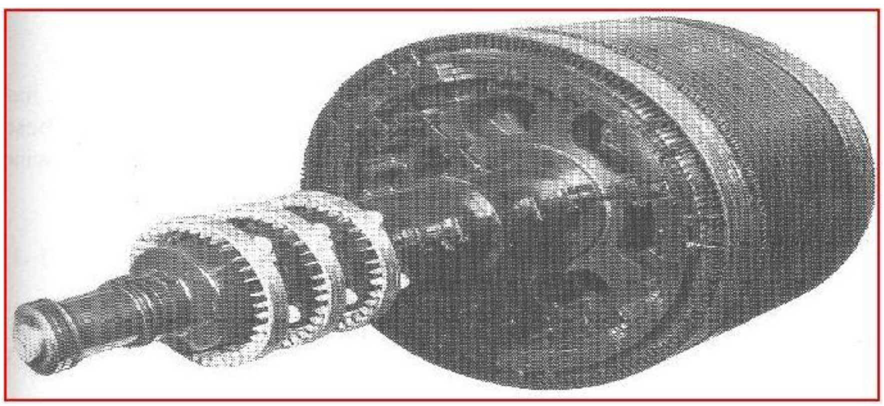
Types, Construction and Working of 3 Phase Induction Motor

Three phase induction motor has two types.
i. Squirrel cage induction motor
ii. Slip ring induction motor
The stator of both motors is same and the rotor is different.**Squirrel cage rotor**

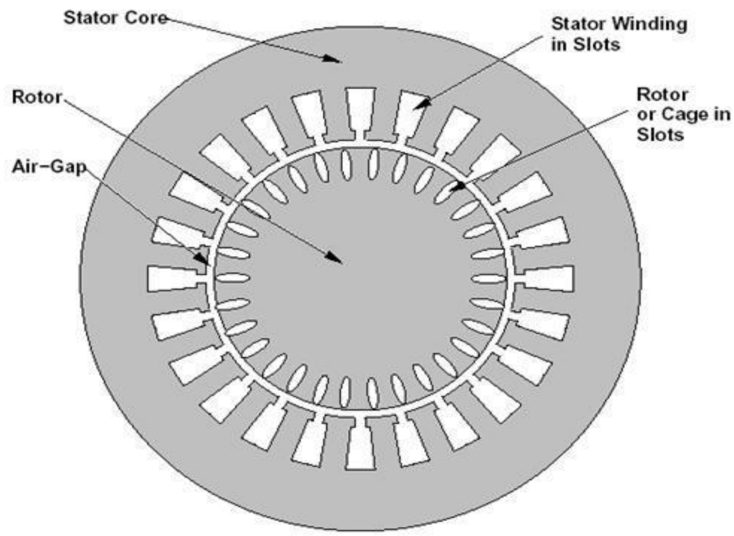


Squirrel Cage Rotor

Wound rotor



Wound Rotor



Physical Arrangement

- A stator consists of steel frame that supports a hollow cylindrical core of stacked laminations.
- Slots on the internal circumference of stator house the stator winding.
- A rotor also composed of punched laminations, with rotor slots for the rotor winding.
- There are two types of rotor windings:
- Squirrel cage windings, which produce squirrel cage induction motor.
- Conventional three phase windings made up of insulated wire, which produce a wound rotor induction motor.
- Squirrel cage rotor consists of copper bars slightly longer than rotor which is pushed in to the slots.
- The ends are welded to copper end rings, so that all the bars are short circuited.
- A wound rotor has three phase winding similar to the stator winding.
- The rotor winding terminals are connected to three slip rings which turn with the rotor.
- The slip rings/brushes allow external resistors to be connected in series with the winding.
- The external resistors are mainly used during start up. Under normal running conditions the windings short circuited externally.

Working

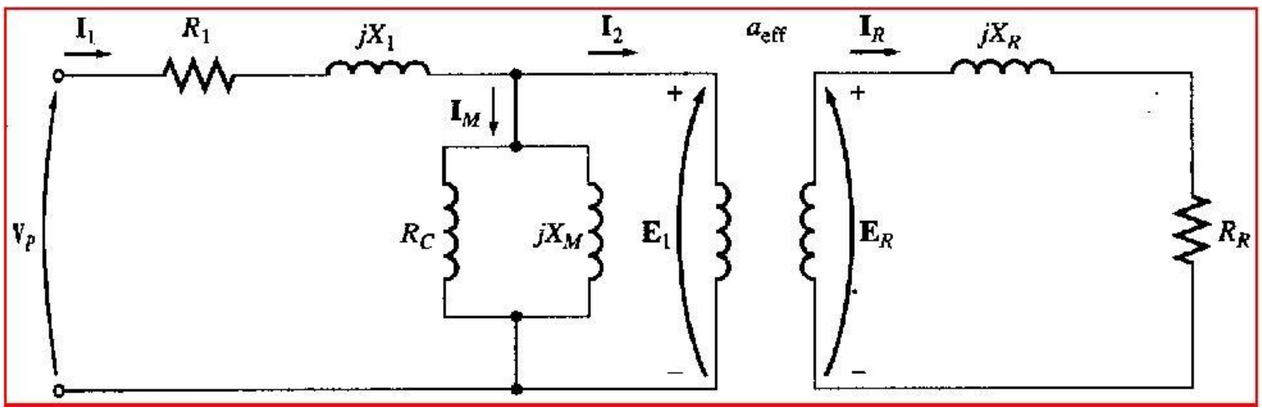
- Induction motor works on the principle of Faraday's laws of electromagnetic induction.
- When the three supply is given to the stator of an induction motor, rotating magnetic field is produced around the stator.
- This field cuts the rotor conductors; an emf is produced as per Faraday's laws of electromagnetic induction.

- The induced voltage produces currents which circulate in a loop around the conductors.
- Since the current carrying conductors lie in the magnetic field, they experience mechanical force (Torque).
- The force is always acts in a direction to drag the conductor along with the magnetic field.

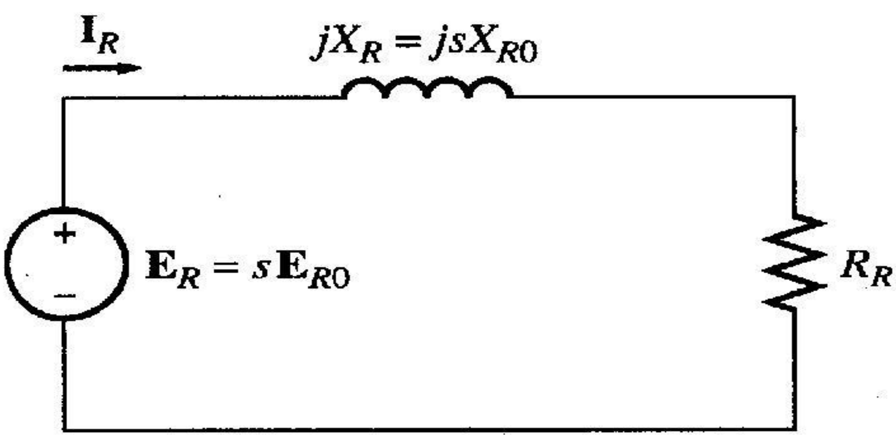
2. Draw the Equivalent circuit diagram for a Three phase Induction Motor and at any slip. And also explain (i) Equivalent circuit of the rotor [CO3-H1-May 2013]

Equivalent Circuit

The induction motor is similar to the transformer with the exception that its secondary windings are free to rotate.



Equivalent Circuit



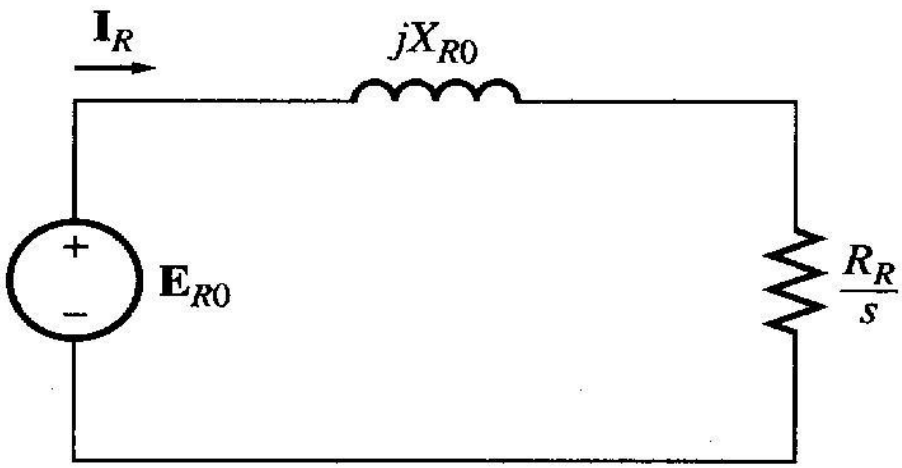
Rotor Equivalent Circuit

Where E_R is the induced voltage in the rotor and R_R is the rotor resistance.
Now we can calculate the rotor current as,

$$I_R = \frac{E_R}{(R_R + jX_R)}$$

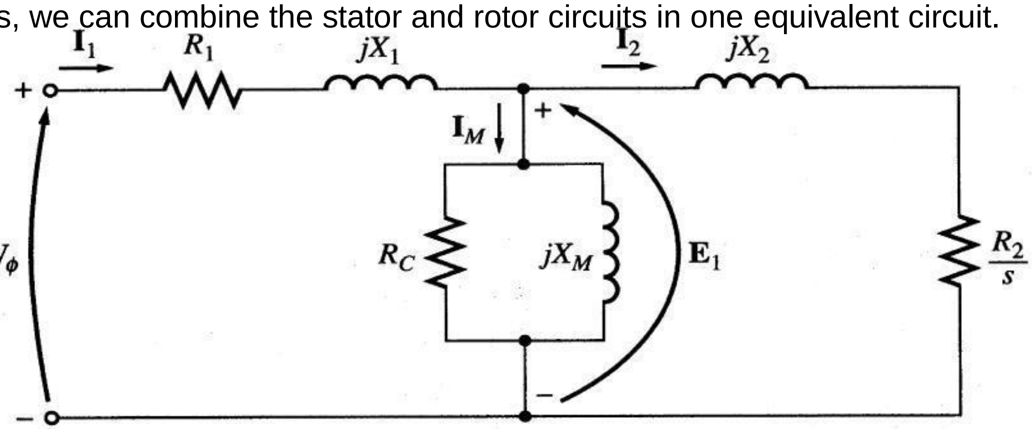
$$R_R = \frac{sE_{R0}}{(R_R + jsX_{R0})}$$

Where E_{R0} is the induced voltage and X_{R0} is the rotor reactance at blocked rotor condition (s = 1).



Reduced Rotor Equivalent Circuit

Now as we managed to solve the induced voltage and different frequency problems, we can combine the stator and rotor circuits in one equivalent circuit.



Commbined (Stator and Rotor) Equivalent Circuit

Where,

$$X_2 = a_{eff}^2 X_{R0}$$

$$R_2 = a_{eff}^2 R_R$$

$$I_2 = \frac{I_R}{a_{eff}}$$

$$E_1 = a_{eff} E_{R0}$$

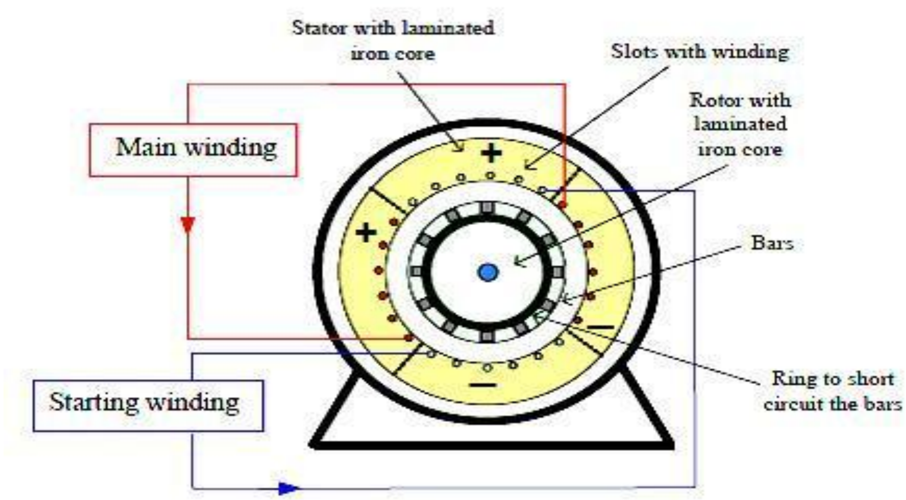
$$a_{eff} = \frac{N_S}{N_R}$$

3.Explain the Construction and Working Principle of Single-Phase Induction Motors with neat sketch. [CO3-H1]

The single-phase induction mac hine is the most frequently used motor for refri gerators, washing machines, clocks, drills, compresssors, pumps, and so forth. The constructional details of sin gle phase induction motor are shown in figure 3. 8.

Stator of Single Phase Induction Motor

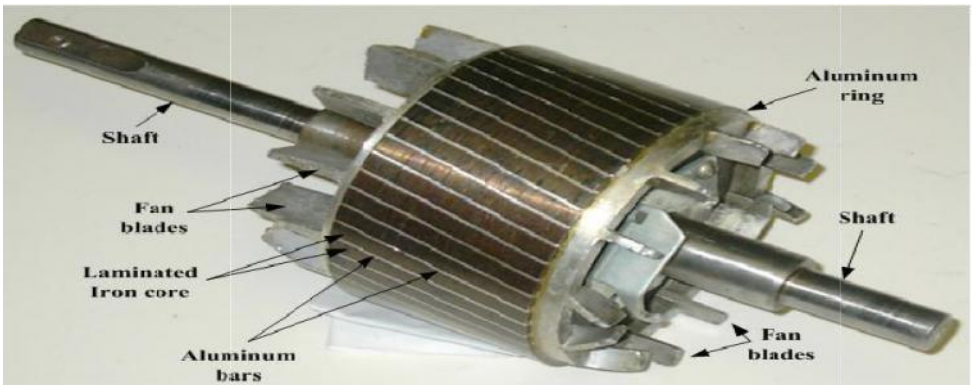
The single-phase motor stato r has a laminated iron core with two windings arranged perpendicularly. One is the main and other is the auxiliary winding or starting winding.



Construction

Rotor of Single Phase Ind uction Motor

The rotor of single phase induction motor is shown in figure 3.9. The co nstruction of the rotor of the single phase induction motor is similar to the squirrel cage three phase inductions motor. The r otor is cylindrical in shape and has slots all o ver its periphery. The slots are not made parallel to each other but are bit skewed as the skewing prevents magnetic locking of stator and rotor teeth and makes the working of induction motor more smooth and quieter. The squirrel cage rotor consists of aluminium, brass or copper bars. These aluminium o r copper bars are called rotor conductors and are placed in the slots on the periphery of the rotor. The rotor conductors are permanent ly shorted by the copper or aluminium rin gs called the end rings. In order to provide mechanical strength these rotor conductor are braced to the end ring and hence form a complete closed circuit resembling like a cage annd hence got its name as "squirrel cage inductio n motor". As the bars are permanently shorted by end rings, the rotor electrical resistance is very small and it is not possible to add external resistance as the bars are permanen tly shorted. The absence of slip ring and brushes make the construction of single phase induction motor very simple and robust.



Rotor

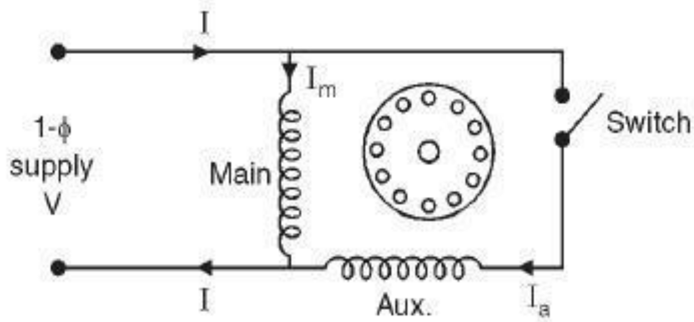
Working Principle of Single Phase Induction Motor

When single phase ac supply is given to the stator winding of single phase induction motor, the alternating current starts flowing through the stator or main winding. This
alternating current produces an alternating flux called main flux. This main flux also links with the rotor conductors and hence cut the rotor conductors. According to the Faraday's
law of electromagnetic induction, emf gets induced in the rotor. As the rotor circuit is closed one so, the current starts flowing in the rotor. This current is called the rotor current. This rotor current produces its own flux called rotor flux. Since this flux is produced due to induction principle so, the motor working on this principle got its name as induction motor. Now there are two fluxes one is main flux and another is called rotor flux. These two fluxes produce the desired torque which is required by the motor to rotate.

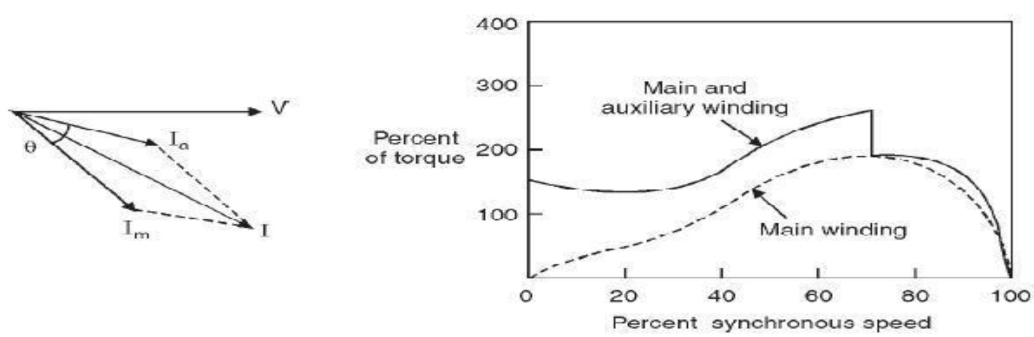
Double Revolving Field Theory

- A single-phase ac current supplies the main winding that produces a pulsating magnetic field.
- Mathematically, the pulsating field could be divided into two fields, which are rotating in opposite directions.
- The interaction between the fields and the current induced in the rotor bars generates opposing torque.

4.Explain the types of Single Phase Induction Motor with neat sketch. [CO3-H1-Nov 2014]
Resistance Split-Phase Motor



Schematic Diagram

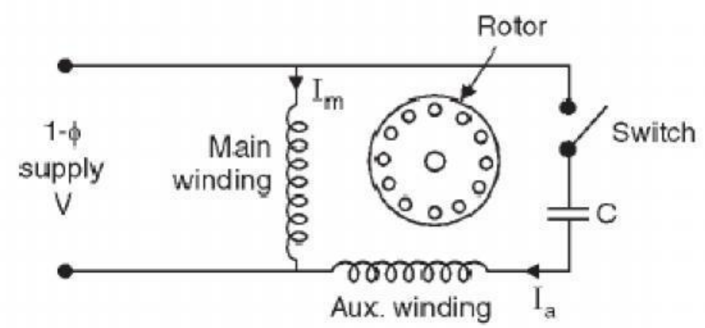


Phasor Diagram and Torque – Speed Characteristics

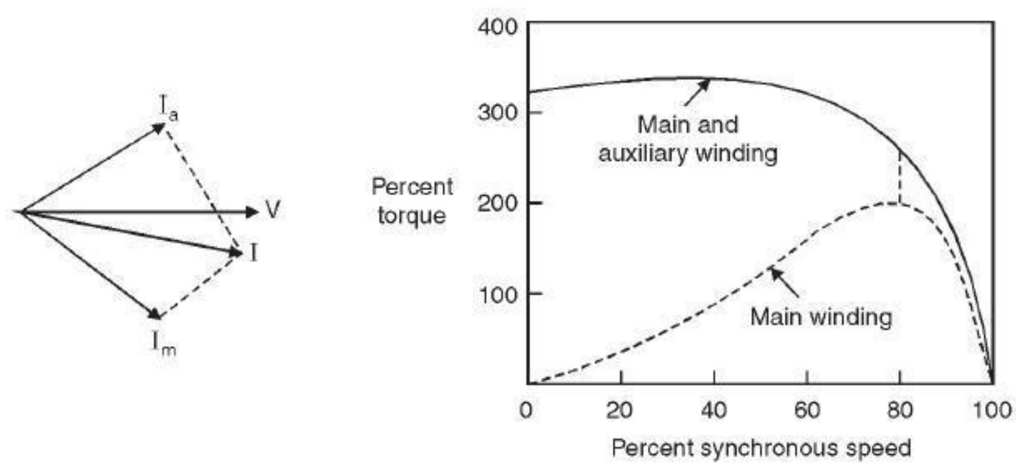
The schematic (circuit) diagram of this motor is given in Figure 3.10. As detailed earlier, another (auxiliary) winding with a high resistance in series is to be added along with the main winding in the stator. This winding has higher resistance to reactance ratio as compared to that in the main winding, and is placed at a space angle of from the main winding as given earlier. The phasor diagram of the currents in two windings and the input voltage is shown in Figure 3.11. The switch, S (centrifugal switch) is in series with the auxiliary winding. It automatically cuts out the
auxiliary or starting winding, when the motor attains a speed close to full load speed. The motor has a starting torque of 100−200% of full load torque, with the starting current as 5 -7 times the
full load current. The torque-speed characteristics of the motor with/without auxiliary winding are shown in Figure 3.11.The change over occurs, when the auxiliary winding is switched off as given earlier. The direction of rotation is reversed by reversing the terminals of any one of two windings, but not both, before connecting the motor to the supply terminals. This motor is used in applications, such as fan, saw, small lathe, centrifugal pump, blower, office equipment, washing machine, etc.

2. Capacitor-Start Motor

The schematic (circuit) diagram of this motor is given in Figure 3.12. It may be observed that a capacitor along with a centrifugal switch is connected in series with the auxiliary winding, which is being used here as a starting winding. The capacitor may be rated only for intermittent duty, the cost of which decreases, as it is used only at the time of starting. The function of the centrifugal switch has been described earlier. The phasor diagram of two currents as described earlier, and the torque-speed characteristics of the motor with/without auxiliary winding, are shown in Figure 3.13. This motor is used in applications, such as compressor, conveyor, machine tool drive, refrigeration and air-conditioning equipment, etc.



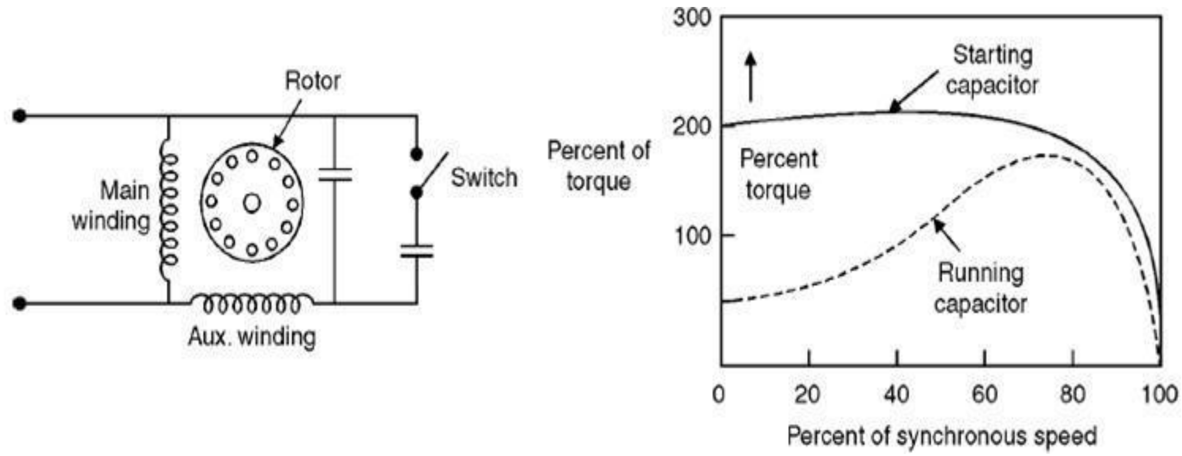
Schematic Diagram



Phasor Diagram and Torque – Speed Characteristics

3. Capacitor-start and Capacitor-run Motor

The schematic (circuit) diagram of this motor is given in Figure 3.14. In this motor two capacitors C_S for starting, and C_r for running, are used. The first capacitor is rated for intermittent duty, as described earlier, being used only for starting. A centrifugal switch is also needed here. The second one is to be rated for continuous duty, as it is used for running. The schematic(circuit) diagram and the phasor diagram of two currents in both cases, and the torque-speed characteristics with two windings having different values of capacitors, are shown in figure 3.14. Hence, using two capacitors, the performance of the motor improves both at the time of starting and then running. This motor is used in applications, such as compressor, refrigerator, etc.



Schematic Diagram, Phasor Diagram and Torque – Speed Characteristics

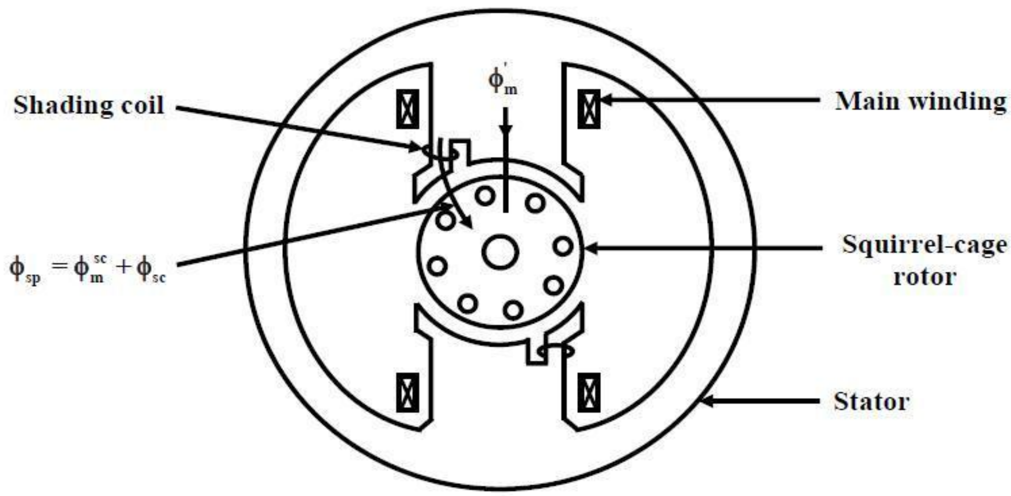
Beside the above two types of motors, a Permanent Capacitor Motor with the same capacitor being utilized for both starting and running, is also used. The power factor of this motor, when it is operating (running), is high. The operation is also quiet and smooth. This motor is used in applications, such as ceiling fans, air circulator, blower, etc.

4. Shaded-pole Motor

A typical shaded-pole motor with a cage rotor is shown in figure 3.15. This is a single-phase induction motor, with main winding in the stator. A small portion of each pole is covered with a short-circuited, single-turn copper coil called the shading coil. The sinusoidally varying flux created by ac (single-phase) excitation of the main winding induces emf in the shading coil. As a result, induced currents flow in the shading coil producing their own flux in the shaded portion of the pole.

The reversal of the direction of rotation, where desired, can be achieved by providing two shading coils, one on each end of every pole, and by open-circuiting one set of shading coils and by short-circuiting the other set.

The fact that the shaded-pole motor is single-winding (no auxiliary winding) self-starting one, makes it less costly and results in rugged construction. The motor has low efficiency and is usually available in a range of 1/300 to 1/20 kW. It is used for domestic fans, record players and tape recorders, humidifiers, slide projectors, small business machines, etc. The shaded-pole principle is used in starting electric clocks and other single-phase synchronous timing motors.



Shaded-Pole Motor

5. With neat sketch, explain the principle, construction, working and types of a three phase alternator. [CO3-H1]

Types, Construction and Working Principle of Alternator

Types of Alternator

Alternators or synchronous generators can be classified in many ways depending upon their application and design. According to application these machines are classified as-

1. Automotive type - used in modern automobile.
2. Diesel electric locomotive type - used in diesel electric multiple units.
3. Marine type - used in marine.
4. Brush less type - used in electrical power generation plant as main source of power.
5. Radio alternators - used for low brand radio frequency transmission.

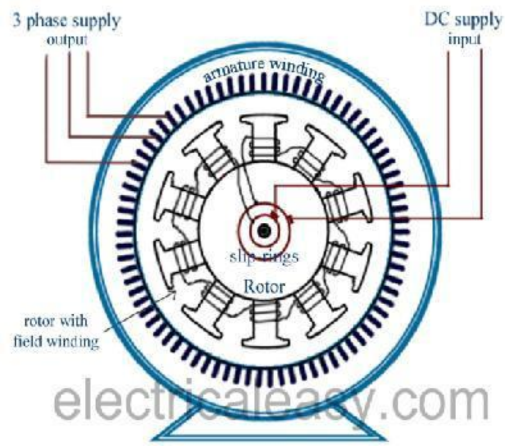
These ac generators can be divided in many ways but we will discuss now two main types of alternator categorized according to their design. This are;

1. Salient pole type. It is used as low and medium speed alternator. It has a large number of projecting poles having their cores bolted or dovetailed onto a heavy magnetic wheel of cast iron or steel of good magnetic quality. Such generators are characterized by their large diameters and short axial lengths. These generator are look like big wheel. These are mainly used for low speed turbine such as in hydro electric power plant.

2. Smooth cylindrical type. It is used for steam turbine driven alternator. The rotor of this generator rotates in very high speed. The rotor consists of a smooth solid forged steel cylinder having a number of slots milled out at intervals along the outer periphery for accommodation of field coils. These rotors are designed mostly for 2 pole or 4 pole turbo generator running at 36000 rpm or 1800 rpm respectively.

Construction and working principle of Alternator

Construction



Construction

Main parts of the alternator, obviously, consists of stator and rotor. But, the unlike other machines, in most of the alternators, field exciters are rotating and the armature coil is stationary.

Stator:

Unlike in DC machine stator of an alternator is not meant to serve path for magnetic flux. Instead, the stator is used for holding armature winding. The stator core is made up of lamination of steel alloys or magnetic iron, to minimize the eddy current losses.

Why Armature Winding Is Stationary In An Alternator?

- At high voltages, it easier to insulate stationary armature winding, which may be as high as 30 kV or more.
- The high voltage output can be directly taken out from the stationary armature. Whereas, for a rotary armature, there will be large brush contact drop at higher voltages, also the sparking at the brush surface will occur.
- Field exciter winding is placed in rotor, and the low dc voltage can be transferred safely.
- The armature winding can be braced well, so as to prevent deformation caused by the high centrifugal force.

Rotor:

There are two types of rotor used in an AC generator / alternator:
(i) Salient and (ii) Cylindrical type

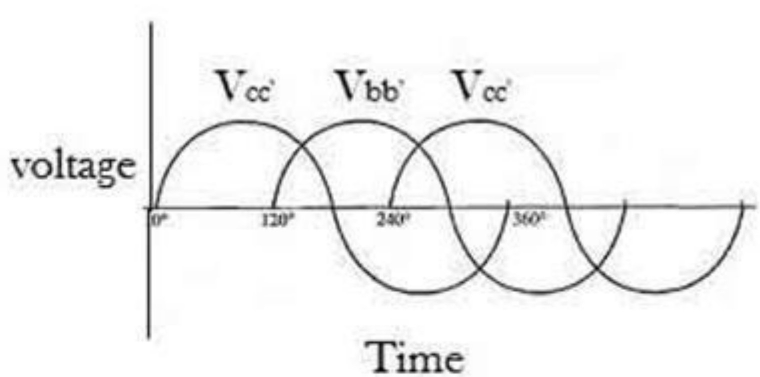
1. Salient pole type: Salient pole type rotor is used in low and medium speed alternators. Construction of AC generator of salient pole type rotor is shown in the figure above. This type of rotor consists of large number of projected poles (called salient poles), bolted on a magnetic wheel. These poles are also laminated to minimize the eddy current losses. Alternators featuring this type of rotor are large in diameters and short in axial length.

2. Cylindrical type: Cylindrical type rotors are used in high speed alternators, especially in turbo alternators. This type of rotor consists of a smooth and solid steel cylinder having slots along its outer periphery. Field windings are placed in these slots.

Working principle

The working principle of alternator is very simple. It is just like basic principle of DC generator. It also depends upon Faraday's law of electromagnetic induction which says the current is induced in the conductor inside a magnetic field when there is a relative motion between that conductor and the magnetic field.

The DC supply is given to the rotor winding through the slip rings and brushes arrangement. Having understood the very basic principle of alternator, let us now have an insight into its basic operational principal of a practical alternator. During discussion of basic working of alternator, we have considered that the magnetic field is stationary and conductors (armature) are rotating. But generally in practical construction of alternator, armature conductors are stationary and field magnets rotate between them. The rotor of an alternator or a synchronous generator is mechanically coupled to the shaft or the turbine blades, which on being made to rotate at synchronous speed N_S under some mechanical force results in magnetic flux cutting of the stationary armature conductors housed on the stator. As a direct consequence of this flux cutting an induced emf and current starts to flow through the armature conductors which first flow in one direction for the first half cycle and then in the other direction for the second half cycle for
each winding with a definite time lag of 120° due to the space displaced arrangement of 120° between them as shown in the figure 3.17. This particular phenomena result in 3φ power flow
out of the alternator which is then transmitted to the distribution stations for domestic and industrial uses.



Three phase generated voltage

6.Derive the expression for Equation of Induced EMF of an Alternator. [CO3-H1-Apr 2013]

Let Φ = Flux per pole, in Wb
P = Number of poles
N_S = Synchronous speed in r.p.m.
f = Frequency of induced e.m.f. in Hz

Z = Total number of conductors
Z_{ph} = Conductors per phase connected in series
$\therefore Z_{ph} = Z/3$ as number of phases = 3.
Consider a single conductor placed in a slot.
The average value of e.m.f. induced in a conductor
$= d\Phi/dt$
For one revolution of a conductor,
e_{avg} per conductor = (Flux cut in one revolution)/(time taken for one revolution)
Total flux cut in one revolution is $\Phi \times P$
Time taken for one revolution is $60/N_S$ seconds.

∴ e_{avg} per conductor = ΦP / (60/N_S)

= Φ (PN_S/60) .... (1)

But f = PN_S/6120

∴ PN_S/60= 2f

Substation in (1),

e_{avg} per conductor = 2 f Φ volts

Assume full pitch winding for simplicity i.e. this conductor is connected to a conductor which is 180^o electrical apart. So there two e.m.f.s will try to set up a current in the same direction i.e. the two e.m.f. are helping each other and hence resultant e.m.f. per turn will be twice the e.m.f. induced in a conductor.

∴ E.m.f. per turn = 2 x (e.m.f. per conductor)

= 2 x (2 f Φ)

= 4 f Φ volts

Let T_{ph} be the total number of turn per phase connected in series. Assuming concentrated winding, we can say that all are placed in single slot per pole per phase. So induced e.m.f.s in all turns will be in phase as placed in single slot. Hence net e.m.f. per phase will be algebraic sum of the e.m.f.s per turn.

Average E_{ph} = T_{ph} x (Average e.m.f. per turn) Average Eph = T_{ph} x 4 f Φ

But in a.c. circuits R.M.S. value of an alternating quantity is used for the analysis. The form factor is 1.11 of sinusoidal e.m.f.

K_f = (R.M.S.)/Average = 1.11 .... for sinusoidal

∴ R.M.S. value of E_{ph} = K x Average value

∴ ∴ E = 4.44 x f Φ T_{ph} volts .... (2)

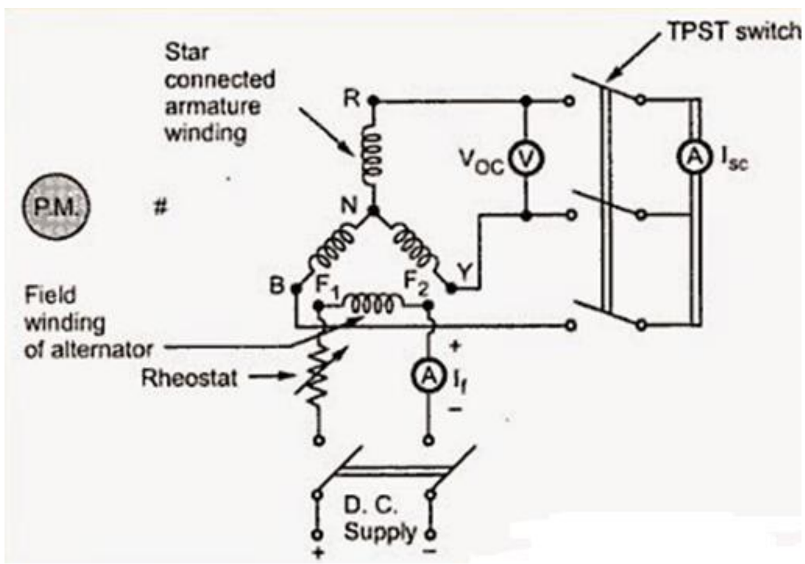
7.Explain the methods to determine the Voltage Regulation of an Alternator. [CO3-H1]

Generally we use this method for high speed Alternators or synchronous generator .This method is also known as E.M.F. method. Before calculating the voltage regulation we need to calculate the following data.

1. Armature Resistance per phase [Ra]

2. Open Circuit characteristics which are a graph between open circuit voltage [Vo.c.] and field current.
3. Short circuit characteristics which is a graph between short circuit current [Is.c.] and field current.

The circuit diagram to perform this O.C test and S.C test is given below. The alternator or synchronous generator is coupled with the prime mover to drive alternator at synchronous speed. The armature of alternator or synchronous generator is connected to TPST switch. The three terminals of switch are short circuited by an ammeter. The voltmeter is connected between two line terminals to measure o.c voltage of the alternator. For the purpose of excitation, a D.C supply is connected field winding .A rheostat is also connected in series with D.C supply which is used to vary the field current i.e field excitation.



Circuit Diagram

OC TEST

1) By using the prime mover start the alternator or synchronous generator and adjust its speed to the Synchronous speed.
2) Note that rheostat should be in maximum position and switch on the D.C supply.
3) The T.P.S.T. switch should be kept open in the armature circuit.
4) Field current is varied from its min. value to the rated value using the rheostat. So

now flux increases, which lead to increase in the induced e.m.f. The voltmeter now the actual line value of open circuit voltage .For various values of field currents, voltmeter readings are noted in a table.

Now plot a graph between o.c phase voltage and field current. The graph obtained is called o.c.c.

SC TEST

1) After the o.c test, the field rheostat should be kept at maximum position, reducing field current to min. value.
2) Now the T.P.S.T switch is closed.
3) The armature gets short circuited because ammeter has negligible resistance. Now increase the field excitation is increased gradually till full load current is obtained through armature windings. This is observed on the ammeter connected in the armature circuit .Tabulate the values of field current and armature current values obtained.
4) Now plot a graph between s.c armature current and field current. The graph obtained is called S.C.C.

The S.C.C is a straight line passing through origin but o.c.c resembles a B.H curve of a magnetic material.
Zs can be determined from O.C.C and S.C.C for any load condition. The value of Ra should be known now. So it can be measured by applying d.c. known voltage across the two terminals.

Now $$Z_s = \sqrt{(R_a)^2 + (X_s)^2}$$

$\therefore$ $$X_s = \sqrt{(Z_s)^2 - (R_a)^2} \ \Omega/ph$$

So now induced e.m.f per phase is calculated as follows:

$$E_{ph} = \sqrt{(V_{ph}\cos\phi + I_a R_a)^2 + (V_{ph}\sin\phi \pm I_a X_a)^2}$$

regulation of alternator or synchronous generator is calculated by using the Voltage below formula,

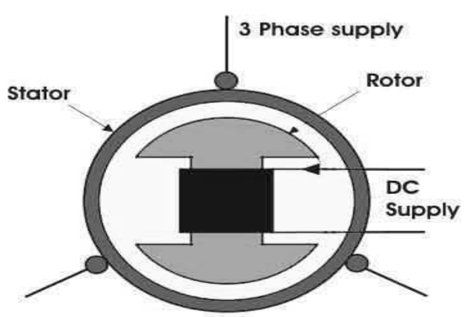
$$\% \text{ Regulation} = \frac{E_{ph} - V_{ph}}{V_{ph}} x100$$

8.Explain the Working Principle and Methods of Starting of Synchronous Motors[CO3-H1]

Based on the type of input we have classified it into single phase and 3 phase motors. Among 3 phase induction motors and synchronous motors are more widely used.
When a 3 phase electric conductors are placed in a certain geometrical positions (In certain angle from one another) there is an electrical field generate. Now the rotating magnetic field rotates at a certain speed, that speed is called synchronous speed. Now if an electromagnet is present in this rotating magnetic field, the electromagnet is magnetically locked with this rotating magnetic field and rotates with same speed of rotating field. Synchronous motors are called so because the speed of the rotor of this motor is same as the rotating magnetic field. It is basically a fixed speed motor because it has only one speed, which is synchronous speed, and therefore no intermediate speed is there or in other words it's in synchronism with the supply frequency. Synchronous speed is given by

$$N_s = \frac{120f}{p}$$

Construction



Synchronous Motor

Normally its construction is alm ost similar to that of a 3 phase induction motor, except the fact that the rotor is given dc supply, the reason of which is explained later. No w, let us first go through the basic construction of this type of motor
From the above figure, it is clear that how this type of motors are designed. The stator is given is given three phase supply and the rotor is given dc supply.

Main Features of Synchronous Motors

- Synchronous motors are inherently not self starting. They require some external means to bring their speed close to synchronous speed to before they are synchronized.
- The speed of ope ration of is in synchronism with the supply freq uency and hence for constant suppl y frequency they behave as constant speed motor irrespective of load condition
- This motor has th e unique characteristics of operating under any electrical power factor. This makes it being used in electrical power factor improvement.

Principle of Operation

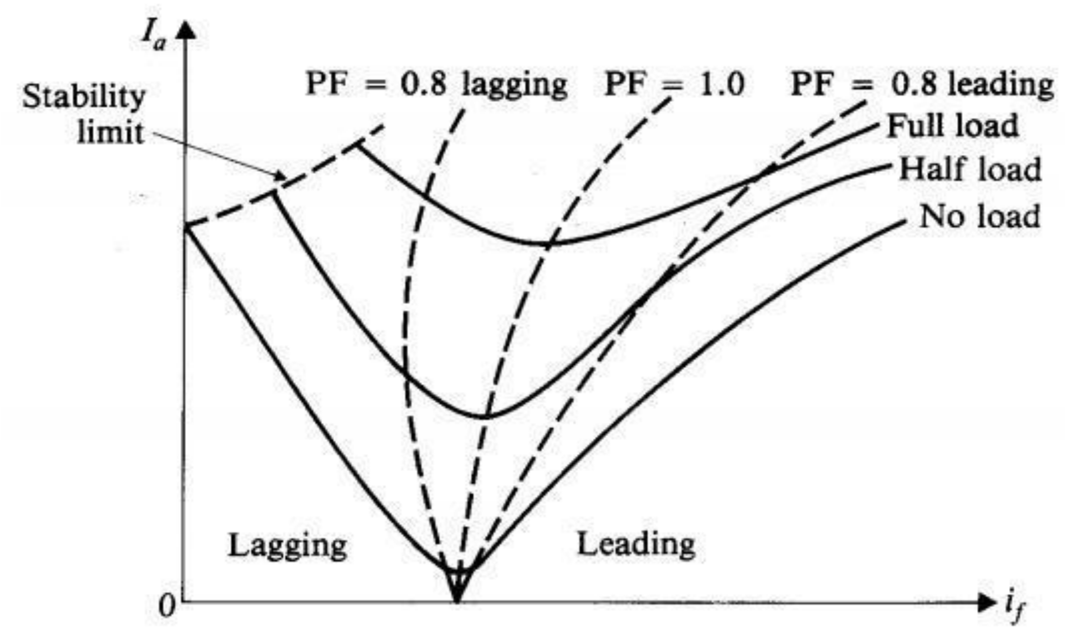
Synchronous motor is a doubly excited machine i.e two electrical inputs are p rovided to it. Its stator winding which consists of a 3 phase winding is provided with 3 phase su pply and rotor is provided with DC supply. The 3 phase stator winding carrying 3 phase currents produces 3 phase rotating magnetic flux. The roto r carrying DC supply also produces a constant f lux. Considering the frequency to be 50 Hz, fro m the above relation we can see that the 3 phase rotating flux rotates about 3000 revolution in 1 min or 50 revolutions in 1 sec. At a particular instant rotor and stator poles might be of same polarity (N-N or S-S) causing repulsive force on rotor and the very
next second it will be N-S causing attractive force. But due to inertia of the rotor, it is unable to rotate in any direction due to attractive or repulsive force and remain in standstill condition. Hence it is not self starting.
To overcome this inertia, rotor is initially fed some mechanical input which rotates it in same direction as magnetic field to a speed very close to synchronous speed. After some time magnetic locking occurs and the synchronous motor rotates in synchronism with the frequency.

Methods of Starting of Synchronous Motor

1. Synchronous motors are mechanically coupled with another motor. It could be either 3 phase induction motor or DC shunt motor. DC excitation is not fed initially. It is rotated at speed very close to its synchronous speed and after that DC excitation is given. After some time when magnetic locking takes place supply to the external motor is cut off.
2. Damper winding: In case, synchronous motor is of salient pole type, additional winding is placed in rotor pole face. Initially when rotor is standstill, relative speed between damper winding and rotating air gap flux in large and an emf is induced in it which produces the required starting torque. As speed approaches synchronous speed, emf and torque is reduced and finally when magnetic locking takes place, torque also reduces to zero. Hence in this case synchronous is first run as three phase induction motor using additional winding and finally it is synchronized with the frequency.

9.Discuss about the V Curves [CO3-H1]

The curve which is drawn between armature current and field is called V-curves which are shown in Figure



V-curves

In general, over excitation will cause the synchronous motor to operate at a leading power factor, while under excitation will cause the motor to operate at a lagging power factor. The synchronous motor thus possesses a variable-power factor characteristic.

UNIT IV

BASICS OF MEASUREMENT AND INSTRUMENTATION

PART-A (2 Marks)

1. What is meant by accuracy of an instrument?[CO4-L1]

It is the degree of closeness with which the instrument reading approaches the true value of the quantity to be measured is called accuracy.

2. With one example explain “instrument error”? [CO4-L1]

These errors arise due to three main reasons

I) Due to inherent shortcomings in the instrument

ii) Due to misuse of the instruments

iii) Due to loading effects of instruments.

3. What is the importance of static characteristic of system? [CO4-L1]

Some applications involve the measurement of quantities that are either constant or vary slowly with time under these conditions, it is possible to define a set of criteria that gives a meaning description of quality of measurement without interfacing with dynamic description that involve the use of the differential equations.

4. What is the significance of calibration? [CO4-L1]

Calibration is the process of making an adjustment or making a scale so that the readings of an instrument agree with the accepted and certified standard. The calibration offers a guaranteed to the device or instrument that is operating with required accuracy under the stipulated environmental conditions.

5. What is importance of dynamic characteristic of the system? [CO4-L1]

Invariably measurement systems, especially in industrial, aerospace and biological applications are subjected to inputs that vary with time. The input varies from instant to instant and therefore, so does the output, the behavior of the system under conditions is desired by its dynamic response.

6. Why must instrument be calibrated? [CO4-L1]

Calibration of all instrument is important since it efforts since it efforts the opportunity to check the instrument against a known standard and subsequently to find errors and accuracy. Calibration of the particular instruments with either 1)primary standard,2)secondary standard 3)an instrument of known accuracy.

7. List three main functional elements in the most of the measurement system? [CO4-L1]

i)A primary sensing element/variable conversion element
ii)A detector
iii)An indicator, recorder or a storage device data presentation

8. Define the static error of an instrument or measurement system. [CO4-L1]

Difference between the measured value and true value of the quantity

$$\delta A = Am - At$$

Where

δA-error value
Am-measured value
At-true value.

9. Differentiate threshold and resolution[CO4-L1]

RESOLUTION	THRESHOLD
The smallest change in the measured quantity that will produce a deductible change in instrument reading.	The minimum value below which no outputs change can be detected.

10.How are the absolute and relative errors exposed mathematically? [CO4-L1]

Absolute error=Yn-Xn

Where

Yn-Expected value
Xn-Measured value

Relative Error=Ag-As/Ag

Where

Ag-Actual value
As-Nominal value

11. What are the static characteristics of instrument system? [CO4-L1]

The main static characteristics are accuracy, sensitivity, Resolution, precession, Drift, Static error, Dead zone, Threshold

12. Define gross error with example[CO4-L1]

This error mainly occurs due to careless or lack of experience of a human being. This error covers human mistakes in readings, recordings and calculating result. This error also appears due to incorrect adjustment of instruments. This error may also be called as personal errors.

13. What do you mean by absolute error of the measurement? [CO4-L1]

The algebraic difference between the indicated value and the true value of the quantity to be measured is called Absolute error

E=At-Am

Where

At-true value of the quantity

Am-measured value of the quantity it does not indicate precisely, accuracy of the measurements

14. What are primary standards? where are they used? [CO4-L1]

It is accurate absolute standards, which can be used as ultimate reference standards. These standards are maintained at National standard laboratories in different countries. These represents fundamental units as well as some electrical and mechanical derived units are calibrated independently.

15. Which are the different types of standard? [CO4-L1]

i) International standard
ii) Primary standard
iii) Secondary standard
iv) Working standard

16. Define the dynamic response of a system and distinguish between steady state response and transient response? [CO4-L1]

The output of the measuring system various with time for certain period and them attains an equilibrium position to show the final reading the time for which o/p various with time is called transient period and the corresponding response is called transient response.

STEADY STATE RESPONSE: The response which exists as time approaches infinity.

17.A meter reads 127.50V and the true value of the voltage is 127.43V.Dtermine the static error correction for this instrument[CO4-L2]

Static error-e=At-Am

=127.43-127.50

=-.07

18. What is the function of the manipulation element in a measured system? [CO4-L1]

It manipulates the signal, preserving the original nature of the signal. It involves the change in numerical value of the signal.

19. Define the term precision and sensitivity? [CO4-L1-Nov 2013]

PRECISION:

It denotes closeness with which individual measurement are departed or distributed about the average of number of measured values.

SENSITIVITY;

It is the ratio of changes in the output of an instrument to a change in the value of the quantity to be measured.

Sensitivity=$\frac{\text{Infinite signal change in o/p}}{\text{Infinite signal change in i/p}}$

20. Give the factors to be considered for selecting a transducer. [CO4-L1]

1. According to principle used in transduction.
2. Basic of the output which may be continuous function of time or the output may be in discrete steps.

21. Define transducer with example. [CO4-L1]

An inverse transducer is defined as device which converts an electrical quantity into a non-electrical quantity. It is a precision actuator which has an electrical input and a low power non-electrical output.

22. Explain the principle of piezo electric transducer and name any two piezoelectric materials. [CO4-L1]

If a varying potential is applied to the axis of a crystal, it will change the dimension of the crystal thereby deforming it. this effect is known as piezo-electric effect.

1. Rochelle salts
2. Ammonium dihydrogen phosphate.

23. State piezoelectric effect. [CO4-L1]

When two opposite faces of a thin slice of certain crystals are subjected to a mechanical force then opposite charges are developed on the forces of the slice. The magnitude of the electric potential between the two faces is proportional to the deformation produced. This phenomenon is called piezoelectric effect.

24. How the transducers are classified on the basic of principle of transduction? [CO4-L1]

1. Linear displacement
2. Rotary displacement.

25. Differentiate sensor from transducer. [CO4-L1]

Transducer will convert one form of energy into another form while sensors will sense receive the signal from receiver.

Transducer will not required any external supply as that of sensors.

26**. Define inverse transducers with example. [CO4-L1]**

An Inverse transducers is defined as device which converts the electrical quantity into an non-electrical quantity.

Example.

Piezoelectric crystal, translational and angular moving coil elements.

27. What is the output out of an LVDT provided with unidirectional excitation, while measuring a displacement 3cm? [CO4-L1]

In general 1mm displacement produces the voltage of 300mv

3cm produce=30*300mv

=9000mv

=9v.

28. How is strain gauge used for pressure measurement? [CO4-L1]

If a metal conductor is stretched or compressed its resistance changes on account of the fact that both length and diameter of the conductor change. The moving principle is piezo resistive effect (Change in the value of resistivity of the conductor when it is strained).

29. Define transducer or what is the function of transducer? [CO4-L1]

A device which converts a physical quantity into a proportional transducer. A transducer is also called pick up.

30. Distinguish between active and passive transducer. [CO4-L2]

Sl.No	Active transducer	Passive transducer
1	They do not require any external source or power for their operation	They require an source of power their operation.
2.	They are all self generating type transducer	They are not self generating type transducer

3.	They produce electrical parameter such as voltage or current proportional to the physical parameter under measurement.	They produce electrical parameter such as inductance, resistance or capacitance in response to the physical parameter under measurement.
	Eg:Thermocouple, photocell piezoelectric transducer	Eg: thermister, RTD, LDR, LVDT, phototransistor.

31. What are direct digital transducers? [CO4-L1]

Digital transducer produces an electrical output in the form of pulse which forms an unique code. Unique code is generated for each discrete value sensed

32. List any four characteristic of transducers[CO4-L1]

The characteristics of transducer are,

i)Accuracy

ii) Ruggedness

iii)Linearity

iv)Repeatability

v) High reliability &Output stability

vi)Sensitivity

vii) Dynamic range

viii) Speed of response.

33.Define factor of strain gauge. [CO4-L1]

The gauge factor of the strain gauge is define as the unit charge in resistance for per unit change in length of the strain gauge wire mathematically it is defined as,

G.F=$\frac{\Delta R/R}{\Delta l/l}$

34. Mention the uses of capacitive transducer[CO4-L1]

1) Using variable distance capacitance transducer can be used for the measurement of force and weight up to 50N.

2) Using variable area capacitive transducer thin installation measurement can be carried out.

3) The variable permittivity capacitive transducer are used for the measurement of moisture in wood.

4) Leaky capacitance hydrometer is used for the measurement of humidity.

35. What is the classification of encoder? [CO4-L1]

1. Tachometer transducer
2. Incremental encoders
3. Absolute encoders.

PART-B

1. Define and explain the static characteristics of an Instrument? [CO4-H1-Nov 2012]

The static characteristics are defined for the instruments which measure the quantities which do not vary with time. The various static characteristics are

i) Accuracy
ii) Precision
iii) Resolution
iv) Error
v) Sensitivity
vi) Threshold
vii) Reproducibility
viii) Zero drift
ix) Stability
x) Linearity

i)Accuracy:-

It is a measure of the closeness with which an instrument measures the true value of the quantity

Accuracy is expressed in different ways

*Accuracy as percentage of full scale reading

If the instrument is uniform scale that time it is measured by percentage of full scale reading.

* Accuracy as percentage of full scale reading

If is the best method.

* Accuracy as percentage of scale span

For the instrument, if a_{max} is the maximum point for which scale is calibrated, full scale reading and a_{min} is the lowest reading on scale span.

*point accuracy:-

It is specified at only one particular point of scale.

ii)Precision

It is the measure of the consistency (or) repeatability of a series measurements. Although does not necessarily imply accuracy. The precision of a given by

$$\text{Precision}=1-\left|\frac{X_i-\bar{X}}{X_i}\right|$$

X_i-Value of i^{th} measurement
x-Average value of n measurements.
The precision is composed of two characteristics
*Conformity:-

The conformity is a necessary, but not sufficient condition for precision similarly, precision is necessary but not the sufficient condition for accuracy .

*Significant figures:-

The precision of the measurement is obtained from the number of significant figures, in which reading is expressed. The significant figures convey the actual information about the magnitude and measurement precision of the quantity.

***error:-**

The algebraic difference between the indicated value and the true value of the quantity to be measured is called an error

$E=A_t-A_m$

A_t-measured value of the quantity
A_m-true value of the quantity.

$$\%er=\frac{A_t-A_m}{A_t}\times 100$$

iv)sensitivity:-

It is defined as the ratio of the changes in the o/p of the instrument to a change in the value of the quantity to be measured.

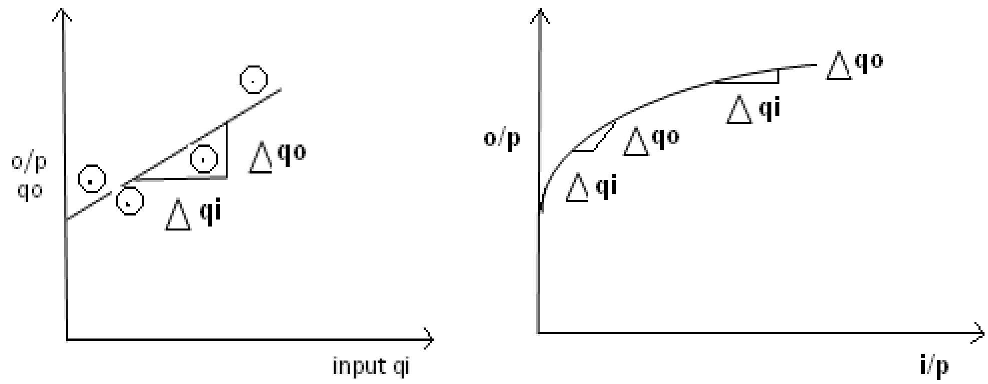
$$\text{Sensitivity}=\frac{\Delta q_o}{\Delta q_i}=\frac{change\ \ in\ o/p}{change\ \ in\ i/p}$$

v) Resolution

It is the smallest increment of quantity being measured which can be deflected with certainty by an instrument.

vi) Threshold

If the input quantity is slowly varied from zero onwards. The o/p does not change until some minimum value of the i/p is exceeded. This minimum value of the input is called threshold.

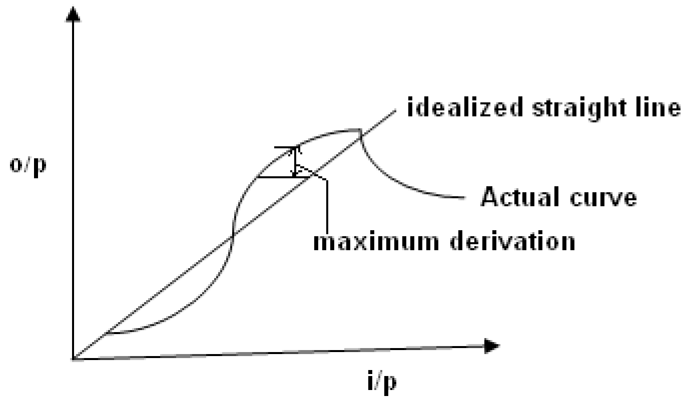


Calibration curve linear inverse sensitivity=Calibration curve non-linear deflection factor

vii) Linearity:-

The instrument requires the property of linearity that is the output various linearity decoding to the input. The linearity is defined as ability to reproduce the i/p characteristics symmetrically and linearly.

∴linearity is other words defined as the maximum deviation of the actual calibration wave from the idealized straight line expressed as a percentage of full scale reading or a percentage of the actual reading



Linearity

$$\therefore Linearity = \frac{Maximum\ \ derivation\ \ of\ \frac{o}{p}\ from\ \ idealized\ \ straight\ line}{full\ \ scale\ \ deflection}$$

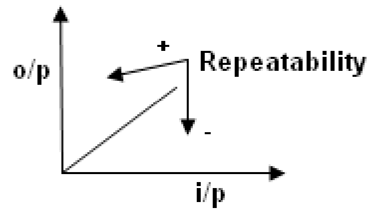
viii)Zero drift

Drift is the gradual shift of the instrument indication, over an extended period during which the value of the i/p variable does not changes. Zero drift is defined as the deviation in the instrument o/p with time, from its zero value when the variable to be measured is constant.

Affect drift:
- Stray electric field, Mechanical vibration
- stray magnetic field, wear and tear
- Temp change
- Contamination of metal, change in atomic structure

ix) Reproducibility:-

It is the degree of closeness with which a given value may be reproducibility indicates no drift in the instrument.



The repeatability is defined as o/p variation of scale reading and is random in nature.

x) Stability:-

The ability of an instrument to retain its performance throughout its specified operating life and the storage life is defined as stability.

***Tolerance:-**

The maximum allowable error in the measurement is specified interms of some value which is called tolerance.

***range:-**

The minimum and maximum value of a quantity for which an instrument is desired to measure is called its range (or) span.

***Bias:-**

The eronstant error which exits over the full range of measurement of an instrument is called bias.

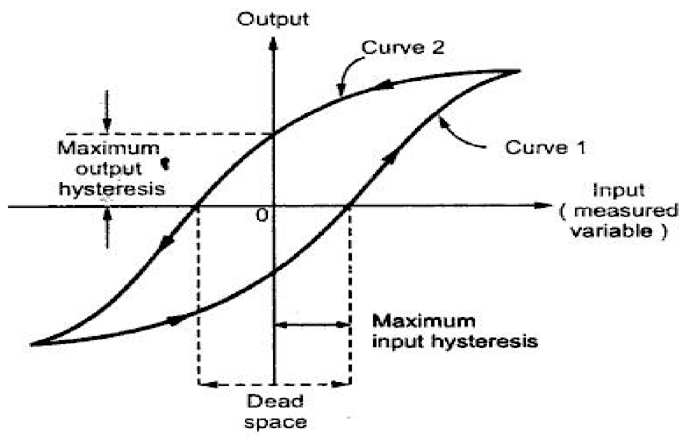
Dead space:-

It is possible that till i/p increases beyond certain value, the o/p does not change so for certain range of i/p values there is no change in o/p. This range of i/p is called dead space.

Span drift:-

If there exists a proportional change in the indication, all along the upward scale then the drift from nominal characteristics is called span drift.

***Hysteresis:-**



If the i/p of the instrument is increased from a-ve value, the o/p also increases, this is in curve 1.If the curve is now decreased steadily the o/p does not follow the curve but lags by certain value.

2. Explain Dynamic characteristics of the Instruments? [CO4-H1]

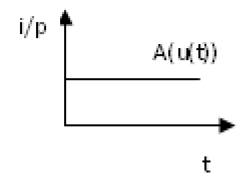
*When the instruments is subjected to rapidly varying i/ps, the relation between the i/p and o/p becomes totally different then that incase of static i/p

*If i/p varies ,o/p also varies, the behavior of system under such condition is called dynamic response of the system.

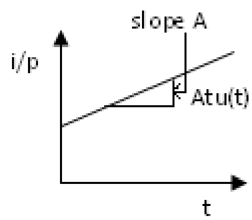
*Due to energy storing element measuring system rarely responded instantaneously to the changes in the measured variables.
*The measuring system goes through the transient state before it settees down to its steady state position.
*Usually the dynamic behavior of the system expressed mathematically by the differential equation. the dynamic behavior or the measuring system is determined by applying some known and predetermined variations of i/p to the sensing element.

i)Step i/p

This represents sudden, instanteous and finite change in the i/p This examples are sudden application of tf switch in an electrical circuit.



ii)ramp i/p



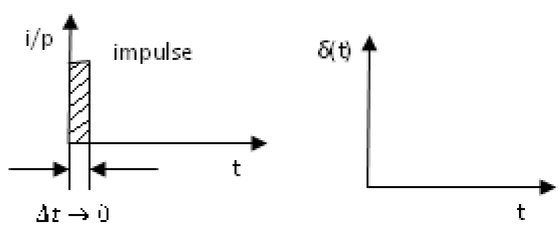
the input to be measured varies linearly with time.
iii)Parabolic i/p:-

i/p signal which is proportional to the square of the time and hence represents constant acceleration.

iv)impulse i/p

It exits only at A=0 and has zero value at any other time

$F(t)=0$ for $t \neq 0$



Speed of response:-

It is rapidity with which the system responds to the changes in the quantity to be measured. It gives the information about how fast the system reacts to the changes in the i/p. It indicates activeness of the system.

Fidelity:-

It indicates how faithfully the system reproduces the changes in the i/p. It is the ability of an instrument to produce a wave shape identical to wave shape of i/p with respect to time.

Lag:-

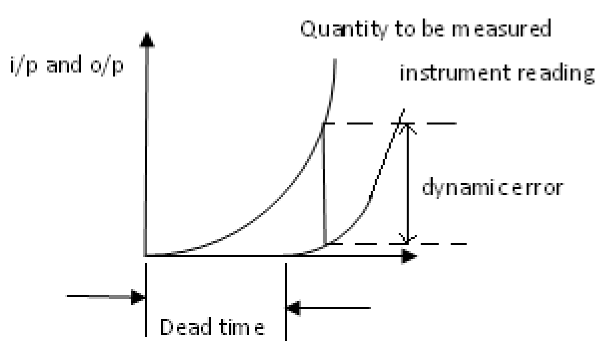
Every system takes some time, whatever small it may be to respond to the changes in the measured variable. This retardation or delay in the response of a system is called lag.

Retardation lag:-

In this case, response begins after some time called dead time, after the application of i/p, such a delay shifts the response along time exits and hence causes the dynamic error.

Dynamic error:-

It is the difference between the true value of the variable to be measured, changing with time and the value indicated by the measurement system, assuming zero static error,



3. Explain different types of errors in measurement? [CO4-H1]

The static error is defined earlier as the difference between the true value of the variable and the value indicated by the instrument.

The static error arise due to

*gross errors

*systematic errors
*Random errors

Gross error:-

The gross errors mainly occur due to cardess or lack of experience of a human being. There cover human mistakes in reading, recordings and calculating results. These errors also occur due to incorrect adjustments of instruments. These errors cannot be treated mathematically. These error also called personal errors

Minimization of gross error.

1 Taking great care while taking the reading, recording the reading and calculating the result.

2 without depending on only one reading.Atleast 3 or more readings must be taken and preferably by different persons. The reading must be taken preferably under the conditions in which the instruments are switched on and off.

Systematic errors:-

The systematic errors are mainly resulting due to the shortcomings of the instruments and the characteristics of the material used in the instrument such as defective or worn parts, ageing affects, environmental effects etc.,

A constant uniform deviation of the operation of an instrument is known as a systematic error,

These are 3 types of systematic error

1 Instrumental errors
2 Environmental errors
3 observational errors.

Instrumental errors:-

This is due to following 3 reasons

1 Short coming of instrument

This is due to mechanical structure of the instruments. Ex-friction of bearing of various moving parts, irregular, spring tensions, reduction in tension due to improper handling.

These errors can be avoided by

*Selection of a proper instrument and planning the proper procedure for the measurement
*Recognizing the effect of such errors and the proper correction factors.
* Calibration the instrument carefully against a standard.

2 Misuse of instrument

If good instrument is used in abnormal way gives misleading results. Poor initial adjustments, improper zero setting, using deads of high resistance etc. are the example of misusing a good instrument, it is not produce permanent damage to the instrument but definitely cause serious errors.

3 loading effects

Loading effects due to improper way of using the instrument cause the serious errors.Ex:- connecting a well calibrated voltmeter across the two points of high resistance circuit. The same voltmeter connected in a low resistance circuit gives accurate reading. Thus the errors due to the loading effect can be avoided by using an instrument intelligently and correctly.

Environmental Errors:-

It is due to the conditions external to the measuring instrument. The various factors resulting these environmental errors are temperature changes, pressure changes, thermal e.m.f., stray capacitance, cross capacitance, effect of external field, ageing of equipment and frequency sensitivity of an instrument.

The various one thoods used to reduce this error

*using the proper correction factors and using the information supplied by the manufacturer or the instrument.

*using the arrangement which will heep the surrounding condition constant. This includes the use of air conditioning, temperature control enclosures etc.

*Reducing the effect of dust, humidity on the components by hermetically sealing the components in the instruments.

*The effects of external fields can be minimized by using magnetic or electro static shields or screens.

*using the equipment which is immune to such environmental effects.

Observational Errors:

It is produced by observer these are many sources of observational errors such as parallax error while reading a mater wrong scale selection, the hobbits of individual observer etc.

*This error can be eliminated by use the instrument with mirrors, knife edged pointers, etc.

*The instruments with digital display are available which can largely eliminate such observational errors.

The systematic errors can be subdivided as static and dynamic errors. The static errors are caused by the limitations of the measuring device, while the dynamic errors are caused by the instrument not responding fest enough to follow the changes in the variable to be measured.

Random errors:-

*some errors still result through the systematic and instrumental errors are reduced or at least accounted for. The cause of this errors are unknown

∴the errors are called random errors.

*It cannot calculated ordinary process

*This errors are generally due to the accumulation of large number of the small effects. These errors are generally small.

∴This errors are of real concern only when the high degree of accuracy is required.

*These errors can be analyzed statically and treated mathematically.

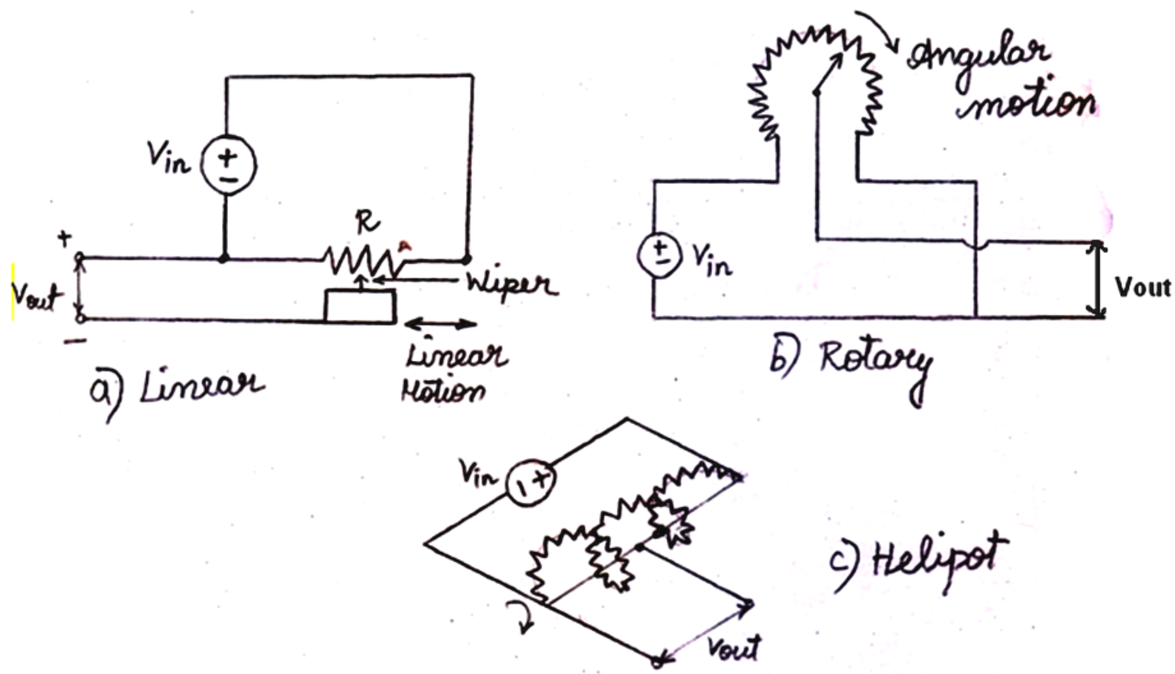
*These errors cannot be corrected by any method of calibration. Reduction of this error is by increasing the number of observations and the best approximation of the reading.

4. Explain the resistive transducer with respectively to potentiometer[CO4-H1]

A potentiometer resistive transducer is generally used to measure linear or angular displacement. A resistive potentiometer consists of a wire wound resistive element along with a sliding contact which is called as wiper. A wire is made up of platinum or nickel alloy with diameter as small as 0.01mm. The resistive element is made up of cement, hot molded carbon or carbon film. The wire is wound on an insulating former. The linear and rotary potentiometers are shown.

Using resistance potentiometer mechanical displacement is converted into an electrical output. Linear or angular displacement is applied to the sliding contact and then the corresponding change in resistance is converted into voltage or current. Note that the resistance potentiometer shown may be excited by either ac voltage or dc voltage.

To measure combination of linear an angular motion, the heliports are used. The resistance element in such potentiometer is in the form of helix, it is called heliport.



5. Describe the piezo electric transducer and give the formula for coupling coefficient. [CO4-H1-Nov 2014]

A piezo electric material is one in which an electric potential appears across certain surface of a crystal. If the dimension of the crystal are changed b the application of a mechanical force. This potential is produce by the displacement of charge. This effects is reversible ie conversely, if a varying potential is apply to the proper axis of the crystal. It will change the dimensions of the crystal there b deforming it. This effect is known as piezo-electric effect. Elements exhibiting piezo electric quantities are called electro resistive element.

Common piezo electric material included Rochelle salts, ammonium dihydrogen phosphate, lithium sulphate, dipotassium tartorate potassium dihydrogen phosphate, quaintly and ceramics A and B except for quantity and ceramic A and B, the rest are manmade crystal ground from aqueous solution under carefully controlled conditions. The ceramic materials are poly crystalline in nature. They do not have piezo electro properties in their original state but these properties are produced by special polarizing element.

The materials that exhibit a significant and useful piezo electric effect are divided in two categories.

1. Natural group 2.Synthetic group.

Quantity and Rochelle salt belong to natural group while materials like lithium sulphate ethylene diamine tartarate are to the synthetic group.

6. Describe the different criteria for selection transducer for a particular application[CO4-H1]

Ricking the right transducer for a measurement application involves consisder the transducers' characteristics, desired system performance, and input requirements. Because there are so many kinds of transducers, proper selection requires careful consideration.

i. Nature of measurement:

The selection of transducer will naturally depend upon the nature of quantity to be measured. For example, for temperature measurement, temperature sensors will be used for measuring stress or strain, strain gauge will be utilized.

ii. Loading effect:

If the transducer in any way affects or changes the value of the parameter under measurement, errors may be introduced. The transducer is selected to have minimum loading effect to keep the errors to minimum.

iii. Environmental considerations:

A careful study to make of the conditions under which a transducer is expected to give satisfactory output. The troublesome aspects of the transducer location are the temperature changes, shock and vibration, and electromagnetic interference.

To minimum the error due to temperature changes, some transducer are temperature compensated. For operation of transducer beyond 300°F, such temperature compensation become externally difficult to design, and special material are used for the transducer internal construction and bonding.

It is often very difficult to eliminate completely the errors due to shock and to have these error as minimum as positive transducers should be selected with a unmovable mass in the sensing mechanical proper damping may extended the range of transducers usefulness under high shock and vibration conditions.

Transducer is often required to operation in the presence of varying strong electromagnetic fields. Transducer with low output impedance, high output voltage ,and short cable length are less susceptible to such interferences.

Other considerations for transducer environments include

a) Simplicity of mounting and cable installation,
b) Convenient size, shape and weight
c) Resistance of corrosion,
d) Accessibility of the transducer for later repairs.

iv. Measuring system compatibility

The transducer selected and the electrical system used for measurement should be compatible. The output impedance of the transducer and the impedance imposed by the measuring system must be such that one does not adversely affect the other.

v. Cost and Availability

General factors involved in selection are cost, availability, basic simplicity, reliability, and low maintenance.

While selecting transducers of comparatively equal merits for a given application, the one that is most simple in operation and contains minimum number of moving parts would usually be selected.

Transducers are selected which do not require excessive repair or continuous calibration checking.

The selection of a transducer for a given application is normally a compromise between a numbers of factors discussed above.

7. Explain how using a differential arrange a capacitive transducer which works the principle of vibration of capacitance displacement between two plates, the response can be made linear. [CO4-H1-Nov 2015]

Figure shown the basic form of a capacitance transducer utilizing the effect of change of capacitance with change in distance between the two plates. One is a fixed plate and the displacement to be measured is applied to the other plate which is movable. Since the capacitance C varies inversely as the distance d between the plates the response of this transducer is not linear.

Thus transducer is useful only for measurement of extremely small displacement

Sensitivity S=$\frac{\partial c}{\partial x} = -\frac{\epsilon A}{x^2}$

Sensitivity of this type of transducer is not constant but varies over the range of the transducer thus as explained earlier this transducer exhibits non-linear characteristics.

The relationship between variations of capacitance C with variation of distance between plates X is hyperbolic and is only approximately linear over a small range of displacement. The linearly can be closely approximately by the use of piece of dielectric material like mica having a high dielectric constant. In this type of transducer, a thin piece of mica thinner than the minimum gap distance is inserted between the plates.

Theoretically, the sensitivity of the transducer can be increased to may, desirable value by making the distance between the plates extremely small. But a practical limit is reached when the electric field strength in the air gap exceeds the breakdown voltage the breakdown limit in air at atmospheric pressure is about 3KV/mm.

Figure shows the arrangement, for measurement of linear displacement. The displacement when applied to the cantilever type spring plates moves it towards the second plates decreasing the distance. This increases the capacitance of the capacitor. It is clear that the capacitance of air dielectric capacitor does not vary linearly with change in distance between the plates and therefore this arrangement fundamentally non-linear However linearity can be closely approximately by keeping the change in the distance or by having a medium of high dielectric constant in the space between the two plates.

Differential Arrangement:

A linear characteristic can be archive by using differential arrangement for the capacitive displacement transducer. This arrangement using three plates is shown P1 and P2 are fixed plates and m is the movable plate to which the displacement be measured is applied. Thus we have two capacitors whose differential output is taken.

Let the capacitance of these capacitors be C1 and C2 respectively, when the plates m is midway between the two fired plates under this condition the capacitance C1 and C2 are equal.

$$C1=\frac{\sum A}{d} \quad and \quad C2=\frac{\sum A}{d}$$

An alternating current voltage E is applied plates P1 and P2 and the difference of the voltage across the two capacitances is measured when the movable plate is midway between the two freed plates C1=C2 and therefore E1=E2+E/2.

Voltage across C1 is $\frac{E_F E_{C2}}{C1+C2}=\frac{E}{2}$

And the voltage across C2 is

$$E_2=\frac{EC1}{C1+C2}=\frac{E}{2}$$

∴ Differential output when the movable plate is midway D.

$$\Delta E = E1 - E2$$

$$=0$$

Let the movable plate be moved by due to displacement x. Therefore the values C1 and C2 become different resulting in a differential voltage output.

$$C1=\frac{\sum A}{d-x} \quad and\ C2 = \frac{\sum A}{d+x}$$

$$E_1 = \frac{C_2 E}{C1=C2} = \frac{\sum A/d+x}{(\sum A/d-x)+(\sum A/d+x)}$$

$$E=\frac{d-x}{2d}E$$

$$E_2 = \frac{C_1 E}{C1=C2} = \frac{\sum A/d+x}{(\sum A/d-x)+(\sum A/d+x)}$$

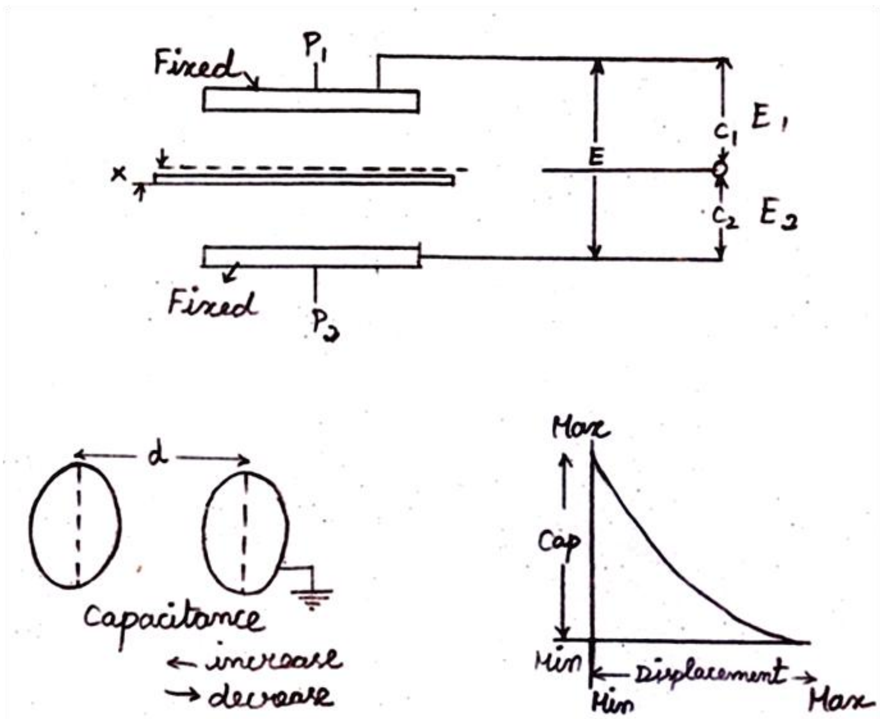
∴ Differential output voltage $=\Delta E = E2 - E1$

$$=\frac{d+x}{2d}E - \frac{d-x}{2d}E$$

$$=\frac{x}{d}E$$

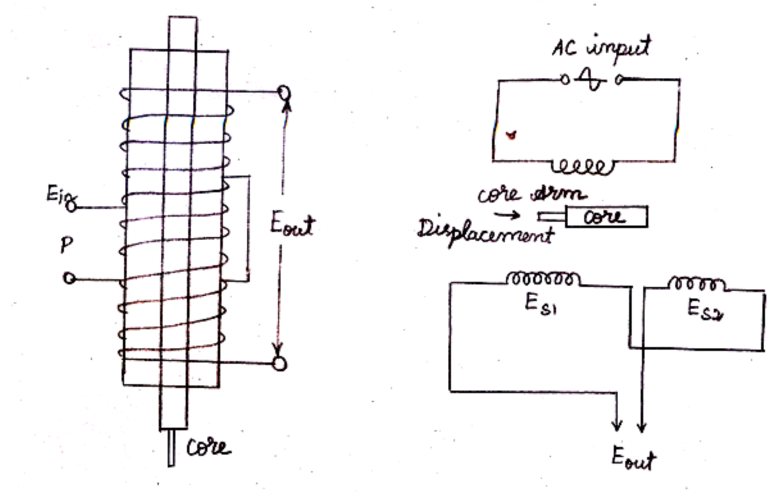
Sensitivity $S=\frac{DE}{x} = \frac{E}{d}$

X=linear displacement.



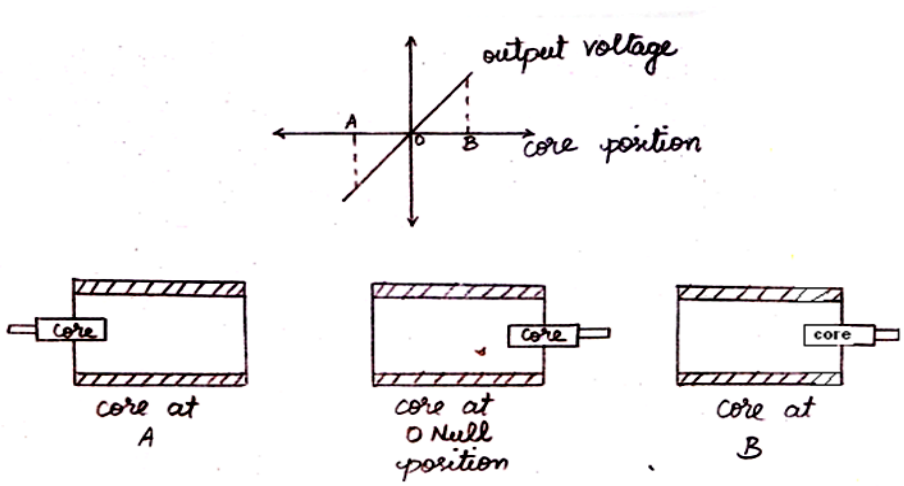
8. Explain the working principle of LVDT with neat sketch and characteristics. Give advantage and disadvantage and applications. [CO4-H1-Apr 2014]

The linear variable differential transformer consists of a single primary winding P1 and two secondary winding S1 and S2 wound on the hollow cylindrical former. The secondaries have an equal number of turns but they are connected in series opposition so that the induced in the coils oppose each other. The primary winding is connected o an ac source, whose frequency may range from 50Hz to 20 KHz. A movable soft position of the movable cone determines the flux linkages between the ac excited primary winding and each of two secondary winding. The cone made up of nickel-iron alloy is slotted longitudinally to reduce eddy current losses. The displacement to be measured is applied to an arm attached to the cone, with the in the centers, or reference position, the induced emf in the secondary's are equal and since they oppose each other, the output voltage will be zero volt.



When an externally applied force moves the core to the left-hand position more magnetic flux links the left hand coil than the right hand coil The emf induced in the left hand coil Es1, is therefore large than the right hand coil Es2.

Similarly, when the core is forced to move to the right, more flux link the right-hand coil than left hand coil and the resulting output voltage, which is the difference Es2 and Es1, is now phase with the emf of the right hand coil.



Thus the LVDT output voltage is a function of the core position .The amount of a voltage change in either secondary winding is proportional to the amount of movement of the core. The output a.c. voltage inverts in phase as the core passes through the central null position. Further as the core moves from the center, the greater is the difference in value between Es1 and Es2 and consequently the greater the output voltage.

The amount of output voltage of an LVDT is a linear function of the core displacement within a limited range of motion.

Advantage of LVDT

i) Linearity: The output voltage of LVDT is almost linear for displacement upto 5mm

ii)Infinite Resolution: The change in output is continues, steeples. The effective resolution depends more on the equipment used for the measurement rather than on the LVDT.

iii) High output: LVDT gives reasonably high output, and hence requires less amplification afterward

iv) High sensitivity: LVDT has high sensitivity of about 300mv/mm.

v) Ruggedness: LVDT is mechanically rugged and can withstand mechanical shock and vibration

vi)Less Friction: Since there are no slide contacts, the function is very less.

vii)Low power consumption: Most LVDT’s less than 1w of power

Disadvantages of LVDT

i) Comparatively large displacement are necessary for appreciable differential output.

ii) They are sensitive to stray magnetic fields. However, this interference can be reduced by shielding.

iii) Temperature affects the transducer.

Application

The LVDT can be used in all application where displacements ranging from fractions of a few mm to a few cm have to be measured.

9. Explain the different principle of working of capacitive transducers. [CO4-H1]

The principle of operation of capacitive transducers is based upon the familiar equation for capacitance of parallel plate capacitor.

$$C=\frac{\sum A}{D}$$

$$=\frac{\sum_r \sum_o A}{d}$$

A=overlapping area of plates;m^2

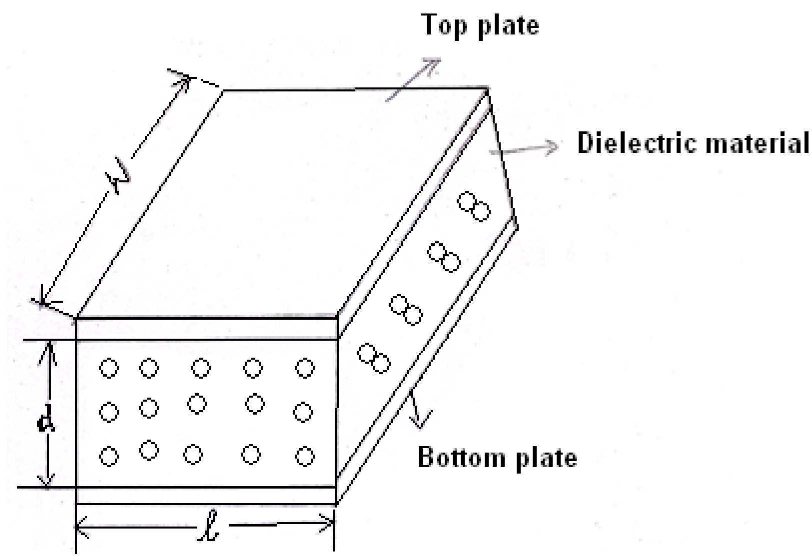
D=distance between two plates; m

$\sum=\sum_r \sum_o$=permittivity of medium; F/m

$\sum_r$ =relative permittivity

$\sum_o$ =permittivity of free space; 8.85×10^{-12}

Parallel plate capacitor is shown.



The capacitive transducer work on the principle of change of capacitance which may be caused by

i) Changes in overlapping Area A,

ii) Change in the distance d between the plates and change in dielectric constant

These changes are caused by physical like displacement, force and pressure in of the cases.

The change in capacitance measurement of liquid or gas level.

The capacitance may be measured with bridge circuits, the output impedance of capacitive transducer is

$$X_c = \frac{1}{2\pi f c}$$

Where C-capacitance and f=frequency of excitation in Hz.

In general the output impedance of a capacitive transducer is high. This fact calls for a careful design of the output circuitry.

The capacitance transducers are commonly used for measurement of linear application (Displacement). This transducer uses the following effects.

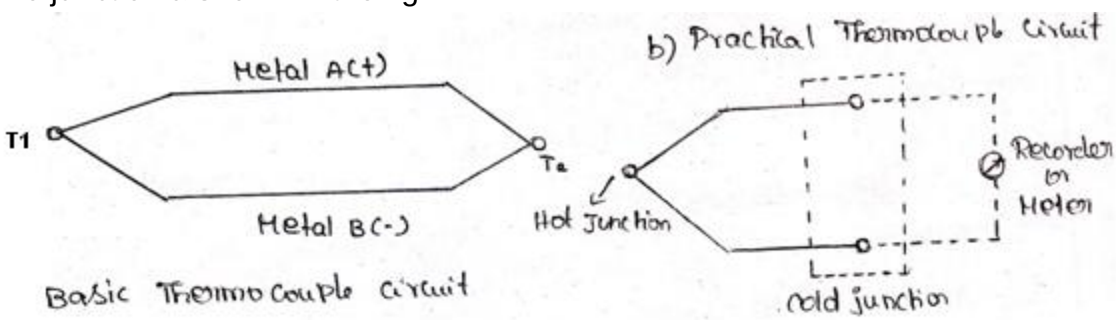
Change in capacitance due to change in overlap area of plates.

Change in capacitance due to change in distance between the two plates.

10. Write short notes Thermo couple. [CO4-H1]

*A Thermocouple is the most commonly used thermoelectric transducer.

*Thermocouple is made up of two wires of dissimilar metals joined together to form two junction a shown in the fig.



* Out of two junctions T1 and T2 which is kept at constant reference temperature. Hence it is referred as cold junction.

* While the temperature changes to be measured are subjected to the junction T1 which is referred as hot junction.

*When the temperature is greater as compared to the cold junction, e.m.f is generated due to the temperature gradient.

*The magnitude of the e.m.f generated depends on the material used for the wires and temperature difference between the two junctions.

*Generally a meter or recorder is used to measure e.m.f as shown in fig.

*The hot junction is sometimes called measuring junction while the cold junction is called reference junction.

*The two wires of the thermocouple are generally twisted and welded together.

*In general a junction may be formed by two methods namely twisted weld and butt weld.

*In twisted weld, two wires are twisted together in several turns and welded together.

*This type of welding is used foe larger sized wires which gives mechanical strength.

*In butt weld, two wires of comparatively smaller sizes are fused into a round bend.

*To measure higher temperature, the wire should be heavier.

*But if the size of the wire increases, the response time of the thermocouple increases.

*so size of the wire is selected such that above mentioned two conditions are compromised.

*Usually for noble metals the wire of diameter 0.5mm is selected; while for the base metals, the diameter of the wire ranges from 1.5 to 3mm.

Thermo couple materials:

Thermo couples are made from number of different metals including copper-constantan, iron- constantan, chro-alumel, platinum-platinum/Rhodium. Cover wide range of temperature going high as 2700°C.

Advantages:

1) The thermocouple is rugged din construction

2) It covers wide range of temperature -270°C to 2700°C.

3) It is comparatively cheaper in cost.

4) the calibration can be easily checked.

5) Speed of response is high.

Limitations:

1) For accurate measurement, cold junction compensation is necessary.

2) The e.m.f. induced verses temperature is non-linear.

11. Write briefly about thermocouples and thermistor as temperature transducer. [CO4-H1]

Thermistor is composed of a sintered mixture of metallic oxides, such as manganese nickel, cobalt, copper, iron and uranium. Their resistance at ambient temperature may range from 100Ω to 100kΩ thermistor are available in a wide variety of shapes and sizes.

Smallest in size are the SE ds with a diameter of 0.15mm and 1.25mm. Beams may be sealed in the tip's of solid glass rods from probes. Disks and washers are made by pressing thermistor material under high pressure into flat cylindrical shapes. Washers can be placed in series or in parallel to increase power dissipation rating.

Thermistor is well suited for precision temperature measurement, temperature and temperature compensation, because their very large change in resistance with temperature. They are widely used for measurement in the temperature range -100°C to +200°C. The measurement of the change in resistance with temperature is carried out with a wheat stone bridge.

Resistance temperature characteristics

The mathematical relationship according to which the resistance of thermistor behaves as temperature is given by

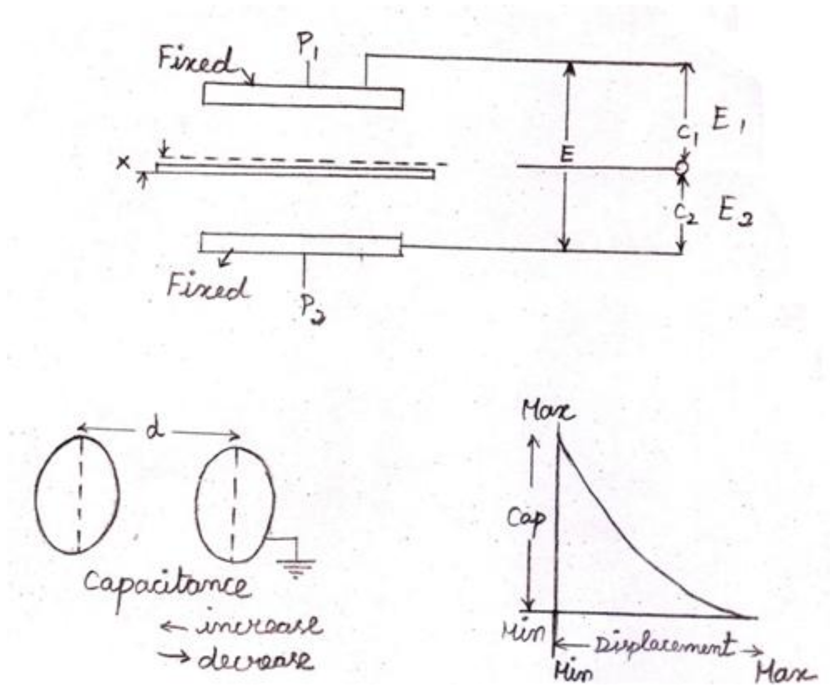
$$R_{T1} = R_{T2} e^{\left(\beta\left(\frac{1}{T1} - \frac{1}{T2}\right)\right)}$$

R_{T1} →Resistance at T1°K

R_{T2} →Resistance at T2°K

$\beta 2$ Constant depending on the thermistor material ranging between 3500 to 4500°k

The equation consists of an exponential term and shows that t si highly non-linear in nature. It has high negative temperature coefficient characteristics. The resistance temperature characteristics are highly non-linear, for small range of temperature, can be assumed to be linear.



Thermo couple:

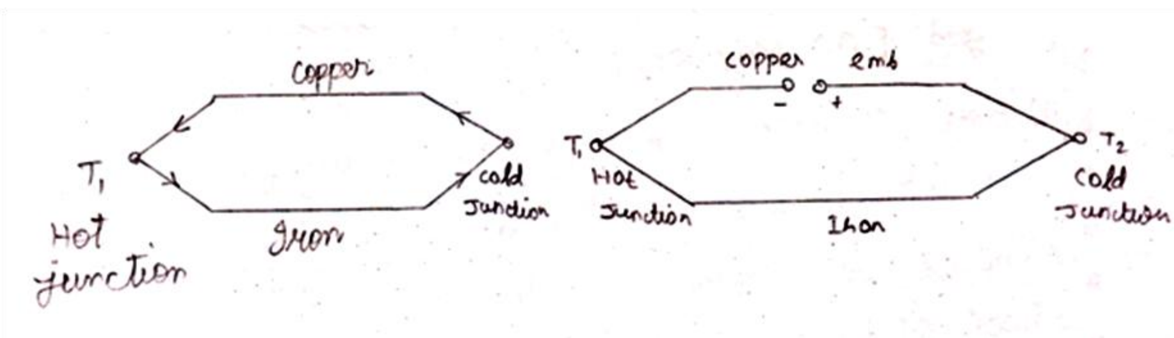
It is temperature transducer which converts thermal energy into an electrical energy. It is the most commonly used thermo electric transducer to measure the temperature.

Thermo couple is made up of two wires of dissimilar metals joined together to form two junctions.

Out of two junctions T1 and T2, T2 kept at constant reference temperature. Hence it is referred as cold junction. While the temperature changes to be measured are subjected to the junction T1 which is referred as hot junction. When the hot junction temperature is greater as compared to the cold junction temperature is greater as compared to the cold junction, emf is generated due to the temperature gradient. The magnitude of the emf generated depends the material used for the wires and temperature difference between the two junctions. Generally a meter or recorder is used to measure e.m.f as shown in figure. The hot junction is sometimes called measuring junction while the cold junction is called reference junction.

The two uses of the thermo couple are generally twisted and welded together. In general junction may be formed by two methods, namely twisted weld and built weld. In trusted weld, two wires are twisted together is several turns and welded together. This type of welding is used for larger sized wires which give mechanical strength. In Dutt weld and wires of comparatively smaller sizes are fused into a round bend.

To measure higher temperature, the wires used should be heavier. But if the size of the wire increases, the response time of the thermocouple increases. So size of the wires is selected such that above mentioned two conditions are compromised. Usually noble metals, the wire of diameter 0.5mm are selected. While for the base metals, the diameter of the wire ranges from 1.5 to 3mm.



12. Explain the construction and working of unbounded and bounded type stains gauges[CO4-H1]

Or

Explain the measurement of resistance using stain gauges[CO4-H1]

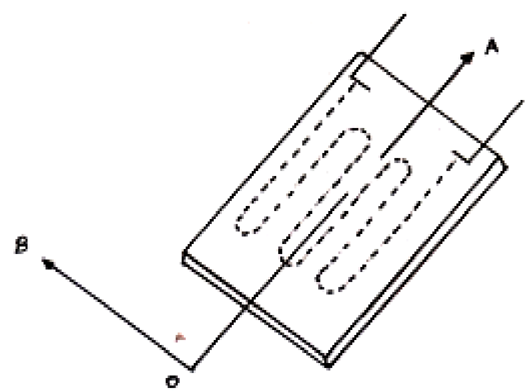
A) Bonded Resistance wire strain gauge:

In bonded resistance wire strain gauge resistive element is cemented to the base which may be a thin sheet of paper, a thin sheet of Bakelite or a sheet of Teflon. The resistive element may be in the form of wire. Foil or film of the material. The most common types of bonded strain gauges are as shown in fig 6.15.

In metallic bonded strain gauge a fine wire element about 25μm or less in diameter is loped back and forth on a (carrier) or mounting plate. The base is cemented to the member subjected to stress. The grid of fine wire is cemented on a carrier which may be a thin sheet of paper. Backlite, or Teflon.

A tensile stress tends to elongate the wire and thereby increase its length and decreases its cross-sectional area. The combined effect is an increases in resistance.

In this gauge, the strain is deflected using a metal foil. The alloys used for the foil and wire are michrome, nickel and platinum.



Bonded type strain Gauges

B.Unbonded resistance wire strain Gauge:

In general, the basic usage of the unbounded strain gauge is as displacement transducer. It can be constructed in variety of configuration. The unbounded strain gauge consists of a stationary frame with an armature supported at the centre of the frame as shown in fig 6.17.

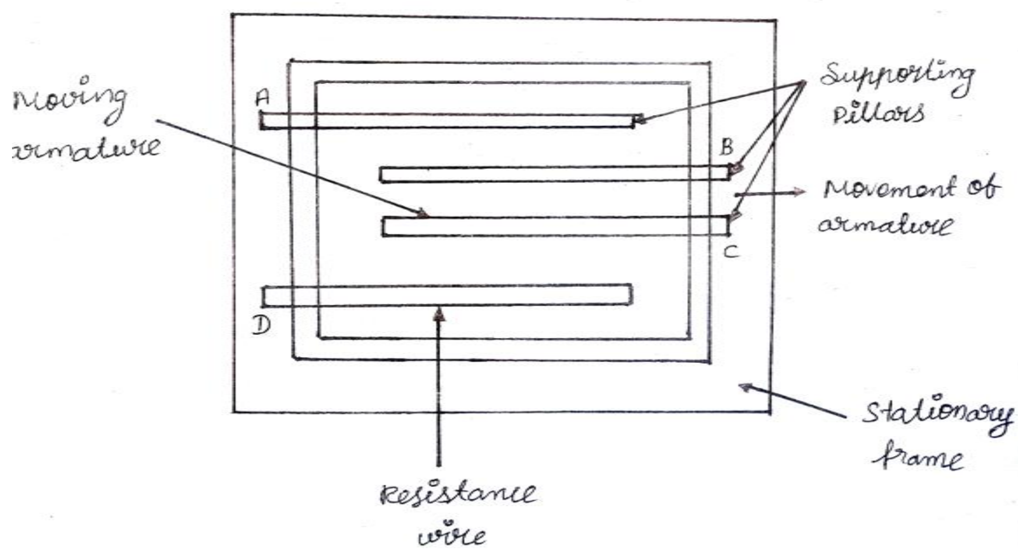


Fig 6.17 Unbounded strain gauge

The strain gauge is constructed such that an armature can move only in one direction. Its travel in that direction is limited by four filaments of strain sensitive wires. These wires are wound on the rigid insulators. These insulators are mounted on the frame and on the armature.

On the application of the external forces, the armature moves in the indicated direction. The length of elements A and D increases, while the length of elements B and C decreases. Then proportional, to the change in length, the resistance of the four strain elements changes. The detect this change in resistance, we can use Wheatstone bridge.

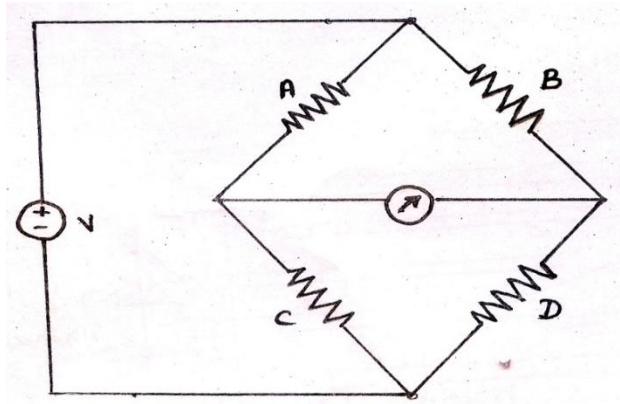


Fig 6.18 Wheatstone bridge circuit using strain gauges

13. Write briefly of Thermistor as temperature transducer. [CO4-H1]

*The mathematical relationship according to which the resistance of thermistor behaves as temperature is given by,

$$R_{T1} = R_{T2} e^{\left[\beta\left(\frac{1}{T1} - \frac{1}{T2}\right)\right]}$$

Where

$R_{T1} = Resistance\ at\ T1°k$

$R_{T2} = Resistance\ at\ T2°k$

$\beta = Constant\ depending\ on\ thermistor\ material\ ranging\ betwee\ 3500\ to\ 4500°k$

*The equation consists of an exponential term and shows that it is highly nonlinear in nature.

*It has high negative temperature coefficient characteristics.

*The resistance temperature characteristics of a thermistor is shown in fig.

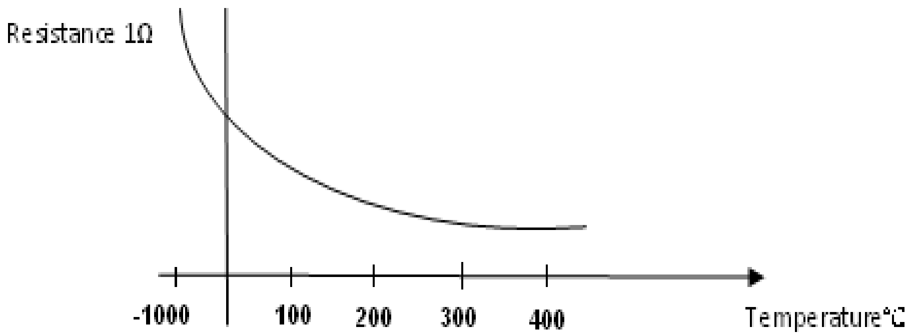


Fig: Resistance characteristics of a thermistor

*Though the characteristics is highly nonlinear for small range temperature, can be assumed to be linear.

14.A 5-plate transducer has plates of dimensions 20mm× 20mm and separated 0.25 mm apart. The arrangement is to be used for measuring displacement. Department the sensitivity of the arrangement. Assume air medium. [CO4-H2]

No.of plates n=5

Area=20*20=400 mm^2

Relative dielectric constant ε_r=1

Absolute dielectric constant $\varepsilon_0 = 8.854 \times 10^{-12} F/m$

D=0.25 mm

Sensitivity s=$\frac{-(n-1)\varepsilon_r \varepsilon_{0\,A}}{d}$

S=$\frac{-(5-1)\times 80854\times 10^{-12}\times 1\times 20\times 10^{-3}\times 20\times 10^{-3}}{0.25\times 10^{-3}}$

S=2.833× $10^{-9} F/m$

15.A linear resistance potentiometer is 50 mm long and is uniformly wound with a wire of total resistance 5kΩ. Under normal conditions, the slider is at the centre of the potentiometer. Determine the linear displacement when the resistance of the

potentiometer, as measured by the Wheatstone bridge, is 1850kΩ.If it is possible to measure a minimum value of 5kΩ resistance with the above arrangement, determine the resolution of the potentiometer in mm. [CO4-H2]

Total resistance =5000Ω

L=10mm

$\frac{R_t}{L} = \frac{5000}{50} = 100\Omega$

Resistance of normal position

=5000/2=2500Ω

Change in resistance

=2500-1850
=650Ω
Displacement

Y=650/100=6.5mm

UNIT V
ANALOG AND DIGITAL INSTRUMENTS
PART-A

1. What are the limitations of Wheatstone bridge?[CO5-L1]

i) The effect of load resistance and contact resistance is very much significant while measuring low resistances.

ii) The resistance used must be very precise having tolerance upto 1% or 0.1% ,hence cost is high.

iii) The excessive current may generate heat which may cause the permanent change in resistance.

iv) The bridge cannot be used for high resistance measurement.

2. What are the applications of A.C. Bridge? [CO5-L1]

i) This bridge can be used for capacitance measurement if the operating frequency is known.

ii) The bridge is also used in a harmonic distortion analyzer, as a notch filter and in audio frequency and radio frequency oscillators as a frequency determining element.

iii) The accuracy of 0.5%-1% can be readily obtained using this bridge.

iv) The bridge is used to measure the frequency in audio range which range from (20-200-2k-20k) Hz. The resistances are used for range changing while the capacitors are used for fine frequency control.

3.What are the applications of A.C potentiometer? [CO5-L1]

The applications of A.C. potentiometer are as follows:

i) Calibration of voltmeter
ii)Calibration of ammeter
iii) testing of energy meter and wattmeter
iv Measurement of self reactance of coil.

4.Eluminate the principle of grounding? [CO5-L1]

The principle of grounding is the reducing the effect of stray capacitance which shunt the bridge arms and causes considerable error in measurement, are uncertain in magnitude and often vary with the adjustment of bridge arms and position of operator.

5. List the applications of DC potentiometer? [CO5-L1]

The applications of DC potentiometer are similar to Ac. as follows

i)Measurement of voltage
ii)Measurement of resistance, current and power.

iii)Calibration of voltmeter, ammeter, wattmeter.

6.What are parasitic voltages? And how are they eliminated[CO5-L1]

The unwanted, extra voltages occurring due to utility power line voltage are called parasitic voltages.

Methods of eliminating parasitic voltages are as follows

i)Isolation transformers

ii)Shielding

7.Mention any four types of A.C bridges? [CO5-L1]

types are as follows

i)Maxwell's bridge

ii)Anderson bridge

iii)Wien bridge

iv)Hay's bridge.

8.What is the roll of toroidal core in tapped ratio transformer? [CO5-L1]

The roll of torodial core in tapped ratio transformer is

i)It helps to minimize the magnetizing current required to produce the flux.

ii)It helps in achieving perfect coupling.

iii)the leakage reactance of the winding put on the torodial core is also minimum.

9.What is electromagatic interference in instruments? [CO5-L1]

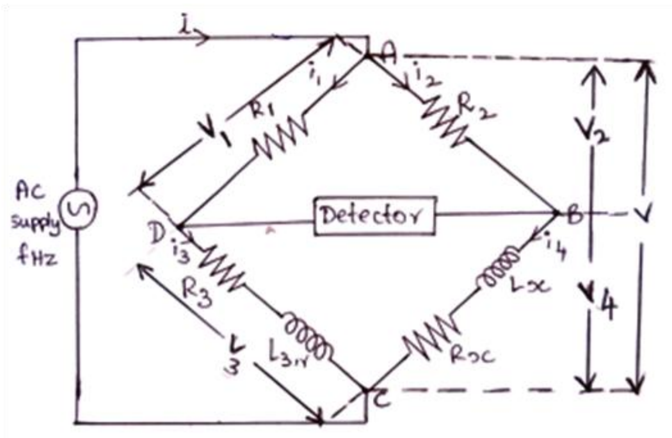
The interface caused due to electromagnetic waves which are the radiations in the form of waves is called electromagnetic interface .so, all sensitive circuits from a measurement system must be protected from radio frequency signals.

10.What are leakage current effects? [CO5-L1]

The leakage currents are produced and are comparable magnitude to the current being measured. Such leakage currents causes errors, which currents depend on humidity and are unpredictable must be eliminated from measurement.

11.Draw maxwell's AC bridge and give the balance equation in terms of resistance. [CO5-L1]

Maxwell's bridge:-



Equation in terms of resistance,

Rx=$\frac{R2}{R1}(R3+r)$

Where Rx=unknown resistance.

12.Explain any two technical parameters to be considered for grounding.

i)wagner ground connection: [CO5-L1]

The elimination of stray capacitances and the capacitances between bridge arms is using a ground connection called wanger ground connection.

ii)Grounding arm:

The circuit is the capacitance bridge where represent stray capacitances. The wagner connection is the use of separate arm consists of resistance and capacitance forming a potential divider. This arm is also called gurding arm.

13.give some applications of wheatstone's bridge. [CO5-L1]

The applications of wheatstone's bridge are as follows:

i)It is used to measure the resistance of motor winding, relay coils etc.,

ii)It is used to measure d.c. resistance of various types of wires for the purpose of quality control wire.

iii)It is used by the telephone companies to locate cable faults.

14.State the advantages of using bridge circuits for the measurement. [CO5-L1]

The various advantages of bridge circuits are.

i)The balance condition remains unchanged if the source and detector are interchanged.

ii)The measurement accuracy is high as the measurement is done by comparing the unknown value with the standard value.

iii)The accuracy is independent of the characteristics of a null detector and is independent on the component values.

15.What is the sensitivity of wheatstone bridge? [CO5-L1]

When the bridge is balanced, the current through the galvanometer is zero. But when bridge is not balanced the current flows through the galvanometer causing the deflection.

The amount of deflection depends on the sensitivity of the galvanometer. This sensitivity can be expressed as the amount of deflection per unit current.

Sensitivity S= $\frac{deflection \;\; D}{current \;\; I}$

16.What are the sources of error in Wheatstone bridge? [CO5-L1]

The errors are due to following factors.

i)The insufficient sensitivity of null detector may cause error.

ii)Heating effect and thermal e.m.f. can also causes error.

iii)the main error is because of limiting errors of the three known resistances hence very precise resistances are required having the tolerance of 1% or even 0.1%

17. Which measurement can be carried out by maxwell's bridge? [CO5-L1]

Maxwell bridge can be used to measure inductance by comparison either with a variable standard self inductance or with a standard variable capacitance. These two measurements can be done by using maxwell's bridge in two different forms.

1)Maxwell's inductance bridge

2)Maxwell's inductance capacitance bridge.

18.List the advantages of using standard capacitance in the Maxwell bridge? [CO5-L1]

The advantages of using standard capacitance in the Maxwell's bridge are as follows:

i)The capacitors are almost lossless.

ii)The capacitors are smaller in size

iii)The capacitors are less expensive than stable and accurate standard inductors.

19.List the advantages and limitations of Maxwell's bridge[CO5-L1]

Advantages of Maxwell's bridge:

i)The balance equation is independent of losses associated with inductances.

ii)The balance equation is independent of frequency of measurement.

iii)The scale of the resistance can be calibrated to read the inductance directly.

Limitations of Maxwell's bridge:

i)There is an interaction between resistance and reactance balances. Getting the balance adjustment is little difficult.

ii)It is unsuited for the coils with low Q values less than one, because of balance convergence problem.

iii)The bridge balance equations are independent of frequency.

20.What is Hay's bridge? [CO5-L1]

The limitations of Maxwell's bridge is that it cannot be used for high Q values but, the hay's bridge is suitable for the coils having high Q values.

21.Compare Hay's bridge and Maxwell's bridge. [CO5-L2]

Hay's bridge	Maxwell's bridge
It is best for the measurement of inductance with high Q, typically greater than 10	It can't be used for the measurement of high Q values.
It requires very low value resistor R1 to measure high Q inductance	It requires scale of the resistance to read Q-value directly.

22.What is wien's bridge? [CO5-L1]

The wien's bridge is used for the frequency measurement but it is also used for the measurement of unknown capacitor with great accuracy.

The wein bridge can be used for the capacitance measurement if the operating frequency is known.

23.Write the classification of external interference signals? [CO5-L1]

The external interference signals are classified based on the physical phenomena. they are

i)Capacitive interference

ii)Inductive interference

iii)Electromagnetic interference

iv)Conductively coupled interference

v)Ground loop interference.

24.What is capacitive interference? [CO5-L1]

When two inductors are near each other, they form a capacitance effect and get electrically coupled with each other. Thus voltages change in one conductor effects the voltage change in other. So low level signal carrying conductors and low level signal transducers get affected due to interference. Such interference due to capacitive effect is also called electrically coupled interference.

25.What is electrostatic shielding? [CO5-L1]

Electrostatic shielding is a method to provide electrostatic shield to the wires carrying low level signals to avoid capacitive effects. The shield consists of metal enclosure and braided metal sleev by which external field cannot penetrate into that field.

26.What is inductive interference? [CO5-L1]

If a closed path is a part of measurement system, then such induced emf and current affect the measurement due to the interference. Such interference is called inductive interference which is also called magnetically coupled interference.

27.Write the methods of reducing inductive interference? [CO5-L1]

The various methods of reducing inductive interference

1.Increase the distance between source and object of magnetic interference.

2.Decrease the area of loop intersecting the interfering magnetic field.

3.Keep the low level signal leads far away from the twisted power cables.

28.State the sources of EM waves, which can cause interference ? [CO5-L1]

sources of EM waves, which can cause interference are

i)Gas discharges in fluorescent light

ii)Sparking in electric switches, relays

iii)Arching in electric generators & motors

iv)Lightning.

29.What is standardization of potentiometer? [CO5-L1]

Standardization of a potentiometer is a process of adjusting the working current supplied by the supply battery such that the voltage drop across a portion of sliding wire matches with the standard reference source.

30. state the principal of digital voltmeter? [CO5-L1]

The digital voltmeter generally referred as DVM,convert analog signal into digital and display the voltages to be measured as discrete numerical instead of pointer deflection, on the digital displays such voltmeters can be used to measure a.c. and d.c. voltages and also to measure the quantities like pressure, temperature etc, using proper transducer and signal conditioning.

31. What are the advantages of digital instrument over analog instruments? [CO5-L1]

1 A digital instrument records the information in digital form.

2. The digital information is stored on punched cards, magnetic tape recorders, type written pages, floppies

3. They provide high quality records minimizing the operator’s work.

4. These are becoming very much popular because of simplicity accuracy and most important is reliability.

32. How are resistors and diodes checked using digital multimeter? [CO5-L1]

To measure the resistance a constant current source is used. The known current is passed through the unknown resistance. The voltage drop across the resistance is applied to analog to digital converter. Hence providing the display of values of the unknown resistance.

33.What are the merits and demerits of digital storage oscilloscope? [CO5-L1]

Merits;-

1. Infinite storage time
2. easy to operate
3. Signal processing is possible
4. Cursor measurement is possible.
5. Pretriggering failure allows the display of the waveform, before the trigger pulse.

Demerits;

1Cost is high

34. What is the sweeper in oscilloscope? [CO5-L1]

The sweepers in oscilloscope are

i) Triggered sweep

ii) Delayed sweep.

PART-B

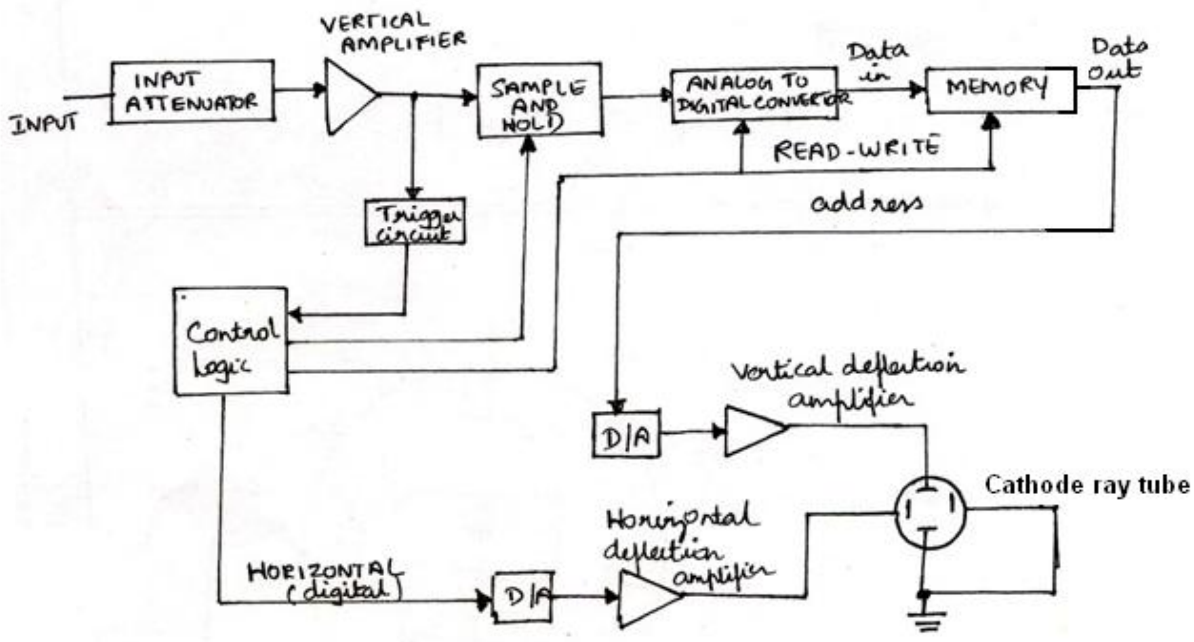
1.With neat figure explain the working principle of a digital storage oscilloscope. What are the advantages over analog CRO? [CO5-H1-Nov 2014]

Or

With neat diagram explain the principle of operation of digital CRO with sampling methods detail. What are the advantages over analog CRO? [CO5-H1]

BLOCK DIAGRAM:-

The block diagram of digital storage oscilloscope is shown in the figure.



As done in all the oscilloscopes the input signal is amplified to the amplifier and attenuator section.

The oscilloscope uses same type of amplifier and attenuator circuitry as used in the conventional oscilloscopes.

The attenuated signal is then applied to the vertical amplifier.

To digitize the analog signal, analog digital (A/D) convertor is used.

The output of the vertical amplifier is applied to the A/D convertor section.

The A/D conversion techniques are discussed earlier while the discussion of the digital storage oscilloscope is its speed, while in digital voltmeter s accuracy and resolution were the main requirements.

The digitized output needed only in the form and not in BCD.

The successive approximation type of A/D convertor is most often used in the digital storage oscilloscopes.

The digitizing the analog input signal means taking samples net periodic intervals of the input signal.

The rate of sampling should be at least twice as fast as the highest frequency present in the signal according to sapling theorem.

This ensures no loss of information.

The sampling rates as high as 100,000 samples per second is used.

This requires very fast conversion rate A/D convertor.

Hence generally flash analog to digital convertors are used, whose resolution decreases as the sampling rate increases.

If a 12 bit convertor is used 0.025% resolution is obtained while if 10 bit A/D convertor is used then resolution of 0.1%(1part in 1024) is obtained.

The total digital memory storage capacity is 4096 for a single channel 2048 for two channels each 1024 for four channels each.

The sampling rate and memory size are selected depending upon the duration and the waveform to be recorded.

Once the input signal is sampled the A/D convertor digities it

The signal is then captured in the memory.

Once it is stored in the memory many manipulations are possible as memory can be read out without being erased.

One important feature of digital storage oscilloscope is its mode of operation called pretrigger view.

This modes means that the oscilloscope can display what happened before a trigger input is applied.

This mode of operation is useful when a failure occurs.

Single shot events such as the waveform of an explosion are transient in nature and very quickly lost.

The observer can not see such events, unless the waveform is photographed or stored.

Such events can be stored in memory of digital storage oscilloscope and reading the memory rapidly and repetitively the continuous waveform can be obtained.

The digital storage oscilloscope has three modes of operation

i)Roll model

ii)Store model

iii)Hold or save model.

ROLL Model:-

Very fast varying signals are displayed clearly in this mode.

In this mode the input signal is not triggered at all.

The fast varying signal is displayed as if its is changing slowly on the screen in this mode.

STORE MODEL:-

This is called refresh. In this case input initiate trigger circuits.

Memory write cycle starts with trigger pulse.

When memory is full, write cycle stops.

Then using digital to analog convertor the stored signal is converted to analog and displayed.

When next trigger occurs the memory is refreshed

HOLD OR SAVE MODEL:-

This is automatic refresh mode when new sweep signal is generated by time base generator, the old contents get over written by new one

By pressing hold or save over writing can be stopped and previously saved signal gets locked.

Advantages:-

i) it is easier to operate and has more capability

ii) The storage time is infinite.

iii) The display flexibility is available the number of traces that can be stored and recalled depends on the size of the memory.

iv) The cursor measurement is possible.

v) The characters can be displayed on screen along with the wave form which can indicate waveform information such as minimum, frequency, amplitude.

vi) The X-Y plots, B.H curve, P-V diagrams can be displayed.

vii) The pretrigger viewing feature allows to display the waveform before trigger pulse.

viii) Keeping the records is possible by transmitting the date to computer system where the further processing is possible.

ix) Signal processing is possible which includes translating the raw data into finished information.

E.g computing parameters of a captured signal like r.m.s value, energy stored etc..

SAMPLING METHOD;-

They are types of sampling method they are:-

i)real time sampling

ii)Random repetitive sampling

iii)Sequential repetitive sampling

Real time sampling:-

This is the most straight forward method of digital signal capturing.

In this method in response to single trigger event, the complete record of nm samples is simultaneously captured on each and every channel.

From these samples recorded in a signal acquisition cycle the waveform is displayed on the screen of digital storage oscilloscope.

Three important features of this method are

1.The display and analysis of waveform can be carried out at later stage while the signal gets recorded in memory at an earlier stage.

2.It is very easy to capture the signals that happen before the trigger event.

3.A truly simultaneously capture of multiple signals is automatic.

This method can bee used in continuously repeating mode but each waveform displayed is captured from a single acquisition cycle.

The larger memory and fast sampling plays an important role in the real time sampling.

The higher sampling rate is required to capture long time interval signal capturing

This is possible due to large memory.

The signal fluctuations occurring entirely between samples will not be captured in the sample record.

The sampling theorem helps to select the proper sampling rate.

It states that if a signal is sampled greater than twice the frequency of highest frequency component in signal then the original signal can be reconstructed exactly from the samples.

Half of the sampling frequency is called negative limit or negative critical frequency higher than fc gets falsely translated to another frequency somewhere between dc and fc by the act of sampling this called aliasing.

A signal of frequency fc +Δ will be aliased to fc -Δ for Δ< fc.

The 3 db band width of the vertical amplifier should be less than fc at the fastest sampling rate.

In practice the 3 db band width is set to fs/4 with about 5% over shoot where fs is sampling frequency.

Random repetitive sampling;-

The band width limited to fs/4 in real time sampling

The major disadvantages of this is increasing bandwidth means increasing sampling rate and fast sample rate digitizers and memory are very expensive.

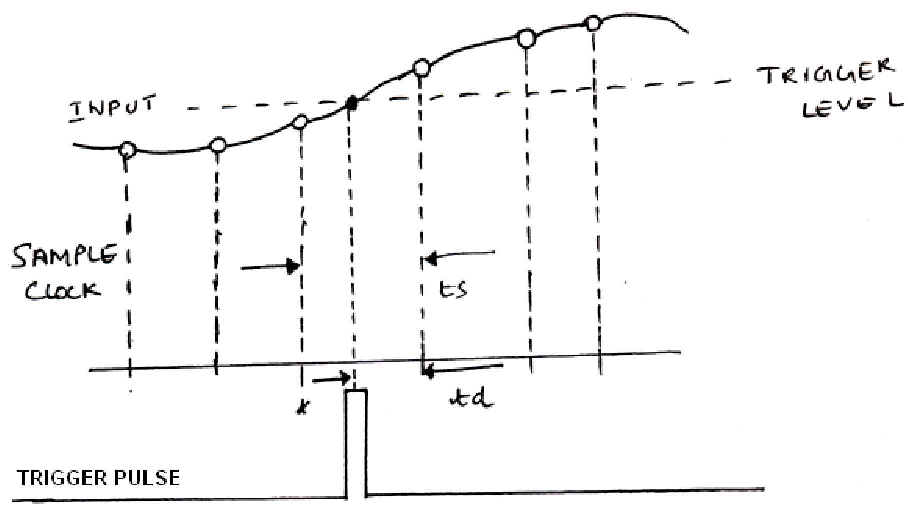
The method in which the band width is not limited by sampling rate is random repetitive method.

In this method repeated real time data acquisition cycles are performed.

Still each sample value is plotted independently on display as a dot.

Interpolation between samples is not done.

Each acquisition cycle produces random time internal +d between trigger point and sample clock as shown in the figure.



The time between the samples from that capture is ts width an off set of td from the trigger point.

The trigger is located and interpolator measures the time interval td on each acquisition cycle.

It is located in the time base

Each successive acquisition is plotted at its measured random offset.

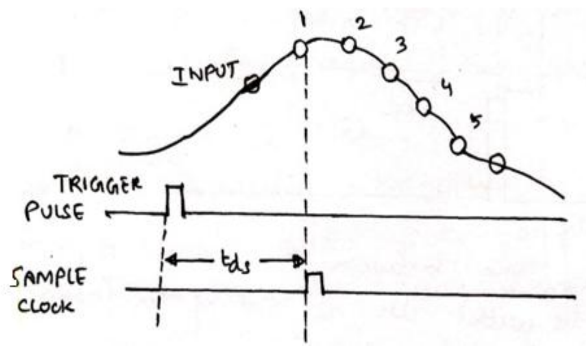
This progressively fills the picture of the waveform.

As the waveform fills in the gapes between the dots become smaller and effective sampling rate increases.

Accuracy of trigger interpolator while measuring td limits the effective sampling rate.

The disadvantages of this method are that the abilities to capture a non recurring transient are lost.

Sequential Repetitive Sampling.



An oscilloscope having bandwidth 20 to 50 GHz need very fast sweep speed settings.

In such case random respective method cannot work satisfactorily

Hence sequential respective sampling is used.

In this method one sample value per trigger event is captured t a carefully controlled time delay tds after the triggering pulses shown figure.

This delay is increased by small amount tse after each point is captured.

The single sample acquisition cycle is repeated till the entire waveform has been plotted.

In this method the increase in delay which is tde is the effective sample time

This method can not capture trigger event or any pretrigger information.

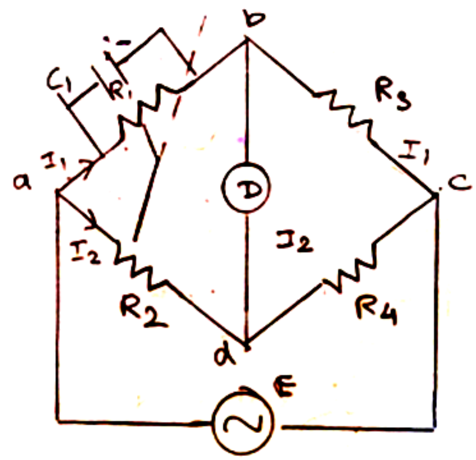
The major disadvantages of this method is pretrigger view feature gets lost.

Hence this method is used only in microwave bandwidth digital oscilloscopes.

2. Explain the frequency measurement in wein's bridge. [CO5-H1-Nov 2015]

Some bridges have balanced equations which involve frequency directly even if the performance of individual bridge element is independent of frequency. These bridges may be used for determination of frequency in terms of value of various bridge elements. We shall describe here in Wein's Bridge which is the most important one for determination of frequency.

Mechanical coupling:-



The wein's bridge is primarily known as frequency determining bridge and is described here not for its use as an a.c. bridge to measure frequency but also its application in various other useful circuits. A wein's bridge for example may be employed in a harmonic distribution analyzer. Where it is used as notch filter, discriminating against one specific frequency. The wien's bridge also finds applications in audio and Hf oscillators as the frequency determining device.

Shows a wein's bridge under balanced conditions.

At balance $\left[\frac{R1}{1+jwc\,1r1}\right]$R4=$\left[R2-\frac{j}{wc\,2}\right]$R3

The self induction is important only when the coils are multi turn coils and supply used is of high frequencies.

Frequency and wave form errors:-

In case of bridges whose results are independent of frequency supply frequency is important only from the point of view of its effects on resistance, inductance and capacitance of the apparatus under test. The presence of harmonics in the supply waveform is also important from the same point of view.

The difficulty is overcome either by employing wave filters which eliminator the unwanted harmonics from the source or by employing tuned detectors in place of head phones such as vibration galvanometer which do not respond to harmonics and responded readily only to the fundamental for which they are used.

3.Explain the working of megger with a neat sketch & write a brief note on earth resistance measurement process. [CO5-H1]

Megger:

*****Ratiometer ohmmeters, described earlier, may be designed to cover a wide range of resistances.

*The principle of ratiometer ohmmeters is particularly adapted to application in portable instruments measuring insulation resistance.

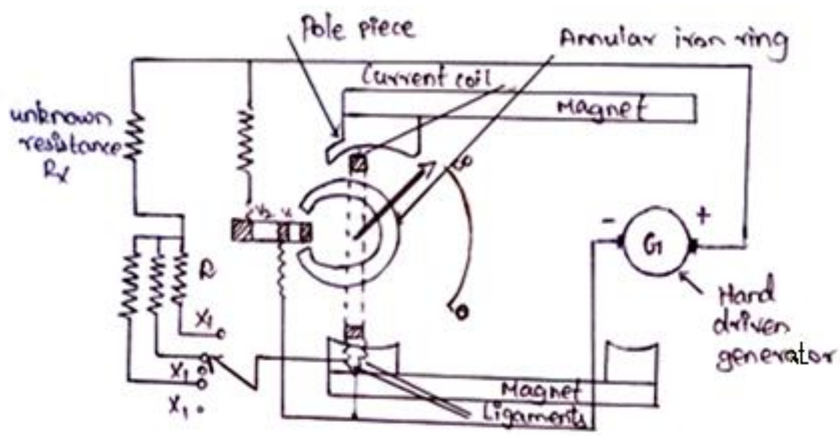
*This principle forms the basis of insulation testing instrument known as megger.

*The essential parts of a megger are shown in fig.

*The current coil is similar to that of the permanent magnet moving coil instrument. There are two voltage coils V1 &V2

*The voltage coil V1, embraces(threads over) the annular magnetic core.

*It is clear from fig. that voltage coil V1, is in a weak magnetic field when the pointer is at ∞ positon and hence this coil can exert very little torque.



*The torque exerted by the voltage coil increases as it moves into a stronger field and this torque is maximum when it is under the pole face and under this condition the pointer is at its zer end of the resistance scale.

*In order to modify further the torque in the voltage circuit, another coil V2 is used.

*This coil is also so located that it moves into stronger field as the pointer moves from the ∞ position towards the zero position of the resistance scale.

*The can finally embraces (threads around) the extension if of the pole piece.

*The combined action of the two voltage coil V1 and V2 may be considered as though the coils constituted a spring of variable stiffness,being very shift near the zero end of the scale where the current in the current coil is very large (on account of unknown resistance Rx being small)

*And very weak near the the ∞ end of the scale where the currents in the current coil is very small (on account of unknown resistance Rx being very large)

*Thus this effect compresses the low resistance portion of the scale and opens up the high resistance portion of the scale..

*This is a great advantage since this instrument is meant to be used as ‘INSULATION TESTER’ as the insulation resistance are quit high.

*The voltage range of the instrument can be controlled by a voltage selector switch.

*This can be done by varying resistance ‘R’ connected in series with the current coil.

*The test voltages, usually 500, 1000 or 2500V are generated by a hand cranked generated G.

*A centrifugal clutch is incorporated in the generator drive mechanism which slips at a predetermined speed so that a constant voltage is applied to the insulation under test.

*This voltage provides a test of strength of low voltage insulation as well as a measure of its insulation resistance.

*Since it is sufficient to cause breakdown at faults.

*Such breakdowns are indicated by sudden motion of the pointer off scale at zero ends.

*As the same magnet system supplies magnetic fields for both instrument and generator, and as current and voltage coil move in a common magnetic field, the instrument indications are independent of the strength of the magnet.

Earth Resistance Measurement Process:

*The insulation resistance of a cable may also be measured by a self-contained insulation testes known as megger.

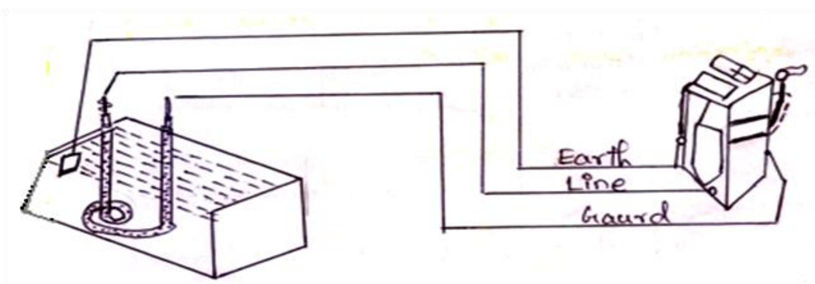
*Such an arrangement is shown in fig.

*Megger is provided with the three terminals known as line, earth and guard terminals.

*The line terminal is connected to the core of the cable. the 'earth' terminal to a plate immersed in the water or the tank side if suitable and the guard terminal to the guard wire wound tightly round the insulation as shown.

*Rotating of handle at steady speed indicates the value of insulation resistance of the cable by the final position taken up by the instrument pointer on its scale.

Fig: Measurement of Insulation Resistance of calibration by megger.



*During the test it may be possible that the instrument pointer fall at first as the handle is tuned and after several seconds rise to the correct position.

*This happens due to electrostatic capacitance of the cable.

*This phenomenon is desired in detail as follow.

*When the instrument handle is rotated with stead speed voltage is generated and the current flow to charge the condenser(the cable has capacitance effect)

*The magnitude of the initial current drawn is thus a measure of the capacitance of the and not its insulation resistance.

*After several seconds charging current ceases to flow and conduction current makes the pointer to rise to indicate correct value of insulation resistance.

*When the capacitance of the cable under test is of the order of $0.1\mu F$ or more. The above initial effect is more maked.

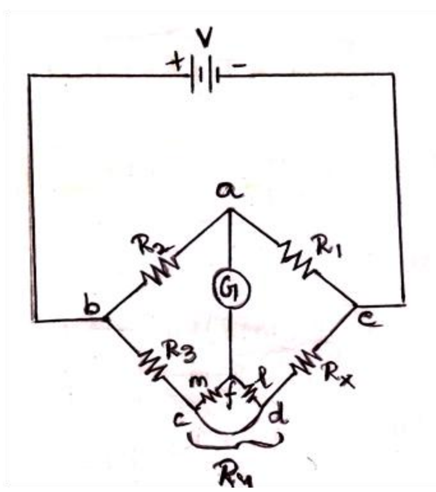
4.Explain the principal of working of kelvin's double bridge. Also obtain the balance conditions for this type of bridge. What are the difficulties associated with measurement of low resistance using Kelvin double bridge. [CO5-H1- Apr 2014]

Kelvin double bridge:-

Principle:-

***The principle of Kelvin double bridge is null deflection when all the arms are balance**

Diagram:



Construction:-

*The circuit diagram of kelvin's double bridge.

*This circuit consists of double bridge.

*Because it incorporates a second set of ratio arms.

*The second set of arms m and I connect the galvanometer to a point f at the appropriate potential between c and d and it eliminates the effect of the resistance Ry

*The ratio of the resistance of arms m and I is the same as the ratio of R1 and R2 the galvanometer indication is zero when the potentials at a and f are equal.

Vab=Vbcf

But, Vab=$\frac{R2}{R1+R2}\times V$------------------------- 1

And V=I$\left[R3+Rx+\frac{(m+i)Ry}{(m+l)Ry}\right]$---------------- 2

Substuting for V in equation 1, we get

Vab=$\frac{R2}{R1+R2}\times I\left[R3+Rx+\frac{(m+i)Ry}{(m+l)Ry}\right]$------------ 3

Similarly, Vbc=I$\left[R3+\frac{m}{M+l}\left\{\frac{((m+l)Ry)}{(m+l)Ry}\right\}\right]$------------------ 4

But, Vab=Vbcf

$\therefore \frac{IR2}{R1+R2}\left[R3+Rx+\frac{(m+i)Ry}{(m+l)Ry}\right]=I\left[R3+\frac{m}{M+l}\left\{\frac{((m+l)Ry)}{(m+l)Ry}\right\}\right]$

Or,R3+Rx+$\frac{(x+l)Ry}{(m+l)+Ry}=\frac{R1+R2}{R2}\left[R3+\frac{mRy}{(m+l)Ry}\right]$

Or,R3+Rx+$\frac{(m+l)Ry}{(m+l)+Ry} = \left[\frac{R1}{R2} + 1\right]\left[R3 + \frac{mRy}{m+l+Ry}\right]$

Or,Rx+$\frac{(m+l)Ry}{m+l+Ry} + R3 = \frac{R1R3}{R2} + R3$+$\frac{mR1\,Ry}{R2(m+l+Ry)} + \frac{mRy}{l+m+Ry}$

Or,Rx=$\frac{R1R3}{R2} + \frac{mR1\,Ry}{R2(m+l+Ry)} + \frac{mRy}{m+l+Ry} - \frac{(m+l)Ry}{m+l+Ry}$

Or,Rx=$\frac{R1R3}{R2} + \frac{mR1Ry}{R2(m+l+Ry)} + \frac{mRy - lRy - mRy}{L+m+Ry}$

Or,Rx=$\frac{R1R3}{R2} + \frac{mR1Ry}{R2(m+l+Ry)} - \frac{lRy}{m+l+Ry}$

Rx=$\frac{R1R3}{R2} + \frac{mRy}{m+l+Ry}\left[\frac{R1}{R2} - \frac{l}{m}\right]$

But $\frac{R1}{R2} = \frac{l}{m}$

Rx=$\frac{R1R3}{R2}$

*The above equation is the usual equation for kelvin’s bridge

*It indicates that the resistance of the connecting load Ry, has no effect, on the measurement, provided that the ratios of the resistance of the two sets of ratio arms are equal.

*The kelvin's bridge is used for measuring very low resistances from 1Ω to 0.00001Ω (accuracy varying from ±0.05% to ±0.2%

5.Explain the necessary diagram how the resistance can be measured using DC potentiometer. [CO5-H1-Nov 2015]

Measurement of Resistance:-

*the circuit of measurement of resistance with a potentiometer is shown in fig.

*The unknown resistance, R is connected in series in series with a standard resistor S.

*The current through the circuit is controlled with the help of a rheostat.

*A two pole double throw switch is used.

*This switch, when put in position 1, 1' connects the unknown resistance to the potentiometer.

*Suppose the reading of the potentiometer is V_R.

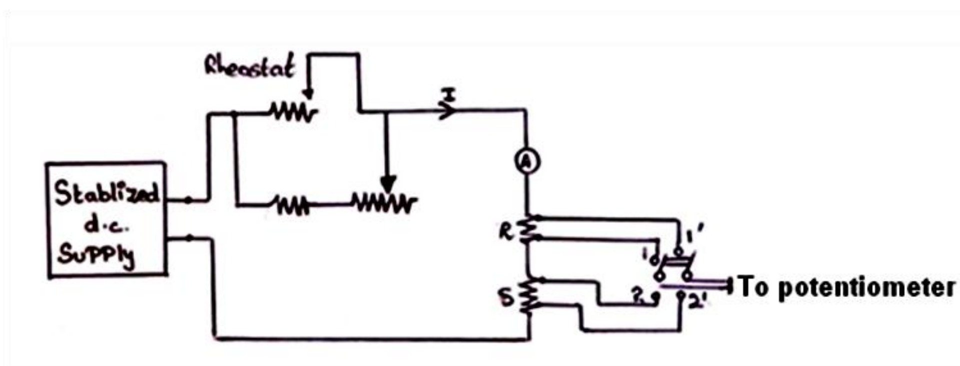


Fig:- Measurement of resistance with potentiometer

$\therefore Vr = IR$ ----------------- 1

*Now the switch is thrown to position 2,2', this connects the standard resistor to the potentiometer suppose the reading of potentiometer is Vs

Vs=Is ------------------------ 2

From I and ii $R=\frac{VR}{Vs}.S$

*Since the value of standard resistance s is accurately known value of R can also be accurately known.

*The accuracy of this method depends upon the assumption that there is no change in the value of current when the two different measurements are taken.

*Therefore a stable d.c. supply is absolutely necessary.

*The difficultly of ensuring this condition is the chief disadvantage of this method.

*The resistance of the standard resistor, S which must be accurately known, should be of the same order as the resistance R, under measurement.

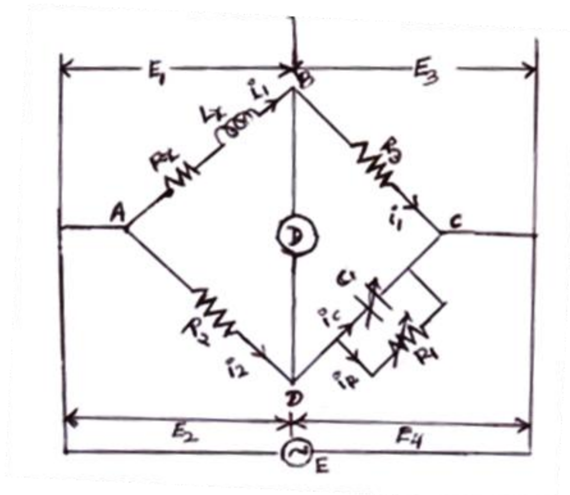
*The ammeter inserted in the circuit is merely for indicating whether the current flowing through the circuit is within the capacity of the resistors or not otherwise the exact value of current flowing need not be known.

*It is desirable that the current flowing through the circuit be so adjusted that the value of voltage drop across each resistor is of the order of 1 volt.

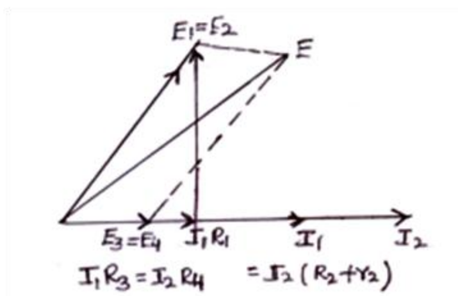
6.Elaborate the Maxwell's inductance-capacitance bridge and give its advantages and disadvantages. [CO5-H1]

In this bridge, an inductance is measured by comparison with standard variable capacitance

Circuit diagram:-



Phasor diagram:-



One of the ration arms consists of resistance and capacitance in parallel. Hence it is simple to write bridge equations in the admittance form.

The general bridge balance equation is,

$$\overline{Z1Zx} = \overline{Z_2Z_3}$$

$$\overline{Zx} = \frac{\overline{Z_2Z_3}}{Z_1}$$

$$\overline{Zx} = \overline{Z_2Z_3}\ .\overline{y1} \text{ ------------------------ } 1$$

Where

$\overline{Y_1} = \frac{1}{\overline{Z1}}$ i.e. R1 in parallel with C1

$\overline{Z_2} = R2$

$\overline{Z_3} = R3$

$\overline{Zx} = Rx + jwLx, as\ Lx\ in\ series\ with\ Rx$

Now $\overline{Y_1} = \frac{1}{R1} + jwc1$--------------------- 2

As $\overline{Z_1} = R1\ II\ j\left(\frac{1}{wc1}\right)$ i.e, 1/j=-j

Substuting the values equation 1

We get,

Rx+ jwLx=R2 R3$\left[\frac{1}{R1} + jwc1\right]$

Rx+ jwLx=$\frac{R2\ R3}{R1} + jR2R3wc1$

Equating real parts,

Rx=$\frac{R2R3}{R1}$

Equating imaginary parts

wLx=R2R3wc1

Lx=R2 R3 C1

The resistors are expressed in ohms, the inductances in henry and capacitance in farads.

The quality factor of the coil is given by,

Q=$\frac{wLx}{Rx}$

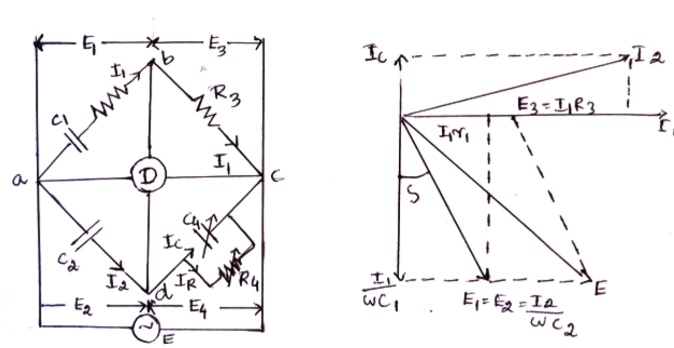
$=\frac{wR2\ R3\ C1}{\left(\frac{R2R3}{R1}\right)}$

Q=wR1C1

Advantages:
1.The two balance equations are obtained is independent if we choose R1 and C1 as variable elements
2.The frequency does not apper in any of the two equations.
3The scale of the resistance can be calibrated to read the inductance directly.
4.the cscale of R1 can be calibrated to read the Q value directly.

Disadvantages:
1.It cannot be used for the measurement of high Q values. It use is limited to the measurement of low Q values from 1 to 10.
2.There is an interaction between the resistance and reactance balances. Getting the balance adjustment is little difficult.
3. It is unsuited for the coils with low Q values, less than one, because of balance convergence problem.
4.The bridge balance equations are independent of frequency. But practically, the properties of coil under the test vary with frequency which can cause error.

7.Explain the operation of Schering bridge to determine the unknown capacitance. Derive the relevant equation and explain computation procedure using phasor diagram. [CO5-H1]



Let

C1=Capacitor whose capacitance is to be determined

R=a series respectively the loss in the capacitance

C2=a standard capacitor this capacitor is either, an air or a gas capacitor and hence it loss free. However, if necessary a capacitions may for the loss angle of this capacitor.

R3=non-inductive resistance

C4=a variable capacitor

R4=a variable non-inductance resistance in parallel with the variable capacitor C4

At balance

$\left(r_1 + \frac{1}{jwc\,1}\right)\left(\frac{R4}{1+jwC\,4\,R4}\right) = \frac{1}{jwC\,2}$.R3

$\left(r_1 + \frac{1}{jwc\,1}\right)\ R4 = \frac{R3}{jwc\,2}(1 + jwC4\ R4)$

$r_1 R_4 - \frac{jR\,4}{wC\,1} = -j\,\frac{R3}{wC\,2} + \frac{R3\ R4\ C4}{C2}$

Equating the real and imaginary terms, we obtain

$r_1 = \frac{R3\ C4}{C2}$

$C_1 = C_2\left(\frac{R4}{R3}\right)$

Two independent balanced equations are obtained if C4 and R4 are obtained for chosen as the variable element

D1=tan S=wC1 r1

D1=w(C2 R4/R3)*(R3 C4/C2

D1=wC4 R4

Therefore the value of capacitance C1,and it dissipation factor are obtained from the value s of bridge element at balance.

Permanently set up Schering bridge for sometimes arranged so balancing is done by adjustment R3 and C4 with C2 and R4 remaing fixed since R3 appears in both the balance equation and therefore there some difficulty in obtaining balance but it has certain advantages as explained below.

The equation for capacitance is C1=(R4/R3) C2 and since R4 and C2 are fixed, the dial of resistor R3 may be caliberated to read the capacitance directly.

Dissipation factor D1=wC4 R4 and in case of the frequency is fixed the dial capacitor C4 can be calibrated to read the dissipated factor directly.

Let us say that the working frequency is 50Hz and value of R4 is kept fixed at 3,180Ω

Dissipation factor D1=$2\pi \times 50 \times 3180 \times C4 = C4 \times 10^6$

Since C4 is a variable decade capacitance box, its setting in μF gives the value of the dissipation factor directly

It should, however, be understood that the calibration for dissipation factor holds good for one particular frequency, but may be used at another frequency if correction is made by multiplying by the ratio of frequency.

8.What are the methods available for reducing earth resistance hoe to measure about earth resistance and soil resistivity. [CO5-H1]

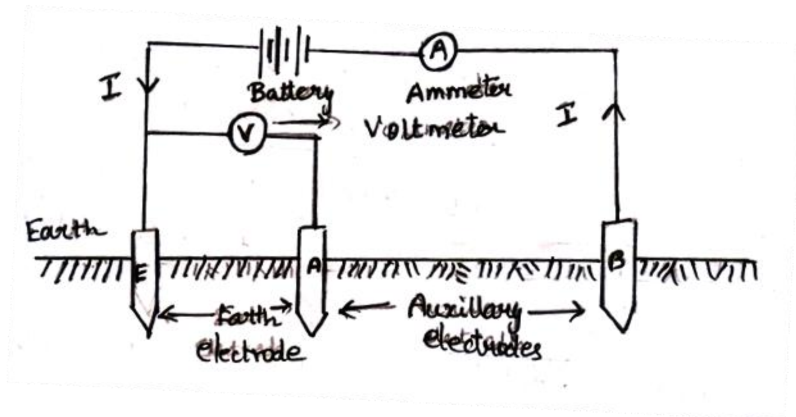
Methods of measuring Earth Resistance:-

The methods of measuring earth resistance has two methods

i)Fall of potential method

ii)earth tester

i)Fall of potential method



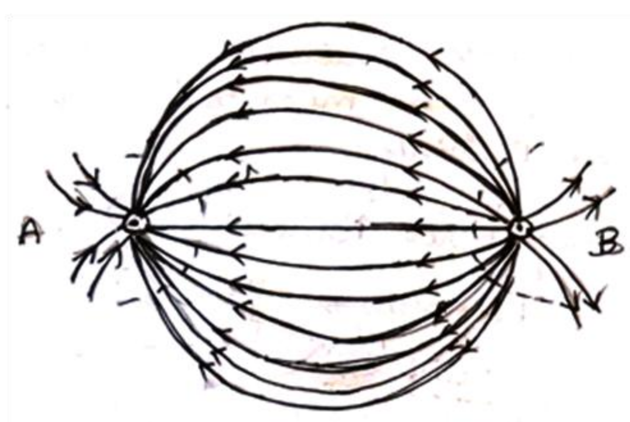
The above figure shows the circuit for measurement of Earth resistance with fall of potential method.

A current is passed through earth electrode E to an auxiliary electrode (B) (which is usually an iron spike inserted in earth at a distance away from the earth electrode.

A secondary auxiliary electrode A is inserted in Earth between E and B

The potential difference V between E and A is measured for a given current I.

The flow of ground currents is shown in the below figure

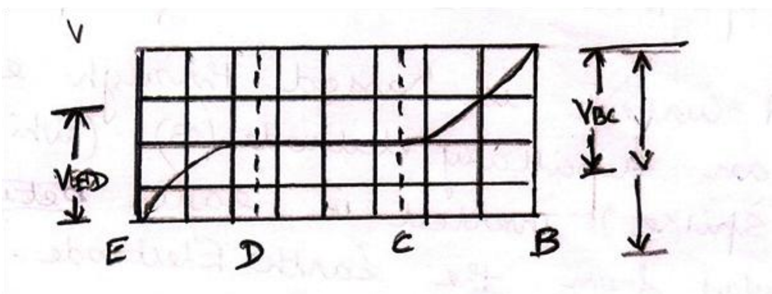


It is apparent from this curve that the potential rises in the proximity of electrodes E and B is constant along the middle section

The lines of the first electrode current diverge and those of the second electrode current converge.

As a result the current density is much greater in the vicinity of the electrode than at a distance from them.

The potential distribution between the electrodes is shown in the below figure



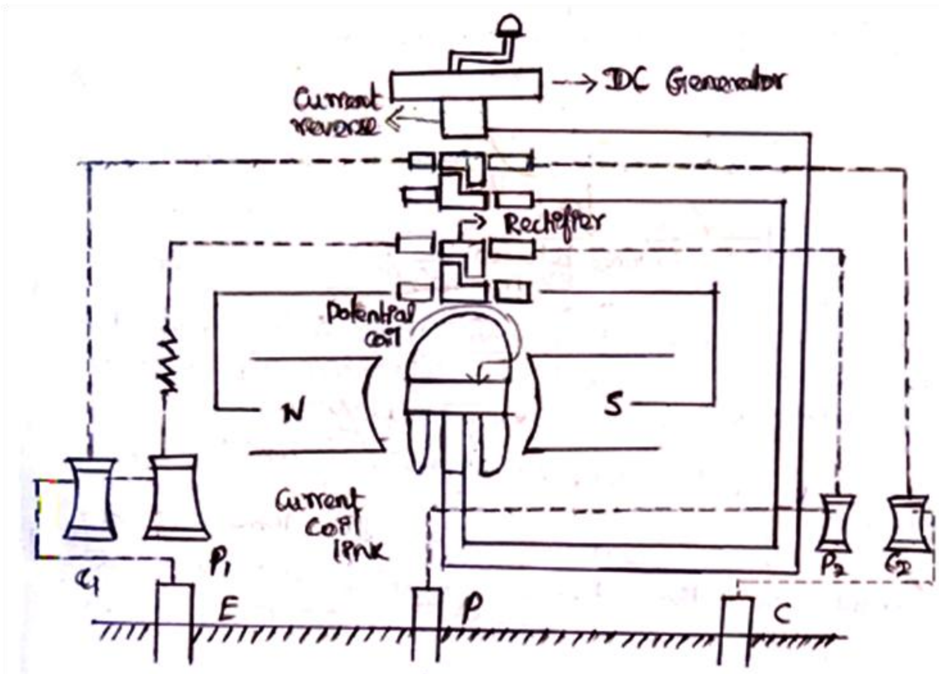
The resistance of earth therefore is RE=V/I or VEA/I.

The position of electrodes E and B is fixed and the position of electrode A changed and resistance measurements are done for various positions of electrod A

A graph is plotted between Earth resistance against the distance between electrode E and E. The graph

ii)Earth tester

The resistance of Earth can be measured by an Earth tester as shown in below figure



The earth tester is a special type of megger and it has some additional constructional features and they are

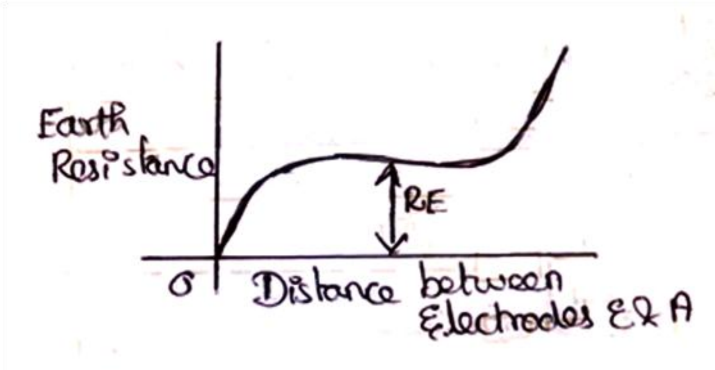
i)A rotating current reverser

ii) A rectifier

Both these addition features consist of simple commutators made up of 'L' shaped segments.

They are mounted on the shaft of the hand drive generator

Each commutators has four fixed brushes. One pair of each set of brushes is so positioned that they make contact alternately as commutator rotates. Is shown as below



From the above graph it is clear that the measured value of Earth resistance depends upon the position of the resistance reses rapidly initially.

When the distance between earth electrode E and auxiliary electrode A is increased, it then becomes constant.

When the auxiliary is thus very important and serious error may be caused by incorrect placing of the electrodes.

The correct value of resistance of earth RE is when the auxiliary electrode A is at such a distance that the resistance lies on the flat part of curve.

Then shaping between the earth electrode E and the auxiliary electrodes A,B should be large so as to get proper results

The distance may be a few hundred meters in case the earth resistance is low.

Measurement of Earth resistance:-

The provision of an earth electrode of an electrical system is necessitated by the following reasons

1.All the parts of electrical equipment like casing of machines, switches and circuit breakers, lead sheeting and armoring of cables tanks of transformers etc… which have to be at earth potential must be connected to an electrode the purpose of this is to protect the various parts of the installation as well as the persons working against damage in case the insulation of the system fails at any point

2.The earth electrode ensures that in the event or system faults those parts of equipment which are normally dead as far as voltages are concerned do not attain dangerously high potentials. 3.In a three phase circuit th neutral of the system is earthed in order to stabilize the potential of the circuit with respect to earth.

An earth electrode will only be effective so long it has a low resistance to the earth and can carry large currents without deteriorating since the amount of current which an earth electrode will carry is difficult to measure the resistance value of the earth electrode is taken as sufficiently reliable indication of its effectiveness the resistance of earth electrode should be low to give good protection and it must be measured.

The second pair of each of set of brushes is positioned on the commutator so that conditions contact is made with one segment what ever the position commutator.

The earth tester has four terminals P1,P2 and C1,C2. Two terminals P1 C1 are shorted tp form a common paint to be connected to the earth electrode.

The other two terminals P2 and C2 are connected to auxiliary electrodes P&C respectively The indication of the earth tester depends the ratio of the voltage across the pressure coil and the current through the coil.

The deflection of its pointer indicates the resistance of earth directly.

Although the earth tester which is permanent magnet moving coil instrument and can operate on d.c.

Only yet by including the reverser and the rectifying device it is possible to make measurements with ac flowing in the soil.

The sending of ac current through the soil has many advantages and therefore this system is used.

The use of a.c. passing through the soli eliminates unwanted effects due to production of a back emf in the soli on account of electrolytic action

Also the instrument is free from effects of alternating or direct currents presents in the soil. The main factor on which the resistance of any earthling system depends are:-

i)Shape and material of the earth electrode or electrode used

ii)Depth in the soil at which the electrode are barried

iii)Specific resistance of soli surroundings and in the neighborhood of electrodes. The specific resistance of the soil is not constant but varies from one type of soil to another the amount of moisture present in the resistance of soil effects its specific resistance and hence the resistance of earth electrode is not a contact factor but suffers seasonal variations. This calls for periodic testing to ensure that the earthing system remains reasonably effective.

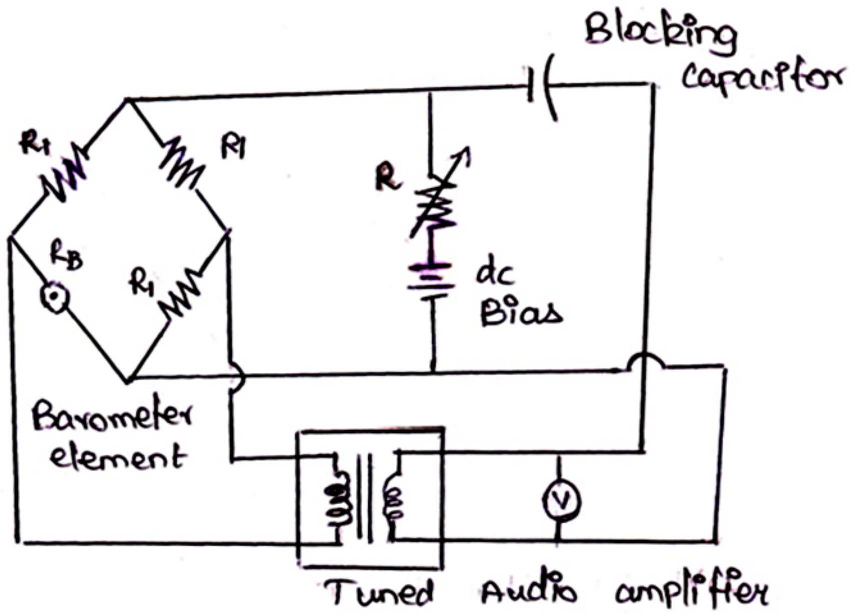
The specific resistance of soil varies between wide limits and is very much dependent upon its moisture content.

Approximate figures for specific resistance of soil are $80*10^3\Omega m$ for moist clay to $80*10^5\Omega m$ for sand of normal moisture content.

A decrease of moisture content of 30% is capable of producing an increase of 300-400%. In specific resistance. Thus it is necessary to make regular checks for the earth resistance during the year round.

9.How the power can be measured using self balancing brige explain with necessary diagram. [CO5-H1]

The power can be measured by using self balancing Bolometer bridge.



The term self balancing is used to describe bridges which are automatically rebalanced when unknown RF power is applied to the bolomater. A typical circuit illustrated in above figure.

The bolometer bridge is used as the coupling network between the output and input of a high frequency selective audio amplifier.

The feedback is in proper phase to produce sustained AF oscillations of such amplitude as well maintain the resistance of the bolometer at the fixed value which nearly balances the bridge.

When the supply is switched on the bridge is unbalanced.The gain of the amplifier is large, so that oscillations are allowed to build up until the bridge is almost balanced.

The higher the gain of the amplifier the closely the bridge balances.

The test RF is now dissipated into the bolometer element which causes an imbalance in the bridge circuit.

The AF output voltage automatically adjusts itself to restore the blometer resistance to its original value.

The amount by which the AF power level in the bolometer is reduced equals the applied RF power.

The voltmeter reads the AF voltage and can be directly.

A typical bridge circuit offers seven power ranges from 0.1-100 mw full scale for use with bolometer having a resistance with in +10% of five selected values from 50-250Ω.

10.Explain the Hay bridge can be used for the measurement of inductance?
Hay bridge[CO5-H1]

This is another modification of the Maxwell wein bridge which may be used to advantage if the phase angle of the inductor$\left[\tan^{-1}\frac{\omega L}{R}\right]$ under test is large.The circuit arrangement which is drawn. In this arrangement L1 is self inductance and R1 is the resistance of the coil under test, R2,R3 and R4 are known non-inductive resistances and C4 is a standard variable capacitor. The bridge is balanced by varying R4 and C4. It is often more convenient to use a capacitor of fixed value and to make R4 and either R2 or R3 adjustable.
When the bridge is balanced

I2=I1; I4+I3; V1=V3 and V2=V4

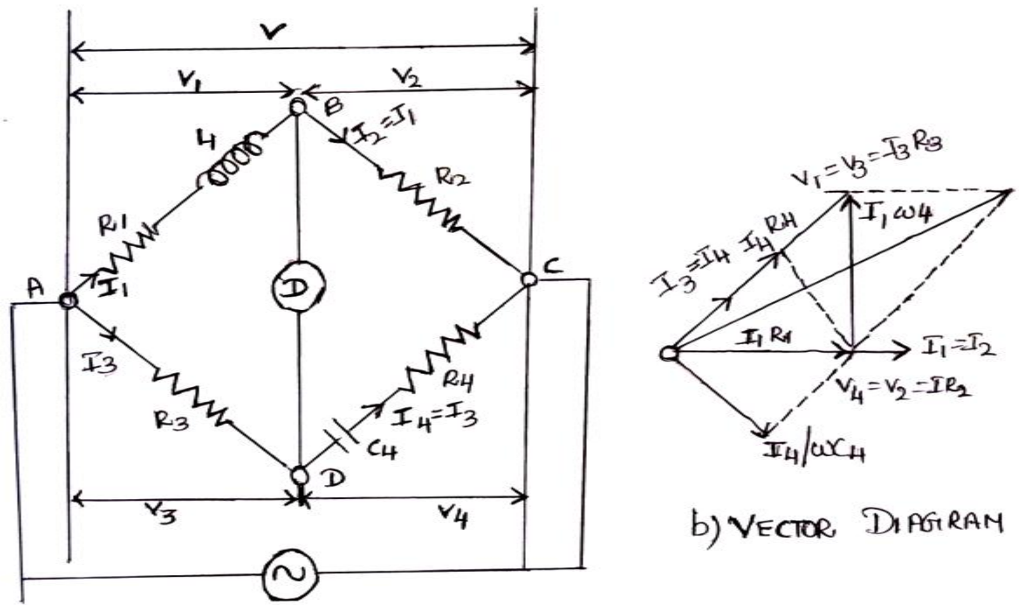
Since V1=I1Z1=I1 (R1+jwL1)

And V3+I3R3

I1(R1+jwL1)=I3R3 ------------------1

And V2=I2 R2=I1R2

V4=I4Z4=I3$\left[R4-\frac{j}{wC4}\right]$ ----------------2



Dividing expression 1 by 2, we get

$\frac{R1+jwL\,1}{R2} = \frac{R3}{\left[R4-\frac{j}{wC\,4}\right]}$ ----------------------------- 3

Or R1 R4+L1/C4+j$\left[wL1\ R4 - \frac{R1}{wC4}\right] + R2R3$

Seperating reals and imaginations, we get

R1 R4+L1/C4=R2 R3 ----------- 4

And wL1 R4-R1/wC4=0

Or R1=w^2 C4L1 R4 --------- 5

Solving expressions 4 and 5 we get

L1=$\frac{R2\ R3\ C4}{1+w^2c^24R^24}$---------------------------------- 6

Substitute 6 in equation 5

And R1=w^2 C4 R4 × $\frac{R2\ R3\ C4}{1+w^2c^24R^24}$

=$\frac{R2\ R3\ R4c^24w^2}{1+w^2c^24R^24}$----- 7

Expressions 6 and 7 indicate that the balance condition is a function frequency. However, the frequency need not be accurately known to determine inductance since w appears only in a term which will be small compared to unity incases where use of hay bridge is indicated(i.e where Q factor of coil is large)

Q-factor of the coil=$\frac{wL1}{R1} = \frac{\frac{wR\ 2R3C4}{1+w^2c^24R^24}}{\frac{R2\ R3\ R4c^24w^2}{1+w^2c^24R^24}}$

=$\frac{1}{wR4C4}$

Now the term $w^2c^24R^24$ in the denominatiors of equation 4 and 6 has the value of 0.01 if q=10 and even more smaller for higher values of Q so the term $w^2c^24R^24$ can be dropped without causing an apprecible error. In case, this term is to be included in calculations of L1 and R1 then it is of such minor importance that it may be approximate value of frequency here it should be noted that if the term $w^2c^24R^24$ is excluded from Maxwell bridge.

L1=$\frac{R2\ R3\ C4}{1+w^2c^24R^24}$

But Q=$\frac{1}{wR4C4}$

So L1=$\frac{R2R3C4}{1+(1/Q)^2}$

For the value of a greater than 10, the term$w^2c^24R^24$ will be smaller than 1/100 and so can be neglected.
Therefore L1=r2R3C4 and it is the same as for the Maxwell bridge.
The bridge has the advantage of requiring only a relatively low- value resistor for R4 where as, for large inductance low resistance coils, THE Maxwell-wein bridge would

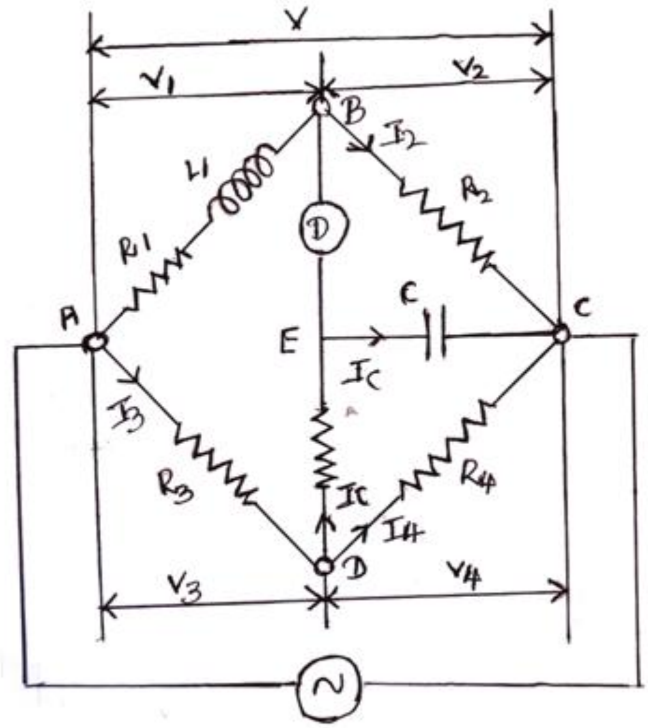
require a parallel resistance R4 of very high, perhaps 10^5 or $10^6\Omega$. Resistance boxes of such a high values are very costly.

This bridge is not suited for the measurement of low Q-factor of the inductors, because in that case, the term $w^2c^24R^24$ in the denominator becomes very important.and then it is required to know the bridge frequency to a very accurate limit. Moreever with low value of Q-factor. It gives poor convergence in balancing.

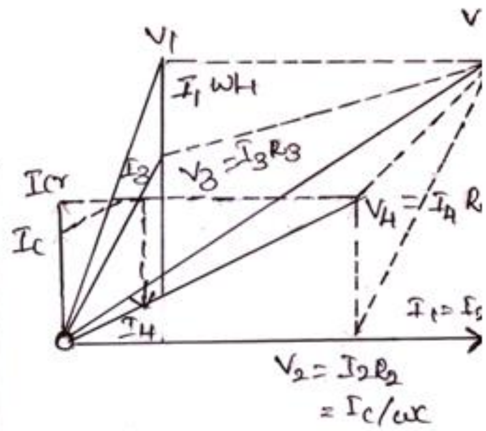
11. Explain the Anderson Bridge with it advantage & Disadvantage[CO5-H1]

This method is one of the commonest and best bridge method for precise measurement of inductance over a wide range. In this method the unknown self inductance is measured in terms os a known capacitance and resistance by comparison. It is actually a modification of the Maxwell-wein bridge and is an example of a more complicated bridge network. The circuit is in which L1 is self inductance and R1 is the resistance of the coil under test R2,R3,R4 r are known non-inductive resistances and C is a standard known capacitor.

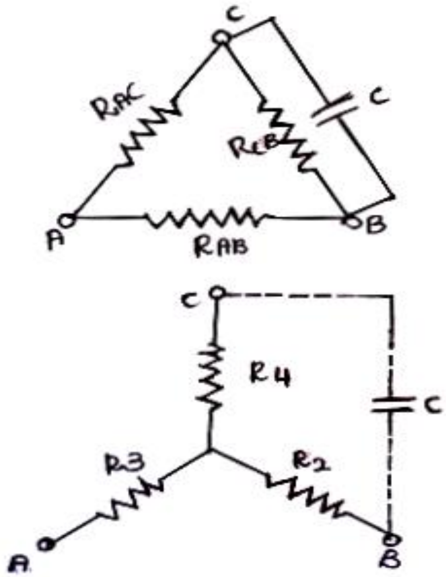
The bridge is preliminary balanced for steady current by adjusting R2, R3 and r4 using an ordinary galvanometer as detector and then bridge is balanced in alternating current by varying r and using vibration galvanometer or telephone depending upon the supply frequency.

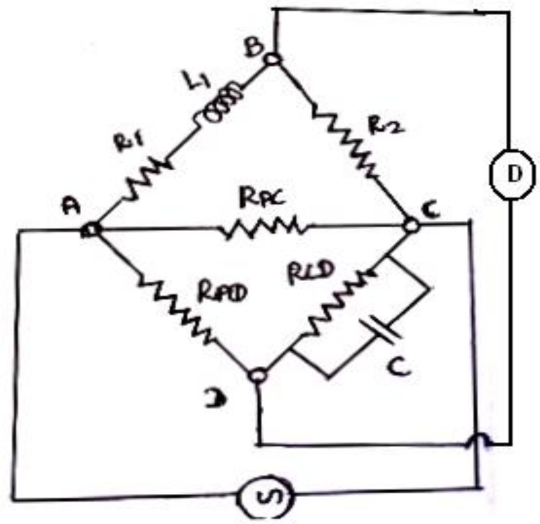


a)Circuit diagram



b)Vector diagram





When the bridge is balanced

I2=I1 Ir=IcI3=I4+Ic

V1=V3+Icr and V2=V4+Icr

From the theory of star-delta transformation

$$R_{AD} = R_{3r}\left[\frac{1}{R4}+\frac{1}{R3}+\frac{1}{r}\right]$$

$$R_{CD} = R_{4r}\left[\frac{1}{R4}+\frac{1}{R3}+\frac{1}{r}\right]$$

$$R_{AC} = R_3R_4\left[\frac{1}{R4}+\frac{1}{R3}+\frac{1}{r}\right]$$

$$\text{R1}=\frac{R4}{R_{CD}} = \frac{R2\ R3\ r\left[\frac{1}{R4}+\frac{1}{R3}+\frac{1}{r}\right]}{R4r\left[\frac{1}{R4}+\frac{1}{R3}+\frac{1}{r}\right]}$$

And L1=CR2R_{AD}=CR2R3r$\left[\frac{1}{R4}+\frac{1}{R3}+\frac{1}{r}\right]$

Or L1=$\frac{CR2}{R4}\left[r(R3+R4)+R3R4\right]$

Note:-
The resistance R_{AC} in parallel with the ac source of supply contributes nothing to the balance of bridge.

Advantages:-
1.Can be used for accurate measurement of capacitance interms of inductance.
2.Other bridge require variable capacitor but a fixed capacitor can be used for Anderson’s bridge.
3.the bridge is easy to balance from convergence point of view compared to Maxwell’s bridge in case of low values of Q.

Disadvantages:-
1.It is more complicated than other bridges
2.Uses more number of components
3.Balance equations are complicated to derive.
4.Bridge cannot be shielded due to additional junction point, to avoid the effects of stray capacitances.

12. The bridge which is used measure the frequency “Wien Bridge” [CO5-H1]

Basically the bridge is used for the frequency measurement but it is also used the measurement of the unknown capacitor with great accuracy.

Its one ratio arm consists of a series RC circuit of the parallel combination of resistance and capacitor i.e R3 and C3. T

$Z_1 = R_1 - j\left[\frac{1}{\omega C1}\right]$

$Z_1 = R_2$

$Z_3 = R_3 \, II \, C_3$

$Y_3 = \frac{1}{R_3} + j\omega C_3$

The balance condition is,

$\overline{Z_1 Z_4} = \overline{Z_2 Z_3}$

$\overline{Z_4} = \frac{\overline{Z_1 Z_4}}{\overline{Z_3}} = Z_1 \overline{Z_4 Y_3}$

$R_2 = \left[R_1 - j\left[\frac{1}{\omega C1}\right]\right] R_4 \left[\frac{1}{R_3} + j\omega C_3\right]$

$R_2 = R_4 \left[\frac{R_1}{R_3} + j\omega R_1 C_3 - j\frac{1}{\omega C_1 R_3} + \frac{C_3}{C_1}\right]$

$R_2 = R_4 \left[\frac{R_1}{R_3} + \frac{C_3}{C_1}\right] + jR_4 \left[\omega R_1 C_3 - \frac{1}{\omega C_1 R_3}\right]$

Equating real parts of both sides,

$R_2 = \frac{R_4 R_1}{R_3} + \frac{C_3 R_4}{C_1}$

$\frac{R_2}{R_4} = \frac{R_1}{R_3} + \frac{C_3}{C_1}$ ----------------------- 1

Equating imaginary parts of both sides,

$\omega R_1 C_3 - \frac{1}{\omega C_1 R_3} = 0$

$\omega^2 = \frac{1}{R_1 R_3 C_1 C_3}$

$\omega = \frac{1}{\sqrt{R_1 C_1} R_3 C_3}$

F=$\frac{1}{2\pi\sqrt{R_1 C_1} R_3 C_3}$ ------------------------- 3

The equation 1 gives the resistance ratio while the equation 3 gives the frequency of applied voltage.

Generally in wien bridge, the selection of the components is such that

$R_1 = R_3 = R$

$C_1 = C_3 = C$

$\frac{R_2}{R_4} = 2$ ------------------- 4

F=$\frac{1}{2\pi RC}$-------------------- 5

The equation 5 is the general equation for the frequency of the bridge circuit.

Applications:-

The bridge is used to measure the frequency in audio. The range is (20-200-2k-20k)Hz. The resistance are for the range changing while the capacitors are used for fine frequency control.

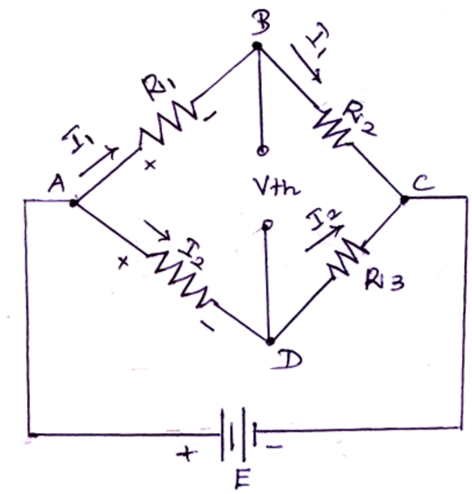
13. Explain voltage sensitive self balancing bridge, and derive the bridge sensitivity of voltage sensitive bridge with fundamental. [CO5-H1]

The bridge sensitivity can be calculated by solving the bridge for small unbalance.

At balance condition R4=R3$\frac{R1}{R2}$

$\frac{R4}{R3} = \frac{R1}{R2}$

Let the resistance R4 is changed by ΔR creating the unbalance. Due to this, the emf appears across the galvanometer. To obtain this emf let use thevenins method. Remove the branch of galvanometer and obtain the voltage across the open circuit terminals.



$E_{AB} = I1R1$

I1=$\frac{E}{R1+R2}$

$E_{AD} = I2(R4+\Delta R)$

I2=$\frac{E}{R3+R4+\Delta R}$

$V_{BD=}V_{TH=}E_{AD} - E_{AB}$

$V_{TH} = \frac{E(R4+\Delta R)}{R3+R4+\Delta R} - \frac{E}{R1+R2}R1$

$V_{TH} = E\left\{\frac{R4+\Delta R}{R3+R4+\Delta R} - \frac{R1}{R1+R2}\right\}$

$\frac{R4}{R3} = \frac{R1}{R2}$

Then $\frac{R1}{R1+R2} = \frac{R4}{R4+R3}$

Using above relation in equation

$V_{TH} = E\left\{\frac{R4+\Delta R}{R3+R4+\Delta R} - \frac{R4}{R3+R4}\right\}$

$=E\left\{\frac{R3R4+R3\Delta R+R4^2+R4\Delta R-R3R4-R4^{2-R4}\Delta R}{(R3+R4)(R3+R4+\Delta R)}\right\}$

$=\frac{ER3\Delta R}{(R3+R4)^{2+(R3+R4)\Delta R}}$

But as ΔR is very small,(R3+R4) ΔR ,<< $(R3+R4)^2$

$V_{TH=}V_g = \frac{ER3\Delta R}{(R3+R4)^2}$

Now SB=$\frac{Q}{\frac{\Delta R}{R}} = bridge\ sensitivity$

ΔR/R=ΔR/R4 as there is change in R4

From the galvanometer sensitivity Sv,

$$\theta = Svxe\ where\ e = voltage\ across\ galvanometer$$

Using θ in the expression of S_B,

$S_B = \frac{Sv\ Vg}{\Delta R/R4} = \frac{Sv\ ER3\ \Delta R\ R4}{(R3+R4)^2} = \frac{SvER3R4}{R3^2+2R3\ R4+R4^2}$

$S_B = \frac{SvE}{\frac{R3}{R4}+2+\frac{R4}{R3}}$

Thus the bridge sensitivity depends on the bridge parameters the supply voltage and the voltage of the galvanometers.