AMIRAJ
COLLEGE OF ENGINEERING & TECHNOLOGY

LABORATORY MANUAL

TESTING AND COMMISSIONING OF ELECTRICAL EQUIPMENT

SUBJECT CODE: 2180901

DEPARTMENT OF ELECTRICAL ENGINEERING

B.E. 8th SEMESTER

NAME: ____________________

ENROLLMENT NO: ____________________

BATCH NO: ____________________

YEAR: ____________________

Amiraj College of Engineering and Technology,
Nr.Tata Nano Plant, Khoraj, Sanand, Ahmedabad.

Amiraj College of Engineering and Technology,

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This is to certify that Mr. / Ms. ____

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Satisfactorily completed the course in __________________________________as

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Date of Submission:-

Faculty Name and Signature

(Subject Teacher)

Head of Department

(ELECTRICAL)

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List Of Experiments

Sr. No.	Title	Date of Performance	Date of submission	Sign	Remark
1.	To study fault finding chart of electrical equipments.				
2.	Study of HV Breakdown Tester.				
3.	To perform and study breakdown test of transformer oil according to IS:6792				
4.	To Perform Brake Test on DC Shunt Motor.				
5.	To Perform Hopkinson's Test On DC Shunt Machines.				
6.	To Perform Field Test On DC Series Motor.				
7.	To Measure The Slip Of Induction Motor At Different Loads Using Stroboscopic Method.				
8.	To study about maintenance of electrical equipment.				
9.	Testing of solid insulation with point-point electrodes.				
10.	To study 3 phase transformer connections				

LABORATORY EXPERIMENT –1

AIM: To study fault finding chart of electrical equipments.

FAULT FINDING CHART

FOR

(3 PHASE AC SLIM, SYNC. MOTOR, SQIM & ALTERNATOR).

SR. NO.	Fault Symptom	Possible Causes	Remedy
1.	No voltage from alternator	a) No excitation to rotor	give proper excitation.
		b) Loose connection or inadequate brush tension.	Check up all connection for tightness and also spring tension as well as free movement of brushes in its holders, so that they are resting on the sliprings properly.
		c) Discontinuity in stack or armature cat.	check and restore the continuity.
2	Low voltage form alternator	a) Low prime mover speed.	Adjust prime mover speed to rated
		b) Loose connection or inadequate brush tension.	Check up all connection for tightness and also spring tension as well as free movement of brushes in its holders, so that they are resting on the sliprings properly.
		c) Low field excitation.	Adjust excitation to rated value.
3	High voltage form alternator	a) over excitation of the field	Adjust excitation to rated value.
4	Motor fails to start.	a) Discontinuity in stator /rotor ckt.	Cheak the continuity and restore
		b) Loose connection or inadequate brush tension.	Check up all connection for tightness and also spring tension as well as free movement of brushes in its holders, so that they are resting on the sliprings properly.

		c) improper supply voltage	check for supply voltage.
		d) Slipring connection are open	connectckt. as per proper ckt. diagram.

SR. NO.	Fault Symptom	Possible Causes	Remedy
5	Motor starts drawing heavy current.	a) Improper connection.	connect primary and secondary terminals of stator as per ckt. diagram.
		b) Single phasing of motor	correct continuity and supply for proper three phase running.
		c) Single phasing in rotor.	Check for proper tension and connection of brushes.
6	Draws heavy current in syn. motor	a) excitation is not set for unity power factor.	set excitation for unity power factor
7	syn. motor does not synchronous at all.	a) no excitation .	set proper excitation .
8	Motor takes low current but does not take load.	a) Stator terminals are connected in star instead of delta.	check for proper connection.
9	Machine overheating	a) Machine overloaded	Check the loading condition and reduce the load.
		b) Over excitation of the machine	Check proper excitation.
		c) Excitation is on when machine is stopped.	Off the excitation.
		d) Cooling air inlet/outlet locked.	Check and blow out blockage due to huff etc. or any other blockage at air inlet/outlet.

FAULT FINDING CHART

FOR

(1 PHASE AC CSIR, CSCR & SPLITPHASE AC MOTOR).

SR. NO.	Fault Symptom	Possible Causes	Remedy
1	Motor fails to start.	a) discontinuity of starting /running winding.	check continuity.
		b) discontinuity in C/F switch.	check and remove the problem.
		c) Loose contacts .	check all the connection for tightness.
		d) No supply voltage.	Check for supply.
2	Motor starts drawing heavy current.	a) C/F switch does not operate.	solve the difficulty.
		b) starting& running wdg. are short.	check the connections.
		c) capacitor may damage.	check for capacitors.
3	Motor does not start in split phase mode.	d) No supply voltage	Check for supply.
		a) Damage / absent of resistance in series with startingwdg.	Check for external resistance.
		b) No supply voltage	Check for supply.

FAULT FINDING CHART

FOR

(UNIVERSAL OR REPULSION MOTOR)

1	Motor fails to start but does not draw any current.	a) Discontinuity in armature or field circuit.	Check the continuity and restore
		b) Loose contacts or inadequate brush tension	Check all the connection for tightness.
		c) Low supply voltage.	Set the voltage to rated value.
2	Motor starts drawing heavy current.	a) Short circuit in armature.	Check and remove the fault where possible.
		b) Improper brush position.	Set the brush position to marked position in rocker.
3	Low speed form motor.	a) Loose connection or inadequate brush tension.	Check all the connection for tightness.
		b) Improper brush position.	Set the brush position to marked position in rocker.
		c) Low supply voltage	Set the voltage to rated value.
4	High speed from motor.	a) No load on motor.	motor is not allowed to run on no load there must be 50 % of full load.
		b) High voltage across armature.	Adjust the voltage to rated value.
		c) Improper brush position.	Set the brush position to marked position in rocker
5	Mechanical noise in machine.	a) Foreign metallic or solid matters inside the machine.	Inspect the interior and clean the machine.
		b) Damaged bearing.	Check the bearing and its housing and replace if necessary.

SR. NO.	Fault Symptom	Possible Causes	Remedy
6	Machine overheating	a) Machine overloaded.	Check the loading condition and reduce the load.
		b) Cooling air inlet / outlet locked.	Check and blow out blockage due to huff etc.
7	very injurious sparking on the brushes.	a) Brushes not bedded properly.	Check and bed the brushes properly.
		b) Improper brush position.	Set the brush position to the marked position.
		c) Overloading in the machine.	Check the loading condition.
		d) Dust or carbon particles on the commutator surface.	Clean the commutator surface with help of send paper.

FAULT FINDING CHART

FOR

(DC MOTOR – GENERATOR)

SR. NO.	Fault Symptom	Possible Causes	Remedy
1	Motor fails to start but does not draw any current.	a) Discontinuity in armature or series field circuit.	Check the continuity and restore
		b) Loose contacts or inadequate brush tension	Check all the connection for tightness.
		c) Low supply voltage.	Set the voltage to rated value.
2	Motor starts drawing heavy current.	a) Short circuit in armature.	Check and remove the fault where possible.
		b) Improper brush position.	Set the brush position to marked position in rocker.
		c) In case of Compound Motor Differeintial compounding.	Reverse the shunt or series field polarity.
		d) No or very low excitation.	Check excitation voltage.
		e) Discontinuty in shunt field circuit.	Check for continuity and restore.
3	Low speed from motor.	a) Loose connection or inadequate brush tension.	Check all the connection for tightness.
		b) Improper brush position.	Set the brush position to marked position in rocker.
		c) Low supply voltage	Set the voltage to rated value.
		d) Over excitation. /componnding	Set proper excitation.
4	High speed from motor.	a) No load on motor in case of series motor.	Series motor is not allowed to run on no load there must be 50 % of full load.
		b) High voltage across armature.	Adjust the voltage to rated value.
		c) Improper brush	Set the brush position to

		position.	marked position in rocker
		d) Under – low excitation. /componnding	Set proper excitation.

		e) In case of Compound Motor Differeintial compounding.	Reverse the shunt or series field polarity.
5	Mechanical noise in machine.	a) Foreign metallic or solid matters inside the machine.	Inspect the interior and clean the machine.
		b) Damaged bearing.	Check the bearing and its housing and replace if necessary.
6	Machine overheating	a) Machine overloaded.	Check the loading condition and reduce the load.
		b) Cooling air inlet / outlet locked.	Check and blow out blockage due to huff etc.
7	very injurious sparking on the brushes.	a) Brushes not bedded properly.	Check and bed the brushes properly.
		b) Improper brush position.	Set the brush position to the marked position.
		c) Overloading in the machine.	Check the loading condition.
		d) Dust or carbon particles on the commutator surface.	Clean the commutator surface with help of send paper.
8	No voltage from Generator.	a) Reversed field or armature connection.	Reconnect correctly .Interchange field connection with armature
		b) Loss of residual magnetism.(Self)	Remagnetise the field circuit.
		c) Armature short circuited.	Check and remove the fault where possible.
		d) Discontinuity in field or armature ckt.	Check and restore the continuity in the ckt by proper joining.

		e) Loose connection or inadequate brush tension.	Check all connections for tightness.
		f) In case of compound generator Differiential compouinding	Reverse shunt or series field winding.

SR. NO.	Fault Symptom	Possible Causes	Remedy
9	Low voltage from Generator.	a) Loose connection or inadequate brush tension.	Check all connections for tightness.
		b) Faulty brush position.	Set the brush position to marked position.
		c) Low prime mover speed.	Check and rectify prime mover speed.
		d) No load in case of series Generator.	Load the generator.
		e) In case of compound generator differential compounding.	Reverse the shunt or series field winding.
10	High voltage from generator.	a) over excitation of field.	Set proper excitation.
		b) Over compounding.	Set proper excitation.
11	Output voltage fluctuation.	a) Loose connection or inadequate brush tension.	Check all connections for tightness.
		c) Fluctuation in prime mover speed or fault in coupling.	Set the coupling and prime mover speed.

FAULT FINDING CHART

FOR
CONTROL PANEL

SR. NO.	Fault Symptom	Possible Causes	Remedy
1	Mains on LED \Lamp does not glow and panel is not operating.	1) R-Y-B Input not coming.	Check for input supply.
		2) Low Supply Voltage.	Check for the same.
		3) Fuse Blown.	Replace it.
		4) LED may be defective.	Replace it.
		5) Nutural is not Connected .	Connect the Nutural.
		6) SCR or Diode May be short	Identify and replace.
2	In DC Supply unit red light glow on & the trip relay operates.	1) Current drawn above permitted limit.	Stop the machine and correct the problem.
		2) Absent of field excitation in dc motor.	Give excitation to machine.
		3) Faulty connection to machine.	Connect the circuit as per circuit diagram.
3	Fuse blows immediately as soon as unit is switched on.	1) Earth fault in connection to machines.	Find out and clear if possible
		2) Current drawn above permitted limit.	Stop the machine and correct the problem.
		3) Wrong connections .	Make the connections as per ckt Diagrams.
		4) Phase unbalance.	Check for phase balance.
4	Panel gives light shocks.	1) Absent of proper earthing.	give proper earthing.
		2) Short ckt in connections.	rectifie the the problem.

5	Meter Deflection is negative.	1) Wrong Polarity.	Reverse the terminal connection. In case of Wattmeter/PF Meter change either pressure or current coil terminals.

6	No DC Voltage even after Speed POT fully clockwise.	1) Check field Circuit Continuity.	Restore the same if open.
		2) Check Potentiometer.	Replace if open.
7	Armature Voltage not going up to rated value.	1) Low input Supply.	Correct the same.
		2) Only one SCR may ok.	Replace the faulty SCR.
		3) ----	Adjust POT 'VFBK' in Electronic PCB

LABORATORY EXPERIMENT –2

AIM: Study of HV Breakdown Tester.

APPARATUS: Multi-meter, HV Breakdown tester panel

THEORY:

- **Breakdown in Solid Dielectrics**

Solid dielectric materials are used in all kinds of electrical circuits and devices to insulate one current carrying part from another when they operate at different voltages.

A good dielectric should have low dielectric loss, high mechanical strength, should be free from gaseous inclusions, and moisture, and be resistant to thermal and chemical deterioration. Solid dielectrics have higher breakdown strength compared to liquids and gases. Studies of the breakdown of solid dielectrics are of extreme importance in insulation studies. When breakdown occurs, solids get permanently damaged while gases fully and liquids partly recover their dielectric strength after the applied electric fields removed. The mechanism of breakdown is a complex phenomenon in the case of solids, and varies depending on the time of application of voltage as shown in Fig.

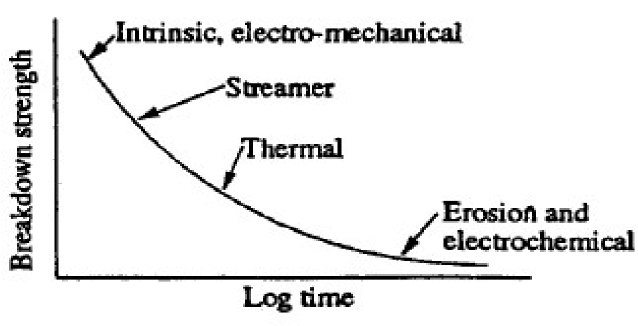


Fig. Variation of breakdown strength with time after application of voltage

The various breakdown mechanisms can be classified as follows:

(a) Intrinsic or ionic breakdown,

(b) Electromechanical breakdown,

(c) Failure due to treeing and tracking,

(d) Thermal breakdown,

(e) Electrochemical breakdown, and

(J) Breakdown due to internal discharges.

- **BREAKDOWN OF SOLID DIELECTRICS IN PRACTICE**

There are certain types of breakdown which do not come under either intrinsic breakdown or thermal breakdown, but actually occur after prolonged operation. These are, for example, breakdown due to tracking in which dry conducting tracks are formed on the surface of the insulation. These tracks act as conducting paths on the insulator surfaces leading to gradual breakdown along the surface of the insulator. Another type of breakdown in this category is the electrochemical breakdown caused by chemical transformations such as electrolysis, formation of ozone, etc. In addition, failure also occurs due to partial discharges which are brought about in the air pockets inside the insulation. This type of breakdown is very important in the impregnated paper insulation used in high voltage cables and capacitors.

- **Breakdown Due to Treeing and Tracking**

When a solid dielectric subjected to electrical stresses for a long time fails, normally two kinds of visible markings are observed on the dielectric materials. They are:

(a) The presence of a conducting path across the surface of the insulation;

(b) a mechanism whereby leakage current passes through the conducting path finally leading to the formation of a spark. Insulation deterioration occurs as a result of these sparks.

The spreading of spark channels during *tracking,* in the form of the branches of agree is called *treeing.*

Consider a system of a solid dielectric having a conducting film and two electrode son its surface. In practice, the conducting film very often is formed due to moisture. On application of voltage, the film starts conducting, resulting in generation of heat, and the surface starts becoming dry. The conducting film becomes separate due to drying, and so sparks are drawn damaging the dielectric surface. With organic insulating materials such as paper and Bakelite, the dielectric carbonizes at the region of sparking, and the carbonized regions act as permanent conducting channels resulting in increased stress over the rest of the region. This is a cumulative process, and insulation failure occurs when carbonized tracks bridge the distance between the electrodes. These phenomena, called tracking is common between layers of bakelite, paper and similar dielectrics built of laminates.

On the other hand treeing occurs due to the erosion of material at the tips of the spark. Erosion results in the roughening of the surfaces, and hence becomes a source of dirt and contamination. This causes increased conductivity resulting either in the formation of a conducting path bridging the electrodes or in a mechanical failure of the dielectric.

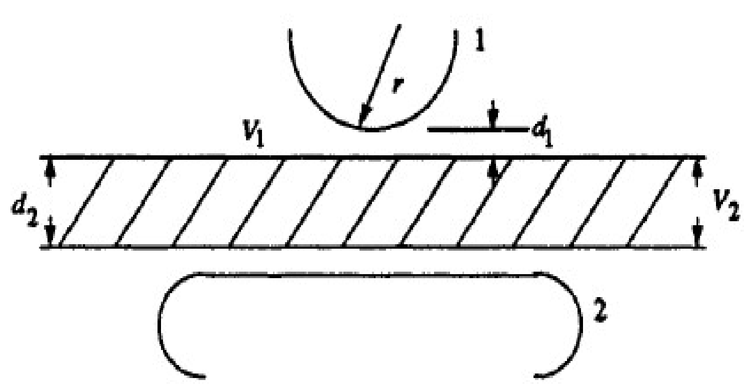


Fig. 2.2 Arrangement for study of treeing phenomena. 1 and 2are electrodes

When a dielectric material lies between two electrodes as shown in Fig. 2.2, there is a possibility for two different dielectric media, the air and the dielectric, to come in series. The voltages across the two media are as shown *(V_1 across the air gap, and V_2 across the dielectric)*. The voltage V_1 across the air gap is given as,

$$V_1 = \frac{V d_1}{d_1 + \left(\frac{\varepsilon_1}{\varepsilon_2}\right) d_2}$$

Where V is the applied voltage.

Since $\varepsilon_2 > \varepsilon_1$, most of the voltage appears across d_1 the air gap. Sparking will

Occur in the air gap and, charge accumulation takes place on the surface of the insulation. Sometimes the spark erodes the surface of the insulation. As time passes,

Breakdown channels spread through the insulation in an irregular "tree" like fashion leading to the formation of conducting channels. This kind of channeling is called treeing.

Under a.c. voltage conditions treeing can occur in a few minutes or several hours.

Hence, care must be taken to see that no series air gaps or other weaker insulation gaps are formed.

Usually, tracking occurs even at very low voltages of the order of about 100 V, whereas treeing requires high voltage. For testing of tracking, low and medium voltage tracking tests are specified. These tests are done at low voltages but for times of about 100 hr or more. The insulation should not fail. Sometimes the tests are done using 5 to 10 kV with shorter durations of 4 to 6 hr. The numerical value of voltage that initiates or causes the formation of a track is called the "tracking index" and thesis used to qualify the surface properties of dielectric materials.

Treeing can be prevented by having clean, dry, and undamaged surfaces and clean environment. The materials chosen should be resistant to tracking. Sometimes moisture repellant greases are used. But this needs frequent cleaning and regressing. Increasing creep age distances should prevent tracking, but in practice the presence of moisture films defeat the purpose.

Usually, treeing phenomena is observed in capacitors and cables, and extensive work is teeing done to investigate the real nature and causes of this phenomenon.

- **BREAKDOWN IN COMPOSITE DIELECTRICS**

It is difficult to imagine a complete insulation system in electrical equipment which does not consist of more than one type of insulation. If an insulation system as wholes considered, it will be found that more than one insulating material is used. These different materials can be in parallel with each other, such as air or SF6 gas in parallel with solid insulation or in series with one another. Such insulation systems are called composite dielectrics.

The composite nature of an insulation system arises from the mechanical requirements involved in separating electrical conductors which are at different potentials. Also, parts of a single system that are normally composed of a single material are infect composite in nature. In actual practice, these single materials will normally have small volumes of another material present in their bulk. For example, a solid will contain gas pockets or voids, while a liquid or gas will contain metallic or dust particles, gas bubbles etc. A commonly encountered composite dielectric is the solid/liquid combination or liquid impregnated flexible solid like thin sheets of paper or plastic. This type of composite dielectric is widely used in a variety of low and high voltage apparatus such as cables, capacitors, transformers, oil-filled switchgear, bushings etc. In recent years solid/SF6 gas technology has become more acceptable.

All the desirable properties of composite dielectrics cannot be realized to the fullest extent owing to the presence of impurities in them. For example, in a solid-liquid system, the presence of gas bubbles in the liquid phase and cavities in the solid phase will give rise to a number of processes, both physical and chemical, which will reduce the dielectric strength of the system.

In the practical system, in order to reduce the undesirable effects mentioned above, composite insulation is used by combining different dielectrics either in series or in parallel such that it is possible to obtain superior dielectric properties than that possible for a single material of the same thickness.

- **SOLID DIELECTRICS USED IN PRACTICE**

Some of the important dielectric properties of these materials are bellow Paper and boards, Fibers, mica and its products, Glass, ceramics, Rubber, Plastics, polyethylene, fluorocarbon plastics, Nylon, Polyvinyl chloride ,polyesters, polystyrenes

OBSERVATION TABLE:

Sr. No.	**Material Used**	**Breakdown voltage (KV)**

PROCEDURE:

- Switch on the supply and increase the voltage gradually and check the breakdown voltage of solid insulating material which is kept between a semi sphere before switch on supply put material in between two semi sphere
- Now switch off the supply and by the insulating rod discharge the semi sphere
- Repeat the procedure for different solid dielectric material and check the respective breakdown voltages
- Switch off the supply and discharge the semi sphere.

CONCLUSION:

LABORATORY EXPERIMENT –3

AIM: To perform and study breakdown test of transformer oil according to IS:6792

APPARATUS:

Sr. No.	Apparatus	Range	Quantity
1	Oil test kit	0-60KV	1
2	input	230AC	1
3	output	60KV	1
4	Dielectric oil	----	-----

THEORY:

❖ **Breakdown Test**

Breakdown tests are normally conducted using test cells. For testing pure liquids the test cells used are small so that less quantity of liquid is used during testing. also test cells are usually an integral part of the purification system as shown in fig1.1.The electrodes used for breakdown voltage measurements are usually spheres of 0.5 to 1 cm in diameter with gap spacing's of about 100-200 μm. the gap is accurately controlled by using a micrometer. Sometimes parallel plane uniform-field electrodes systems are also used. Electrode separation is very critical in measurements with liquids and also the electrode surface smoothness and the presence of oxide films have a marked influence on the breakdown strength. The test voltages required for these tests are usually low of the order of 50-100KV because of small electrode spacing's. The breakdown strengths and D.C conductivities obtained in pure liquids are very high of the order of 1MV/cm and $10^{-18} – 10^{-20}$ mho/cm respectively. The conductivity being measured at electric fields of the order of 1 KV/cm. However the corresponding values in commercial liquids are relatively low.

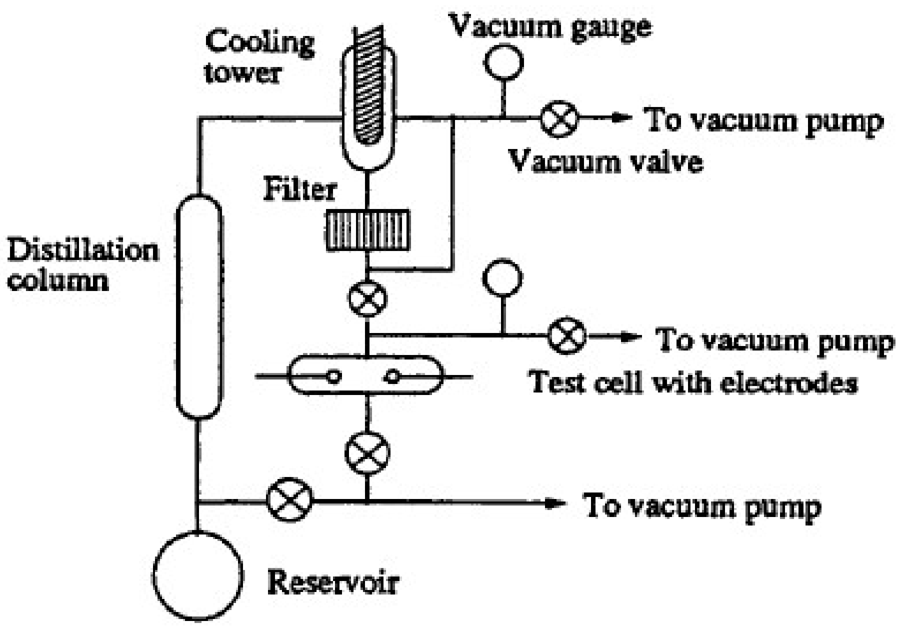


Fig: 1.1Liquid purification system with test cell

❖ Conduction and breakdown in pure liquids

When low electric fields less than 1kv/cm are applied conductivities of10^{-18} –10^{20} mho/cm are obtained. These are probably due to the impurities remaining after purification. However when the fields are high the currents not only increase rapidly but also undergo violent fluctuations which will die down after some time. A typical mean value of the conduction current in hexane is shown in fig 1.2.

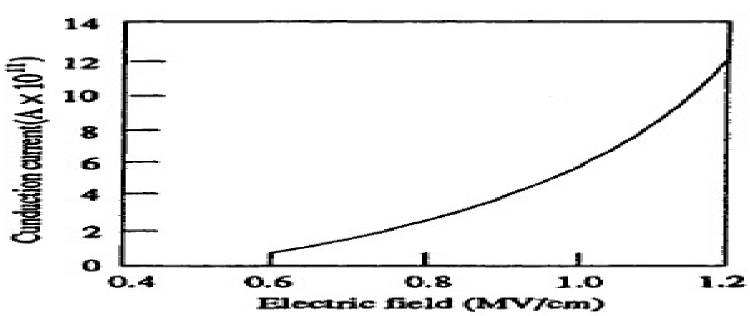


Fig:1.2 conduction current-electric field characteristic in hexane at high fields

This is the condition nearer to breakdown. However, if this figure is redrawn starting from very small currents, a current-electric field characteristic as shown in Fig. 1.3, can be obtained. This curve will have three distinct regions as shown. At very Low fields the current is due to the dissociation of ions. With intermediate fields the current reaches a saturation value, and at high fields the current generated because of the field-aided electron emission from the cathode gets multiplied in the liquid medium by a Townsend type of mechanism. The current multiplication also occurs from the electrons generated at the interfaces of liquid and impurities. The increase in current by these processes continues till breakdown occurs.

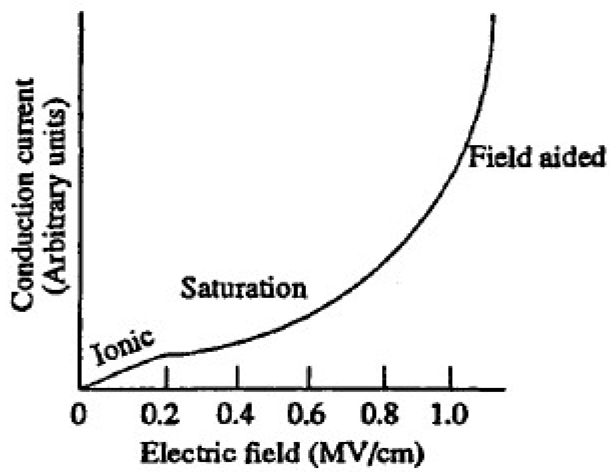


Fig.1.3 conduction current-electric field characteristic in a hydrocarbon liquid

The exact mechanism of current growth is not known; however, it appears that the electrons are generated from the cathode by field emission of electrons. The electrons

So liberated get multiplied by a process similar to Townsend's primary and secondary ionization in gases. As the breakdown field is approached, the current increases rapidly due to a process similar to the primary ionization process and also the positive ions reaching the cathode generate-secondary electrons, leading to breakdown. The breakdown voltage depends on the field, gap separation, cathode work-function, and the temperature of the cathode.

In addition, the liquid viscosity, the liquid temperature, the density, and the molecular structure of the liquid also influence the breakdown strength of the liquid. Typical maximum breakdown strengths of some highly purified liquids and liquefied gases are given in Table.

Table: Maximum breakdown strengths of some liquids

Liquid	Maximum breakdown strength (MV/cm)
Hexane	1.1-1.3
Benzene	1.1
Transformer oil	1.0
Silicone	1.0-1.2
Liquid Oxygen	2.4
Liquid Nitrogen	1.6-1.9
Liquid Hydrogen	1.0
Liquid Helium	0.7
Liquid Argon	1.10-1.42

It has been observed that the increase in breakdown strength is more, if the dissolved gases are electronegative in character (like oxygen).

Similarly, the increase in the liquid hydrostatic pressure increases the breakdown strength. These properties are shown in Figs. 1.4 and 1.5.

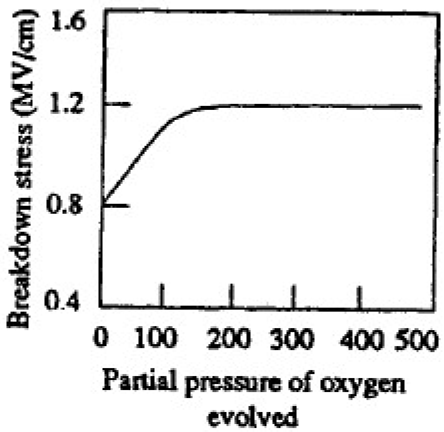


Fig.1.4 Effect of oxygen gas evolved on the breakdown stress in n-hexane.

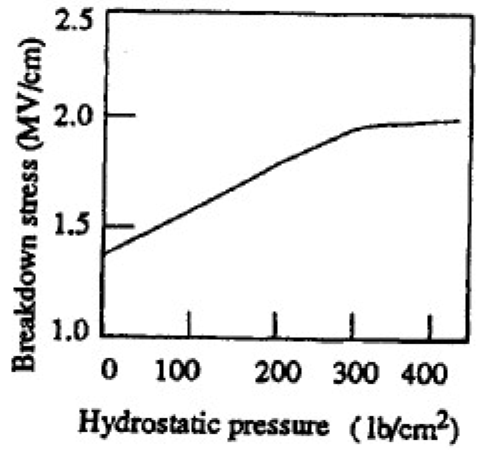


Fig.1.5. Effect of hydrostatic pressure on breakdown stress in n-hexane

To sum up, this type of breakdown process in pure liquids, called the electronic breakdown, involves emission of electrons at fields greater than 100 kV/cm. This emission occurs either at the electrode surface irregularities or at the interfaces of impurities and the liquid. These electrons get further multiplied by Townsend's type of primary and secondary ionization processes, leading to breakdown.

- **CONDUCTION AND BREAKDOWN IN COMMERCIAL LIQUIDS**

As already mentioned commercial insulating liquids are not chemically pure and have impurities like gas bubbles, suspended particles, etc. These impurities reduce the breakdown strength of these liquids considerably. The breakdown mechanisms are also considerably influenced by the presence of these impurities. In addition, when breakdown occurs in these liquids, additional gases and gas bubbles are evolved and

Solid decomposition products are formed. The electrode surfaces become rough, and

At times explosive sounds are heard due to the generation of impulsive pressure through the liquid.

The breakdown mechanism in commercial liquids is dependent, as seen above, on several factors, such as, the nature and condition of the electrodes, the physical properties of the liquid, and the impurities and gases present in the liquid. Several theories have been proposed to explain the breakdown in liquids, and they are classified as follows:

- Suspended Particle Mechanism
- Cavitation and Bubble Mechanism
- Stressed Oil Volume Mechanism

These are explained briefly below.

- **Suspended Particle Theory**

In commercial liquids, the presence of solid impurities cannot be avoided. These impurities will be present as fibers or as dispersed solid particles. The permittivity of these particles *(ε_2)* will be different from the permittivity of the liquid (ε_1). If we consider these impunities to be spherical particles of radius r, and if the applied field is *E* then the particles experience a force F, where

$$F = \frac{1}{2r^3} \frac{(\varepsilon_2 - \varepsilon_1)}{2\varepsilon_1 + \varepsilon_2} \text{grad } E^2$$

This force is directed towards areas of maximum stress, if $\varepsilon_2 > \varepsilon_1$ example, in the case of the presence of solid particles like paper in the liquid. On the other hand, if only gas bubbles are present in the liquid, i.e.$\varepsilon_2 > \varepsilon_1$, the force will be in the direction of areas of lower stress. If the voltage is continuously applied (d.c.) or the duration of the voltage is long (a.c.), then this force drives the particles towards the areas of maximum stress. If the number of particles present is large, they become aligned due to these forces, and thus form a stable chain bridging the electrode gap causing a breakdown between the electrodes.

If there is only a single conducting particle between the electrodes, it will give rise to local field enhancement depending on its shape. If this field exceeds the breakdown strength of the liquid, local breakdown will occur near the particle, and this will result in the formation of gas bubbles which may lead to the breakdown of the liquid. The vales of the breakdown strength of liquids containing solid impurities were found to be much less than the values for pure liquids. The impurity particles reduce the breakdown strength, and it was also observed that the larger the size of the particles the lower were the breakdown strengths.

- **Cavitation and the Bubble Theory**

It was experimentally observed that in many liquids, the breakdown strength depends strongly on the applied hydrostatic pressure, suggesting that a change of phase of the medium is involved in the breakdown process, which in other words means that a kind of vapour bubble formed is responsible for breakdown. The following processes have been suggested to be responsible for the formation of the vapour bubbles:

(a) Gas pockets at the surfaces of the electrodes;

(b) Electrostatic repulsive forces between space charges which may be sufficient to overcome the surface tension;

(c) Gaseous products due to the dissociation of liquid molecules by electron

Collisions; and

(d) Vaporization of the liquid by corona type discharge from sharp points and Irregularities on the electrode surfaces.

Once a bubble is formed it will elongate in the direction of the electric field under the influence of electrostatic forces. The volume of the bubble remains constant during elongation. Breakdown occurs when the voltage drop along the length of the bubble becomes equal to the minimum value on the Paschen's curve for the gas in the bubble. The breakdown field is given as

$$E_0 = \frac{1}{(\varepsilon_1 - \varepsilon_2)}\left[\frac{2\pi\sigma(2\varepsilon_1 + \varepsilon_2)}{r}\left\{\frac{\pi}{4}\sqrt{\left(\frac{V_b}{2rE_0}\right)} - 1\right\}\right]^{\frac{1}{2}}$$

Where σ is the surface tension of the liquid, ε_1 is the permittivity of the liquid, ε_2 is the permittivity of the gas bubble, *r* is the initial radius of the bubble assumed as a sphere and V_b the voltage drop in the bubble (corresponding to minimum on the Paschen's curve). From this equation, it can be seen that the breakdown strength depends on the initial size of the bubble which in turn is influenced by the hydrostatic pressure and temperature of the liquid.

This theory does not take into account the production of the initial bubble and hence the results given by this theory do not agree well with the experimental results.

This is shown in Fig. 1.6.

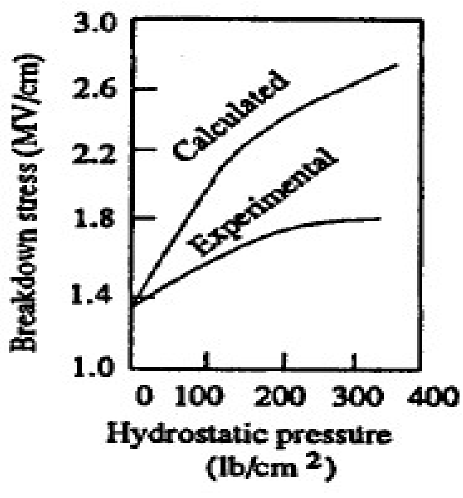


Fig.1.6.Theoretical and experimental breakdown stresses in n-hexane

Later this theory was modified, and it was suggested that only incompressible Bubbles like water globules can elongate at constant volume, according to the simple gas law *pv= RT*. Under the influence of the applied electric field the shape of the globule is assumed to be approximately a prolate spheroid.

The incompressible bubbles reach the condition of instability when β, the ratio of the longer to the shorter diameter of the spheroid, is about 1.85, and the critical field producing the instability will be:

$$E_c = 600 \sqrt{\frac{\pi \sigma}{\varepsilon_1 R}} \left[\frac{\varepsilon_1}{\varepsilon_1 - \varepsilon_2} - G \right] H$$

Where σ= surface tension,

R = initial radius of the bubble,

ε_1 = permittivity of the liquid dielectric,

ε_2 = permittivity of the globule,

$$G = \frac{1}{\beta^2 - 1} \left[\frac{\beta \cosh^{-1}\beta}{(\beta^2 - 1)^{1/2}} - 1 \right]$$

and $$H^2 = 2\beta^{\frac{1}{3}} \left(2\beta - 1 - \frac{1}{\beta^2} \right)$$

For a water globule having R = 1 μm with σ = 43 dyne/cm and ε_1 = 2.0(transformer oil), the above equation gives a Critical field E_c= 226 kV/cm which is approximately the maximum strength obtained for commercial oils.

In the case of gas bubbles the equation for the critical field is rewritten as

$$E_c = 600 \left[\frac{\pi \sigma}{\varepsilon_1 R} \right]^{1/2} \left[\frac{\varepsilon_1}{\varepsilon_1 - \varepsilon_2} - G \right] \left[\frac{8A^2 B}{3\beta(\varepsilon_1 - \varepsilon_2)} \right]^{1/4} (\cosh \theta)^{1/2}$$

where,

$$A = \frac{2}{\beta} - 1 - \frac{1}{\beta^2}$$

$$B = 2\varepsilon_1 \beta^3 - \varepsilon_2 (1 - \beta^2)$$

G, a and *R* are as above for liquid globules, and

$$\theta = \frac{1}{3}\cosh^{-1}\left[\frac{PR}{\sigma}\left\{\frac{27\beta^5(\varepsilon_1-\varepsilon_2)^3}{2B^3}\right\}^{1/2}\right]$$

Where *P* is the hydrostatic pressure. The expressions are quite complicated, and the breakdown voltages were obtained using a computer. Results thus obtained showed good agreement with the experimental results in n-hexane. This theory suggests that sub-microscopic particles (diameter100-250 A) and bubbles greatly influence the maximum electrical strength attainable in commercial liquids.

This theory can also be extended to the study of pure liquids. The critical conditions reached when cavities are formed due to zero pressure conditions given by

$$P_c = P_{vp} = P_{es} + P_s + P_h,$$

Where, Pc = coulombic pressure,

p_{vp}= vapour pressure inside the cavity,

P_{es}= electrostatic pressure,

P_s= pressure due to surface tension, and

P_h=hydrostatic pressure

From this condition, an expression has been obtained for the maximum breakdown strength of pure liquids which was found to be in good agreement with the experimental results.

In general, the cavitations and bubble theories try to explain the highest breakdown strengths obtainable, considering the cavities or bubbles formed in the liquid dielectrics.

- **Thermal Mechanism of Breakdown**

Another mechanism proposed to explain breakdown under pulse conditions is thermal Breakdown. This mechanism is based on the experimental observations of extremely large currents just before breakdown. This high current pulse is believed to originate from the tips of the microscopic projections on the cathode surface with densities of the order of 1 A/cm3. These high density current pulses give rise to localized heating of the oil which may lead to the formation of vapour bubbles. The vapour bubbles are formed when the energy exceeds 10 W/cm. When a bubble is formed, breakdown follows, either because of its elongation to a critical size or when it completely bridges the gap between the electrodes. In either case, it will result in the formation of a spark. According to this mechanism, the breakdown strength depends on the pressure and the molecular structure of the liquid. For example, in n-alkanes the breakdown strength was observed to depend on the chain length of the molecule. This theory is only applicable at very small lengths (< 100m) and does not explain the reduction in breakdown strength with increased gap lengths.

- **Stressed Oil Volume Theory**

In commercial liquids where minute traces of impurities are present, the breakdown strength is determined by the "largest possible impurity" or "weak link'. On a statistical basis it was proposed that the electrical breakdown strength of the oil is defined by the weakest region in the oil, namely, the region which is stressed to the maximum and by the volume of oil included in that region. In non-uniform fields, the stressed oil volume is taken as the volume which is contained between the maximum stress (E_{max}) contour and 0.9 E_{max} contour. According to this theory the breakdown strength is inversely proportional to the stressed oil volume.

The breakdown voltage is highly influenced by the gas content in the oil, the viscosity of the oil, and the presence of other impurities. These being uniformly distributed, increase in the stressed oil volume consequently results in a reduction in the breakdown voltage. The variation of the breakdown voltage stress with the stressed oil volume is shown in Fig. 1.7.

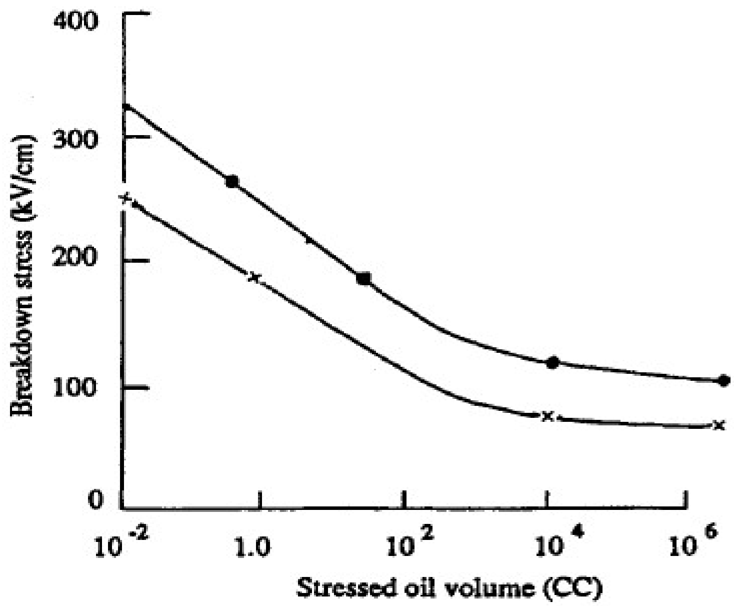


Fig. 1.7 Power frequency (50 Hz) a.c. breakdown stress as a function of the stressed oil volume

• With steady voltage rise

x One minute withstand voltage

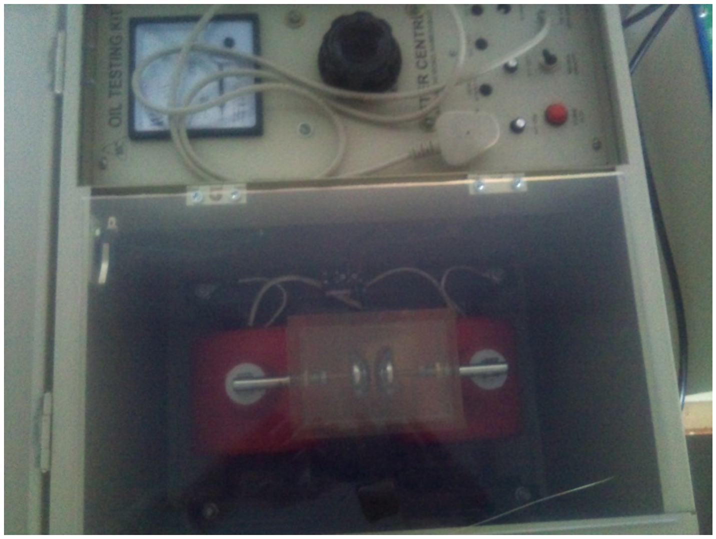


Fig 6 Arrangement of Transformer Oil Testing Kit

OBSERVATION TABLE:

SR NO.	Gap spacing in mm	Breakdown voltagein KV

PROCEDURE:

- Switch on the main supply.
- Keep the toggle switch in “UP” mode.
- Now press the “H.T” on switch.
- Now continuously observe the electrodes which are placed in oil.
- When the spark will occur between two electrode, breakdown occurs and note down this breakdown voltage
- H.T will get automatically turned off
- Now keep the toggle switch in down made
- Repeat the above process (step 3 to 6) again to get reading for breakdown voltage
- Switch off the main supply.

CONCLUSION:

LABORATORY EXPERIMENT –4

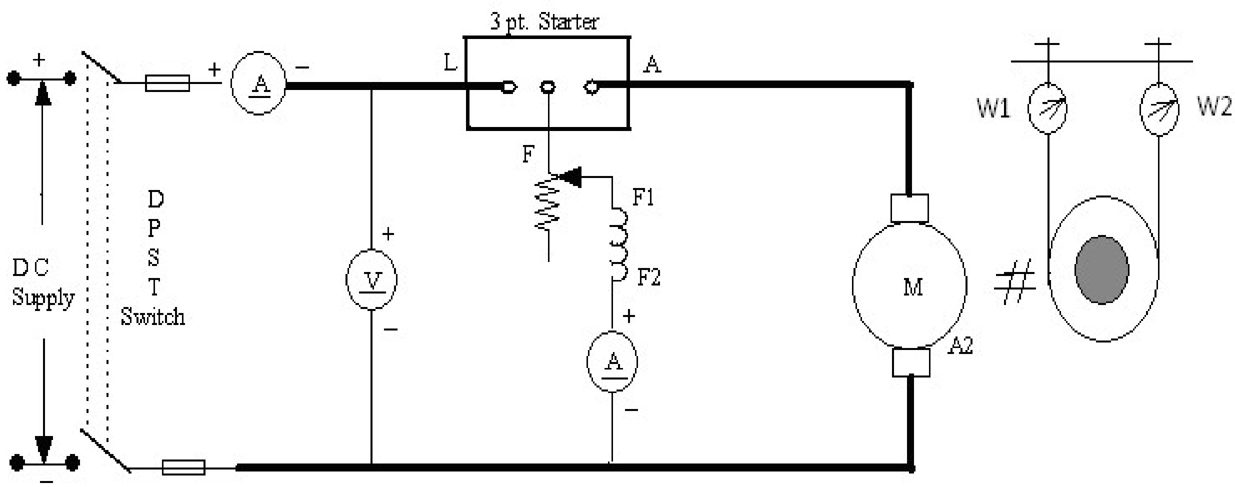
AIM: To Perform Brake Test On DC Shunt Motor.

APPARATUS:

Sr. No.	Apparatus	Range	Quantity
1	DC shunt motor	3 H.P, 220V, 12A, 1500 rpm, Field Voltage 220V, Field Current 0.6A	1
2	Mechanical Brake		1
3	Rheostat		1
4	1Φ wattmeter for no load test	600 V, 5A, 750W	2
5	Tachometer	0-2000 rpm	1

THEORY:

In this direct method and consisting of applying a brake to a water cooled pulley mounted on the motor. The brake band is fixed with the help of wooden blocks gripping the pulley. One end of the band is fixed to earth via a spring balance s and the other is connected to a suspended weight W1. The motor is running and the load on the motor is adjusted till it carries its full load current. The simple brake test described above can be used for small motors only. Because in the case of large motor it is different to dissipate the large amount of heat generated at the brake. Another simple method of measuring motor output is by the use of pony brake one form of the diagram. The tension of rope can be adjusted with the help of swivels obviously. In this method belt is wound round the pulley and two ends are attached to the two springs. The force acting on a pulley is equal to the difference between the readings of two spring balances.



CIRCUIT DIAGRAM:

PROCEDURE:

1) Connections are made as per the circuit diagram.
2) Observing the precaution the DPST switch is closed and the motor is started with the help of 3-point DC starter slowly.
3) The motor field rheostat is adjusted and the motor is brought to rated speed.
4) Load on the motor is varied with the help of pony brake arrangement.
5) Spring balance, ammeter, voltmeter and speed readings are noted down for various line currents as the load is applied. Care must be taken to avoid the speed reaching dangerously high values while reducing the load.

OBSERVATION TABLE:

	Supply Voltage V (Volts)	Load Current I (Amps)	Speed N (RPM)	W1 (Kg)	W2 (Kg)	W1-W2 (Kg)
1						
2						
3						
4						
5						
6						

CALCULATIONS:

Shaft Torque Tsh = $(w_1 - w_2)$ x R x 9.81 Nm

R= Radius of the pulley in meter

Input Power P_i = VI Watts

Output Power P_m = 2πNTsh/ 60 Watts

N= Speed in RPM

Efficiency ή = output / input x 100

CONCLUSION:

LABORATORY EXPERIMENT –5

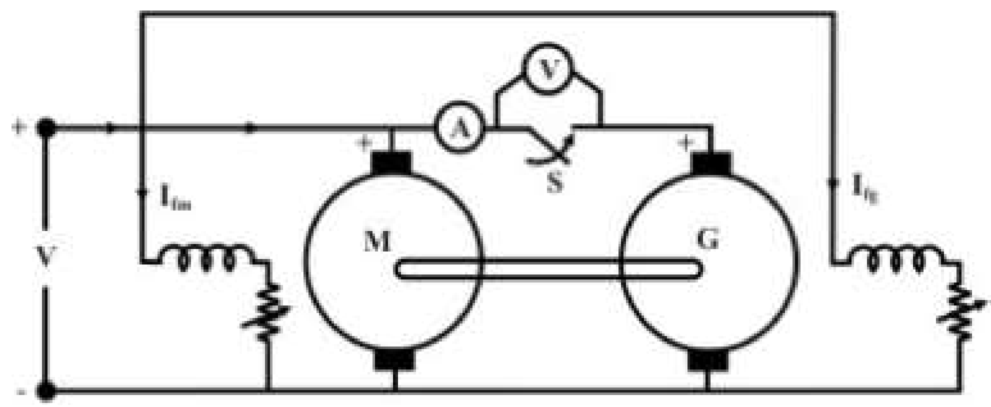
AIM: To Perform Hopkinson's Test On DC Shunt Machines.

APPARATUS:

Sr. No.	Apparatus	Range	Quantity
1	DC shunt motor	3 H.P, 220V, 12A, 1500 rpm Field Voltage 220V, Field Current 0.7A	1
2	DC shunt generator	2kW, 220V, 9A, 1500 rpm Field Voltage 220V, Field Current 0.7A	1
3			1
4	1-Φ wattmeter	600 V , 10/20 A	2
5	Tachometer	0-2000 rpm	1

THEORY:

This as an elegant method of testing dc machines. Here it will be shown that while power drawn from the supply only corresponds to no load losses of the machines, the armature physically carries any amount of current (which can be controlled with ease). Such a scenario can be created using two similar mechanically coupled shunt machines. Electrically these two machines are eventually connected in parallel and controlled in such a way that one machine acts as a generator and the other as motor. In other words two similar machines are required to carry out this testing which is not a bad proposition for manufacturer as large numbers of similar machines are manufactured.



CIRCUIT DIAGRAM:

PROCEDURE:

1) Connect the two similar (same rating) coupled machines as shown in figure.
2) With switch S opened, the first machine is run as a shunt motor at rated speed. It may be noted that the second machine is operating as a separately excited generator because its field winding is excited and it is driven by the first machine.
3) To connect the two machines in parallel, we must first ensure voltmeter reading is small. In case we find voltmeter reading is high, we should switch off the supply, reverse the armature connection of the generator and start afresh. Now voltmeter is found to read small although time is still not ripe enough to close S for paralleling the machines. Any attempt to close the switch may result into large circulating current as the armature resistances are small.
4) Now by adjusting the field current I_{fg} of the generator the voltmeter reading may be adjusted to zero ($E_g \approx E_b$) and S is now closed. Both the machines are now connected in parallel.
5) After the machines are successfully connected in parallel, we go for loading the machines i.e., increasing the armature currents. Just after paralleling the ammeter reading A will be close to zero as $E_g \approx E_b$. Now if I_{fg} is increased (by decreasing R_{fg}), then E_g becomes greater than E_b and both I_{ag} and I_{am} increase, Thus by increasing field current of generator (alternatively decreasing field current of motor) one can make $E_g > E_b$ so as to make the second machine act as generator and first machine as motor.
6) In practice, it is also required to control the field current of the motor I_{fm} to maintain speed constant at rated value. The interesting point to be noted here is that I_{ag} and I_{am} do not reflect in the supply side line. Thus current drawn from supply remains small (corresponding to losses of both the machines). The loading is sustained by the output power of the generator running the motor and vice versa. The machines can be loaded to full load current without the need of any loading arrangement.

OBSERVATION TABLE:

SR. NO.	LINE VOLTAGE V(volt)	MOTOR SIDE		GENERATOR SIDE	
		LINE CURRENT I_1(amp)	FIELD CURRENT I_2(amp)	OUTPUT CURRENT I_3(amp)	FIELD CURRENT I_4(amp)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

CALCULATIONS:

Total Input Power	$= VI_1$ watts
Motor armature cu loss	$= (I_1+ I_3- I_2)^2$ Ra watts
Generator armature cu loss	$= (I_3+I_4)^2$ Ra watts
Motor field cu loss	$= VI_2$ watts
Generator field cu loss	$= VI_4$ watts
Total Stray losses W	$= VI_1–[(I_1+I_3-I_2)^2Ra+(I_3+I_4)^2Ra+VI_2+VI_4]$ watts.
Stray loss per machine	= W/2 watts.

Motor Efficiency:

Input Power	$= (I_1+ I_3)$ V
Total Losses	= Armature Cu loss + Field loss + stray loss
	$= (I_1+I_3-I_2)^2Ra + VI_2 + W/2$ watts
Output power	= Input power – Total losses
Efficiency ή	= output / input x 100

Generator Efficiency:

Output Power	$= VI_2$ watts
Total Losses	= Armature Cu loss+ Field Loss + Stray loss
	$= (I_3+I_4)^2$ Ra + VI_4 + W/2 watts
Input power	= Output power+ Total losses
Efficiency ή	= output / input x 100

CONCLUSION:

LABORATORY EXPERIMENT –6

AIM: To Perform Field Test On DC Series Motor.

APPARATUS:

Sr. No.	Apparatus	Range	Quantity
1	DC series motor	3 H.P, 220V, 12A, 1500 rpm Field Voltage 220V, Field Current 0.7A	1
2	DC series generator	2kW, 220V, 9A, 1500 rpm Field Voltage 220V, Field Current 0.7A	1
3	Voltmeter(A.C.) for no load test	0-600V	1
4	Tachometer	0-2000 rpm	1

THEORY:

This is one of method of testing the dc series motors. Unlike shunt motors, the series motor cannot be tested by the methods which are available for shunt motor as it is impossible to run the motor at no-load. It may run at dangerously high speed on no-load in case of small series motors brake test may be employed. The series motors are usually tested in pairs .The field test is applied to two similar series motors which are coupled. One machine is made to run as a motor while the other as a generator which is separately excited the fields of the two machines are connected in series so that both the machines are equally excited.

This will make iron losses same for the two machines .The two machines are running at the same speed . The generator output is given to the variable resistance. The resistance is changed until the current taken by motor reaches full load value. This will be indicated by ammeter. The other readings of different meters are then recorded.

CIRCUIT DIAGRAM:

PROCEDURE:

1) Make the connections are made as per the circuit diagram.
2) Before starting the experiment make sure that generator is loaded.
3) Switch ON the power supply and start the motor by using 2-point starter.
4) Obtain the rated speed by using varying load.
5) Note down the readings of corresponding meters.
6) Measure the ammeters field resistance of both machines immediately after switch OFF the supply
7) Calculate the efficiency of both machines.

OBSERVATION TABLE:

SR. NO.	SUPPLY VOLTAGE V(volt)	MOTOR SIDE		GENERATOR SIDE	
		LINE CURRENT I_1(amp)	INPUT VOLTAGE V_1(volt)	OUTPUT CURRENT I_2(amp)	OUTPUT VOLTAGE V_2(volt)
1					
2					

CALCULATIONS:

Total input power to the whole set = VI_1

Output power = V_2I_2

Total losses = $VI_1 - V_2I_2$

Total copper losses = $I_1^2 (Rsem + Rseg) + I_1^2 Ram + I_2^2 Rag$

Stray losses Ws = Total losses – Total copper loss

Stray losses for each machine = Ws/2

Motor Efficiency

Input to the motor	$= V_1 I_1$
Armature copper losses	$= I_1^2$ (Ram + Rsem)
Stray losses	= Ws/2
Total losses	= Ws/2 + Armature copper losses.
Motor output	= Motor input -Total losses
Efficiency ή	= output / input x 100

Generator Efficiency

Generator output	$= V_2 I_2$
Armature copper losses	$= I_2^2$ Rag + I_1^2Rseg
Stray losses	= Ws/2
Total losses	= Ws/2 + Armature copper losses.
Generator input	= Generator output +Total losses
Efficiency ή	= output / input x 100

CONCLUSION:

LABORATORY EXPERIMENT –7

AIM: To Measure The Slip Of Induction Motor At Different Loads Using Stroboscopic Method.

APPARATUS:

Sr. No.	Apparatus	Range	Quantity
1	Induction motor	3-Φ, 3H.P/2.2kw, 415V, 4.7A, 1400 rpm	1
2	Stroboscope	3000rpm	1
3	Voltmeter (A.C.)	0-600 V	1
4.	Techo meter	3000rpm	1

THEORY:

Measurement of slip of induction motor

1) By actual measurement of motor speed

This method requires measurement of actual motor speed N in rpm and calculation of synchronous speed Ns in rpm. N is measured with the help of speedometer/tachometer and Ns is calculated from the knowledge of supply frequency f in c/s and the no of poles of the motor for which it is designed and is usually referred from the rated speed on the name plate.

So, Ns in rpm = 120f/P And %S= [(Ns-N)/Ns]*100

1) By comparing rotor and stator supply frequency

This method is based on the fact that fractional slip S= f_r/f where f_r= rotor voltage/current frequency. In the usual case where f is 50 cycle/sec, $f_r$is so low that individual cycles can be easily counted. For this purpose a d.c. moving coil milli-voltmeter preferably of center zero is employed.

a) In the case of slip-ring motor, the leads of the mili-voltmeter are lightly pressed against the two adjacent slip-rings as they revolve. Usually there is sufficient voltage drop in brushes and their short circuiting strap to provide an indication on mili-voltmeter. The current in the mili-voltmeter follows the variations of the rotor current and hence the pointer oscillates about its mean zero position. The no of complete cycles made by the pointer per second can be easily counted (it is worth remembering that one cycle consists of a movement from zero to maximum to the right, back to zero and on to a maximum to the left and then back to zero.

b) For squirrel cage motors (which do not have slip-rings) it is not possible to employ the above method but a large flat search coil of many turns is placed centrally against end plate on the non driving end of the motor. Quite often it is possible to pick up sufficient voltage by induction from the leakage fluxes to obtain a reading on the mili-voltmeter. Obviously a large 50c/s voltage will also be induced in the search coil although it is too rapid to affect the mili-voltmeter. Commercial slip indicator use such a search coil and in addition contains a low pass filter amplifier for eliminating fundamental frequency and a bridge circuit for comparing stator and rotor current frequencies.

Stroboscopic Method:

In this method a circular disc is taken and painted with alternately black and white segments. The no of black segments=No of white segments=No of poles of the motor. For a 6 pole motor, there will be six white and six black sectors.

The painted disc is mounted on the end of the shaft illuminated by means of a neon filed lamp (Stroboscopic lamp) which is supplied with 50c/s a.c. supply.

Instead of disc one may paint the no black segment = no of white segment = no of poles on the coupling of the motor, if it is not be possible to mount the disc on the shaft.

1) Consider the case when the revolving disc or coupling seen in flash light of bulb of the stroboscope fed with a.c. 50c/s supply. If the disc were to rotate at synchronous speed, it would appear as the disc or shaft coupling to be stationary. As in each cycle there will be two flashes of neon lamp and therefore the time required between two consequent flashes will be =1/2f=1/100sec

Also the time required any one black sector to rotate so that it can occupy the next consecutive black sector is also 1/100 sec as shown below:

Time for 1 revolution=1/n_s=1/ (2f/6) =1/ (100/6) =6/100 sec and

Time required for black sector= (6/100)*(1/6) = (1/100) sec

Now since time between two consecutive flashes is same as the time required for black segment to occupy the next consecutive black segment the disc or coupling seems to be stationary. Since in actual practice, its speed N is less than the synchronous speed Ns, it appears to rotate slowly backwards.

When next flash comes, they have nearly reached to position. Hence the same sector has almost reached position but slightly backward and one flash later the same sector will occupy the position giving clear idea that the disc or the shaft start apparently rotating in backward direction. Now count the number of black sector 'x' moving backward from a fixed point in a particular time t sec.

Then the no. of revolution moving backward = x/p

And the no. of revolution moving backward in 1sec = x/pt and this = Ns-N.

% slip = Ns-N/ Ns =[(x/pt)/ (2f/p)] × 100 = [(x/pt)/ (100/p)] × 100 = x/t

2) In a stroboscope the supply 50c/s is given to the oscillator inside it and from the oscillation it goes to the neon lamp.

Since the rotor is not running at synchronous speed the disc will not be seen stationary so to make the disc stationary the oscillator output frequency to neon lamp is varied by changing the knob position in oscillator which in turn changes the capacitor in the circuit and hence the frequency to neon lamp.

Move the knob position till the disc is found stationary. Now this change is calibrated on the scale of the oscilloscope in terms of the speed. Reading it directly gives the rotor speed and hence **%**s=[(Ns-N)/Ns]*100can be found out.

However, this method and by tachometer methods the results are not accurate, lot of error is there but the first method of the stroboscope is the most accurate and normally adopted.

CIRCUIT DIAGRAM:

PROCEDURE:

1) First connect the circuit as shown in fig .
2) Mark a line on the rotor shaft with chalk.
3) Give 3-ϕ supply to the stator.
4) Then when the stroboscope switched on light appears on the rotor shaft.
5) You will observe the motion of the line marked with white chalk.
6) Vary stroboscope oscillator output frequency to neon lamp by changing the knob position on the stroboscope untill the marking on the rotor appears stationary.
7) This reading on the stroboscope is approximately same as rotor speed.

OBSERVATIONS:

(1) For Stroboscopic method

Sr. No.	Frequency	Time for 5 revolution of sector	%slip= slipspd/Ns*100

(2) For Techometer

Sr. No.	Frequency	Ns	N	%slip= Ns-N/Ns*100

CALCULATION:

% s = (Ns – N)/ Ns x 100 = _______ %

CONCLUSION:

LABORATORY EXPERIMENT –8

AIM: To study about maintenance of electrical equipment.

MAINTENANCE

- **MAINTENANCE IN GENERAL**

UNPACKING:

A thorough visual inspection of the packing cases should be made to check for any damage in transit. If damaged the matter should be reported to the suppliers as well as to insurance agencies if insured for transit risks. After unpacking check the machines too for damages.

STORAGE:

Always store the machines in clean and dry place preferably with proper covering. They should be protected from moisture, alkalis, acids, oil, gas, dust, corrosive fumes and other injurious substances while in use or in storage. While storing care should be taken to give proper anti rust protective coating to all exposed machine parts such as shaft extensions, keys etc., The machines should be periodically inspected and their insulation values should be *meggar*ed.

HANDLING:

Machines should be handled carefully so as to prevent any damages to their parts especially bearings, bearing housings, commentators and windings. They should never be dragged on the floor but should be lifted through proper means. One can make use of the lifting hooks.

ENVIRONMENT &LOCATION:

Care should be exercised to maintain cleanliness of the exposed parts. It should be installed in a clean dry place. Sufficient open space around the machine should be available for good cooling air circulation. Machine should always be installed in a horizontal position unless otherwise stated or consulted to do so.

LEVELLING &ALIGNMENT:

Foundation should be rigid and of adequate stiffness to ensure protection against vibration. Base should be spirit leveled and machine should be properly aligned with the driving or driven machinery. In case of direct-coupled drive a flexible coupling may be used. If the drive is by means of pulleys, check the position of pulleys to bring them into line. Machine should always be installed in a horizontal position unless otherwise stated or consulted to do so.

ELECTRICAL CONNECTION:

Ensure that all electrical connections are as per the connection diagram. Do not allow loose connections as they are likely to damage the terminals by the heat generated caused by possible sparking. They can also effect a change in the performance characteristics of the machine. After proper connections are made, proceed step by step to start the machines.

- **MECHANICAL MAINTENANCE :**

To ensure consistent performance it is necessary to draw a periodical maintenance schedule depending on the service and operating conditions as follows:

CLEANLINESS:

As already said try to keep the surroundings clean. Periodically blow off all the dust and fluffy particles that may get deposited on the air inlets, outlets and body of the machines by means of a high-pressure blower. A hand blower or a vacuum cleaner is ideal for this purpose.

STATIONARY PARTS:

Occasional Inspection of windings, frames, and other parts such as foundation bolts, machine pole bolts etc., for tightness should be made.

COUPLING*:*

The alignment of the coupling should be checked at regular intervals and corrected if necessary. If flexible couplings are used, the coupling should be checked for wear and tear.

LUBRICATION OF BEARINGS:

Ball bearings used in the Dynamometer should run for long periods without any attention. To ensure trouble free running, they are charged with the right quality and quantity of grease before dispatch. Over greasing should be avoided as it overheats the bearings. Grease should be replaced only after a period of 2,000 to 3,000 hours of operation.

ELECTRICAL MAINTENANCE

The machine should be stopped and isolated from the supply source before doing any electrical maintenance job.

BRUSHES & BRUSH GEAR:

Brushes should be replaced when they are worn to one half of the original height. They should be replaced by brushes having identical grade and dimensions. It is advisable to have one set of spare carbon brushes at any time.

Brushes should be checked for spring tension. It should be sufficient to keep them always in firm contact with the commutator / slipring. Any carbon dust deposit found around brushes may make it tight in its holders. Then the dust should be blown off and the brush cleaned so as to make it free in its holders. The flexible tail should be so positioned that it will not touch the earthed part or the moving part.

When the brushes are replaced with new ones they require bedding i.e., the commutator/slipring curvature and the brush curvature match well so that the entire brush contact area mates the commutator surface. The easiest way to do this is to insert a strip of flint/ sand paper between the commutator and the brush such that the rough side of the paper is in contact with the brushes. With full pressure applied to the brushes by the brush holder spring, draw the paper forward and backward until the brush contact curvature is bedded fully. After bedding the carbon dust must be blown off with hand blower and the brush surface should be wiped with clean cotton cloth. Then the brush tension should be adjusted to original value.

If any blackening of the commutator surface is noticed the spring pressure should be checked and adjusted to correct value. Also check the angle of the brushes. The commutator surface can be improved by polishing either with a fine commutator stone or fine carborundem cloth. During this operation the brushes should be lifted and the machine driven at normal speed. The abrasive should be moved from side to side to prevent the formation of any ridges. After polishing, the dust should be blown out, the brush gear cleaned and the grooves between the commutator segments cleaned out.

When a reasonably good brush fit is obtained the machine may be loaded at about half load for several hours. During this period, the commutator surface should occasionally be wiped with canvass to remove carbon deposits and surface of the carbon brushes

Inspected for burning, bar marking, brush fit and copper pick up. If the commutator maintains a fairly uniform polished surface and the brush fit and the surfaces are satisfactory the load can be increased to normal. The commutator surface should be occasionally wiped as before and continued inspection made of the commutator and brush surfaces until such time as a stable commutator film or polish is obtained.

BRUSH BEDDING:

The bedding process consists of giving the contact face of a new brush the exact curvature of the commutator, in such a manner as to assure good mechanical and electrical contact when the brush is put into service. Bedding is more often carried out on the machine itself, in accordance with various procedures depending upon the importance and sensitivity of the machine. The easiest way to do this is to insert a strip of Flint or Sand Paper between the commutator/slipring and the brush such that the rough side of the paper is in contact with brushes. With the full pressure applied on the brushes by brush holder, draw paper by hand to and fro.

NOTES:

1) Brushes should be inspected for wear, chipping and cracking.
2) Replaced brushes should be of the proper grade and dimension and be bedded where possible.
3) All hardware should be checked for tightness.
4) Brush holders should be adjusted according to the manufacturer's specifications, typically 2 to 2.5 mm above the commutator surface
5) Brush pigtail connections should be tight and long enough to allow brush movement as it wears.
6) Brush pressure should be checked to ensure that it is correct.

COMMUTATOR / SLIPRING:

Commutator OR Slipring is the heart of a DC / AC machine and it should be inspected periodically. Any carbon or mica dust should be removed by brushing along the grooves with stiff brush. If any oil, grease or other dirt were found on the surface it can be removed with a clean, fluff free cloth moistened with carbon tetrachloride.

The commutator/Ring surface should be smooth, concentric and properly undercut. An eccentric or ridged commutator should be skimmed on a lathe by taking a light cut not exceeding 1.5 mm. After skimming the mica between segments should be undercut approximately to 1.2 mm. The mica dust should then be blown off.

Best commutating conditions are obtained when the commutator surface has a uniform, low resistance film. Such film can be obtained by care and attention to the brushes and commutator surface during initial operating period.

Before operating, the commutator surface should be inspected for damage during shipping and installation and all brushes should be removed and wiped clean.

Then The machine should be operated for a few hours at no load. Brushes should be checked for uniform and proper brush pressure and the brush faces inspected for fit, and metal particles, which may cut or thread the commutator surface.

Commutator Undercutting Specifications:

If the commutator is resurfaced, or during inspection or overhaul, insure the mica segments are undercut below the commutator surface. Commutator undercutting should be made to a depth of 1.0 to 1.5 mm. Following commutator resurfacing (stoning/turning), the segments are "scarfed" by lightly breaking the sharp corners of the copper segments with a knife or tool made for that purpose. Scarfing segments will reduce carbon brush dust buildup and improve brush life.

NOTE:

Do not use Emery paper or cloth in place of flint / sand paper since any residual particles of the same may damage the commutator surface due to their cutting action.

BRUSH ROCKER SETTING

The brush position is set in each machine in the magnetic neutral position and is marked by a white line matching the stationery housing and the movable rocker. If the machine is dismantled it is necessary that the brush rocker be reassembled in this position to avoid sparking. This is done by 'KICK NEUTRAL METHOD'.

KICK NEUTRAL METHOD***:*** A dc supply is connected to the excitation winding so that about 10% to 20 % of the rated excitation current passes through the winding. Connect a milli-voltmeter, preferably of the center zero type. Suddenly make and break the field current. If the voltmeter deflects, the brush position is not proper. Turn the brush position round the commutator surface at different positions and simultaneously make and break the field and notice the voltmeter deflection. At some position the voltmeter either does not deflect or deflects the least. This is the neutral position.

MILLI VOLT DROP TEST

Whenever any short circuit in armature is suspected either between the coils itself or on the commutator between the segments or whenever an armature is repaired and its connections are to be checked to see whether all coils are in series, best way is to by checking the milli volt drop between the adjacent segments.

Take a low voltage DC supply of about 2% to 2½% of the rated armature supply. Connect the two supply points to two segments on commutator so that about 30% of the numbers of commutator segments are covered between them. Take a center zero milli voltmeter of about ± 250 milli volts value. Connect the probes of this to adjacent segments to read the drop.

Choose a convenient reading of about 100 milli volts on milli voltmeter by adjusting either the voltage taken for test or by reducing or increasing the number of segments covered between the test voltages.

Check the value of milli volt drop between all adjacent segments covered within the selected number of segments. This should be equal. Now, choose the balance portion of commutator and check up the drop there. In this portion also the drop should be equal between segments. If in any segments the drop is zero or less than the others that means there is short circuit between them or some conducting dust or solder particles are shorting the segments. Undercut the segments so that the short circuit is cleared.

If the voltage drop across the segments is more than the usual drop, then either there are more coil is in series between them or the coils are burnt or open circuited due to dry solder etc., Remove this fault to give equal drop, by reconnecting the coil leads to commutator properly. Also detect any burning of coils in which case the rotor may require rewinding.

INSULATION:

Premature failure of insulation is likely due to following reasons:

1) Contamination
2) Mechanical factors
3) High temperatures

CONTAMINATION: Contamination includes excessive moisture, oily vapours, conducting and non-conducting dust, chips and chemical fumes. Contamination is best avoided by proper enclosure and ventilation. Filters, ventilation from a remote clean air source, unit coolers, and a totally enclosed construction are all possible means of protecting DC machines in adverse environments. Space heaters can be used to protect the machine from the damage caused by moisture at freezing temperatures while in storage and idling.

MECHANICAL FACTORS*:* Mechanical factors like shock, vibration, over speed, etc., leads to insulation failure. Maintaining machines in good mechanical conditions, including isolation from excessive external shock and maintenance of smooth running conditions, will contribute to long insulation life.

HIGH TEMPERATURE: When machine is overloaded or it runs on full load with low RPM then because of overheating Insulation may be damage. The insulation resistance of the windings as corrected to 40°C should measure at least 1.0 Mega Ohms when tested with a 500 V Meggar. If the measurements are less than this limit, the machine should be dried or cleaned in an attempt to increase the insulation resistance. Regular, periodic measurements of insulation resistance can give a useful indication of the rate of insulation system deterioration. External connections should be removed to isolate the windings to be tested and megger value logged.

A sudden drop or consistent trend towards low values of insulation resistance, although possibly caused by moisture or contamination, generally gives evidence that the insulation system is deteriorating and that failure may be eminent.

CLEANING OF WINDINGS

If the windings become contaminated, suitable cleaning methods can be used to alleviate the problem.

The machine should be de-energized and slowly rotated by hand to permit maximum dust removal. Dry dirt, dust, or carbon should first be vacuumed – without disturbing adjacent areas or redistributing the contamination. Use a small nozzle or tube connected to the vacuum cleaner to enter into narrow openings (i.e., between commutator risers). A soft brush on the vacuum nozzle will loosen and allow removal of dirt ore firmly attached.

This vacuum cleaning may be supplemented by blowing with compressed air which has passed through a dryer to remove moisture before entering the motor. Dirt can collect on the inside surface of the drive-end coil support and on the underside of the armature coils. This dirt can be easily removed with compressed air or a vacuum.

It is important to realize that when blowing out a machine, dirt may settle in a previously cleaned areas and it may be necessary to repeat the cleaning process to ensure that a thorough job is done. Dirt can be removed from stationary parts of the machine by either compressed air or a vacuum nozzle or a combination of both. Air should be directed between the stator coils, into the pocket corners of bearing brackets, around the cables, and onto the brush rigging. Special care should be taken to keep the commutator clean. The commutator should be wiped with a clean lint-free cloth after blowing out.

CONCLUSION:

LABORATORY EXPERIMENT –9

AIM: Testing of solid insulation with point-point electrodes.

THEORY: Breakdown in Non-uniform Fields

In non-uniform fields, such as coaxial cylinders, point-plane and sphere-plane gaps, the applied field vary across the gap. Similarly, Townsend's first ionization coefficient (a) also varies with the gap. Hence *ad in* Townsend's criterions rewritten by replacing *ad* by J a *dx.* Townsend's criterion for breakdown now becomes

$$\gamma\left\{ \exp\left[\int_0^d \alpha dx\right] - 1\right\} = 1$$

Meek and rather also discussed the non-uniform field breakdown process as applied to their Streamer theory, and the Meek's equation for the radial field at the head of an avalanche when it has crossed a distance *x* is modified as

$$E_r = \frac{5.27 \times 10^{-7} \alpha_x \exp\left(\int_0^x \alpha dx\right)}{(x/p)^{1/2}} \text{ V/cm}$$

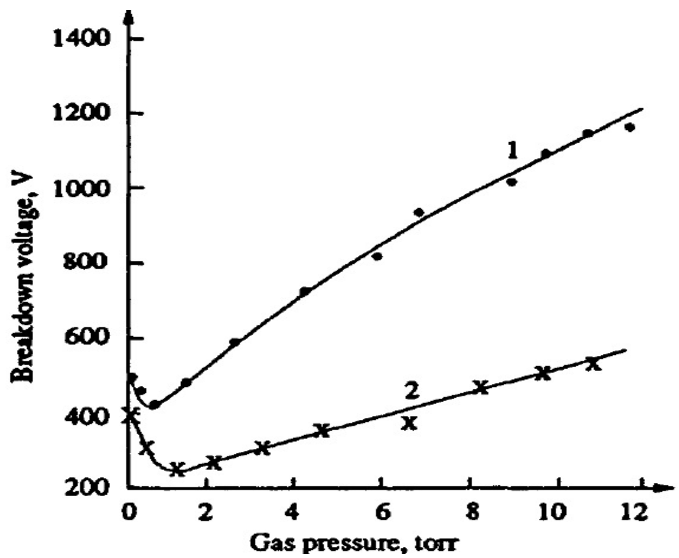


Fig 8-Breakdown characteristics for nitrogen between wires
And a coaxial cylinder of radii 0.083 and 2.3 cm. 1-wire positive, 2-wire negative

Where Ox is the value of a at the head of the avalanche, and *p* is the gas pressure. The criterion for the formation of the streamer is reached when the space charge field *Er* approaches a value equal to the applied field at the head of the avalanche.

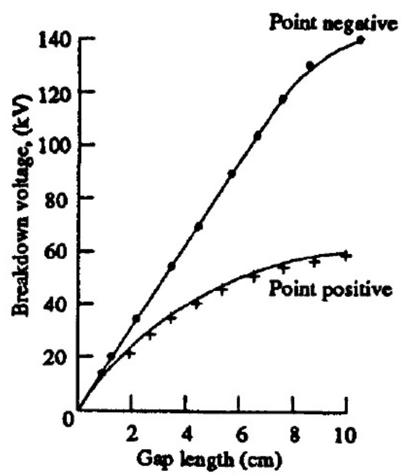


Fig 8.1-d.c. breakdown characteristics for air between 30° conical point and a Plane

This equation has been successfully used for determining the corona onset voltages of much non-uniform geometry. However, the condition for the advancement of streamers has not been arrived at so far. Figures 8 and 8.1 show the d.c. breakdown characteristics for a wire-coaxial cylinder geometry in nitrogen and for a point-plane geometry in air, respectively.
From the practical engineering point of view, rod-rod gap and sphere-sphere gap are of great importance, as they are used for the measurement of high voltages and for the protection of electrical apparatus such as transformers. The breakdown voltages were also observed to depend on humidity in air. In the case of rod gaps the field is non-uniform, while in the case of sphere gaps field is uniform, if the gap is small compared with the diameter. In the case of sphere gaps, the breakdown voltages do not depend on humidity and are also independent of the voltage waveform. The formative time lag is quite small (~ 0.5 |i s) even with 5% over voltage. Hence sphere gaps are used for breakdown voltage (peak value) measurements.

Fig 8.2- Arrangement of Point point electrodes

PROCEDURE:

- Connect the circuit as per diagram.
- Adjust the length of two electrodes.
- Switch on the panel.
- Switch on Control supply.
- Switch on HT Switch.
- Increase High voltage by push button switch.
- Observe spark between two sphere and take reading.

CONCLUSION:

LABORATORY EXPERIMENT –10

AIM: To Study 3 Phase Transformer Connections.

THEORY:

The individual transformers are connected in a variety of ways in a power system. Due to the advantages of polyphase power during generation, transmission and utilization polyphase power handling is very important. As an engineering application is driven by techno-economic considerations, no single connection or setup is satisfactory for all applications. Thus transformers are deployed in many forms and connections. Star and delta connections are very commonly used. Apart from these, vee or open delta connection, T connection, auto transformer connections etc. are a few possibilities. Apart from the characteristics and advantages of these, one must also know their limitations and problems, to facilitate proper selection of a configuration for an application. Many polyphase connections can be formed using single phase transformers. Each winding has two ends designated as 1 and 2. The HV winding is indicated by capital letters and the LV winding by small letters. If more terminals are brought out from a winding by way of taps there are numbered in the increasing numbers in accordance to their distance from 1 (egA1,A2,A3...). If the induced emf at an instant is from A1 to A2 on the HV winding it will rise from a1 to a2 on the LV winding. Out of the different polyphase connections three phase connections are mostly encountered due to the wide spread use of three phase systems for generation, transmission and utilization. Three balanced 3-phase voltages can be connected in star or delta fashion to yield a balanced 3-phase 3-wire system. The transformers that work on the 3-phase supply have star, delta or zig-zag connected windings on either primary secondary or both.

Star connection is normally cheaper as there are fewer turns and lesser cost of insulation. The advantage becomes more with increase in voltage above 11kv. In a star connected winding with earthed-neutral the maximum voltage to the earth is (1/√3) of the line voltage. Also star connection permits mixed loading due to the presence of the neutral.
Delta connections are advantageous in low voltage transformers as insulation costs are insignificant and the conductor size becomes (1/√3) of that of star connection and permits ease of winding. The common polyphase connections are briefly discussed now. The capital letters indicates primary and the small letters the secondary.

Star/Star (Yy0, Yy6): This is the most economical one for small high voltage transformers. Insulation cost is highly reduced. Neutral wire can permit mixed loading. 3^{rd}harmonics are absent in the lines. These 3^{rd}harmonic currents cannot flow, unless there is a neutral wire. This connection produces oscillating neutral. Three phase shell type units have large 3^{rd}harmonic phase voltage. However three phase core type transformers work satisfactorily. A tertiary delta connected winding may be required to stabilize the oscillating neutral due to third harmonics in three phase banks.

Delta/Delta (Dd0, Dd6): This is an economical configuration for large low voltage transformers. Large amount of unbalanced load can be met with ease. Delta permits a circulating path for 3^{rd}harmonics thus attenuates the same. It is possible to operate with removal of one transformer as open delta or Vee connection meeting 58% of the balanced load. Three phase units cannot have this facility. Mixed single phase loading is not possible due to the absence of neutral.

Star/Delta (Yd): This arrangement is very common for power supply transformers. The delta winding permits 3^{rd}harmonic currents to circulate in the closed path and attenuates them.

Delta/Star (Dy): Commonly used in a step-up transformer due to the advantages that wye connection on the HV side reduces insulation costs, the neutral point on the HV side can be grounded, stable with respect to unbalanced loads.

Generally speaking a bank of three single phase transformers cost about 15% more than their 3-phase counterpart. Also, they occupy more space. But the spare capacity cost will be less and single phase units are easier to transport. Delta connected three phase transformers resemble 3- single phase units but kept in a common tank. In view of this single tank, the space occupied is less. Other than that there is no big difference. The 3-phase core type transformer on the other hand has a simple core arrangement. The three limbs are equal in cross section. Primary and secondary of each phase are housed on the same limb. The flux setup in any limb will return through the other two limbs as the MMF of those limbs is in the proper directions so as to aid the same. Even though magnetically this is not a symmetrical arrangement, as the reluctance to the flux setup by side limbs is different from that of the central limb, it does not adversely affect the performance. This is due to the fact that the magnetizing current itself forms a small fraction of the total phase current drawn on load. The added advantage of 3-phase core is that it can tolerate substantially large value of 3rd harmonic MMF without affecting the performance. The 3rd harmonic MMF of the three phases will be in phase and hence rise in all the limbs together. The 3rd harmonic flux must therefore find its path through the air. Due to the high reluctance of the air path even a substantially large value of third harmonic MMF produces negligible value of third harmonic flux. Similarly unbalanced operation of the transformer with large zero sequence fundamental MMF content also does not affect its performance. Even with Yy type of poly phase connection without neutral connection the oscillating neutral does not occur with these cores. Finally, three phase cores themselves cost less than three single phase units due to compactness.

In addition to giving different voltage ratios, they introduce phase shifts between input and output sides. These connections are broadly classified into 4 popular vector groups.

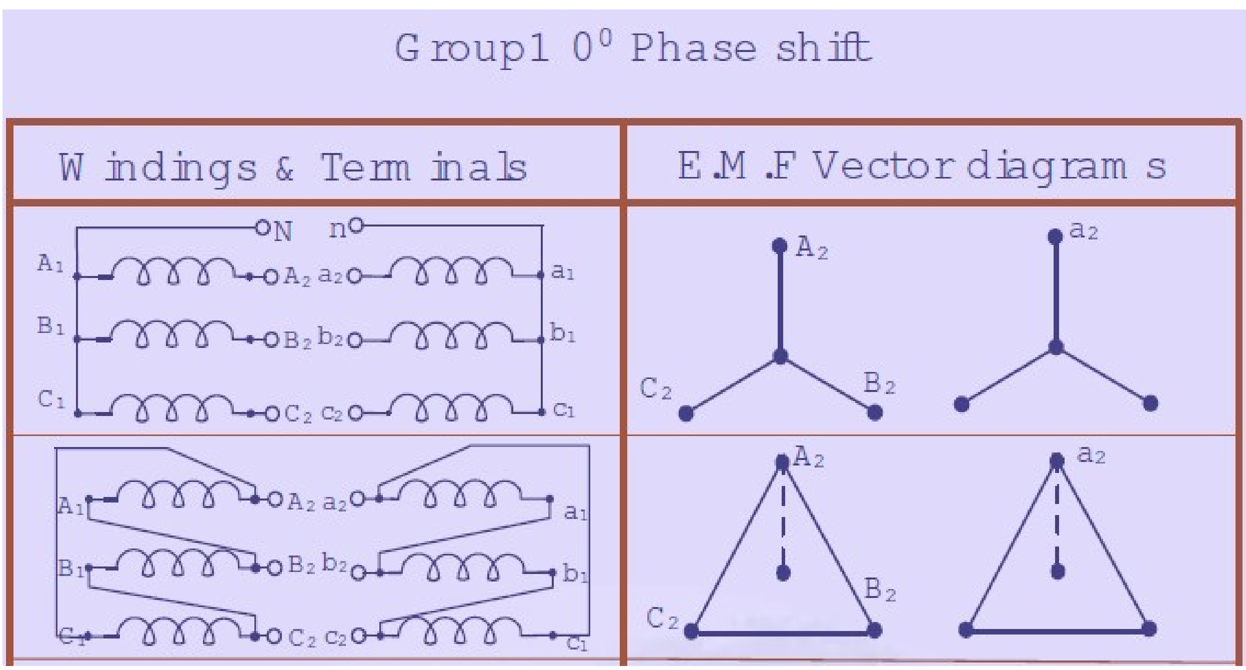
1. Group I: Zero phase displacement between the primary and the secondary.

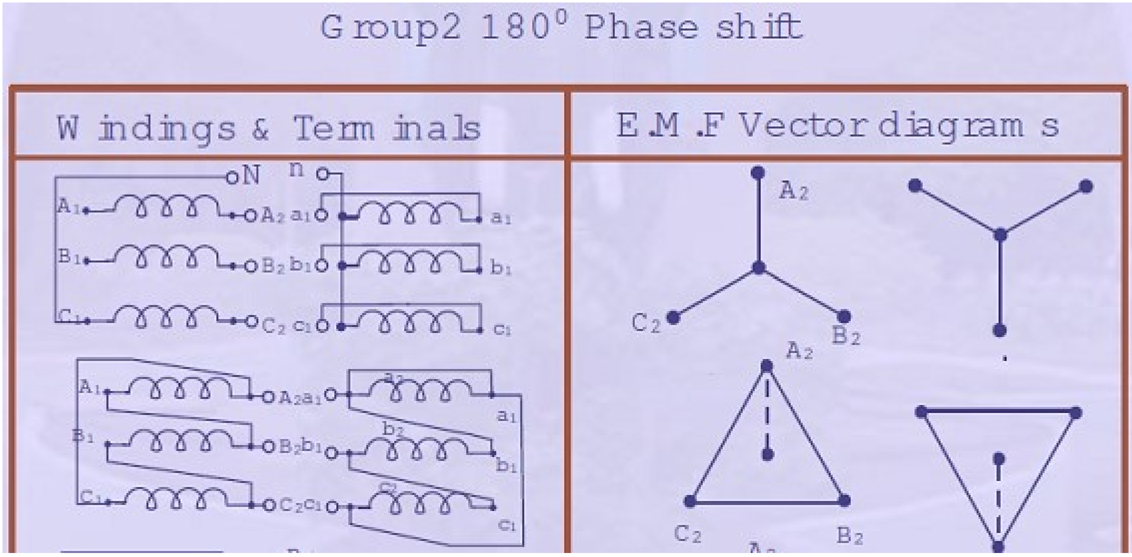
2. Group II: 180^0phase displacement.

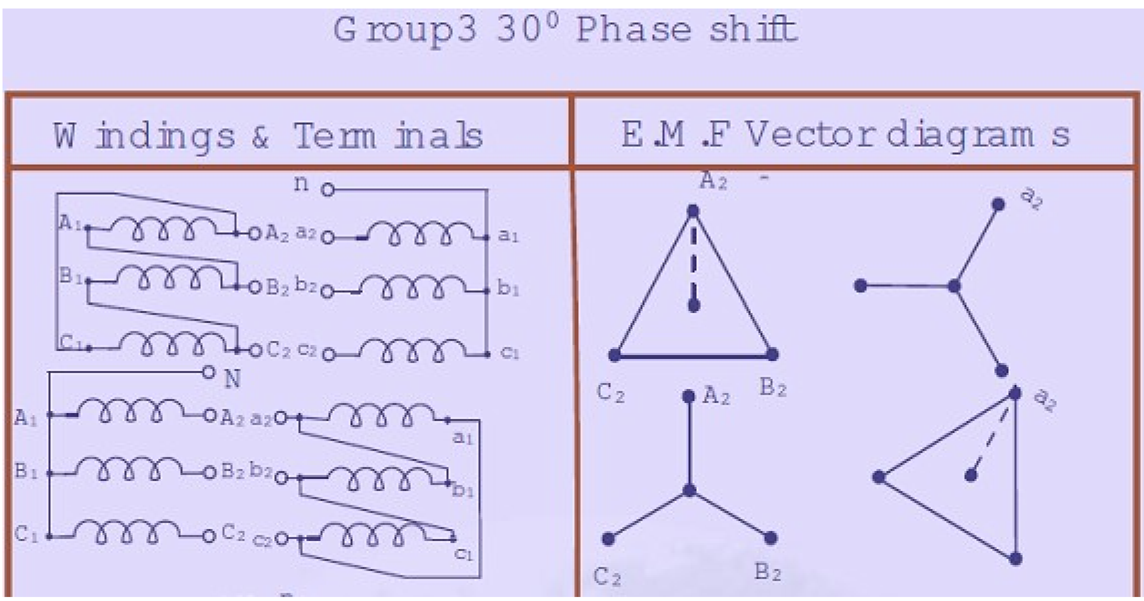
3. Group III: 30^0lag phase displacement of the secondary with respect to the primary.

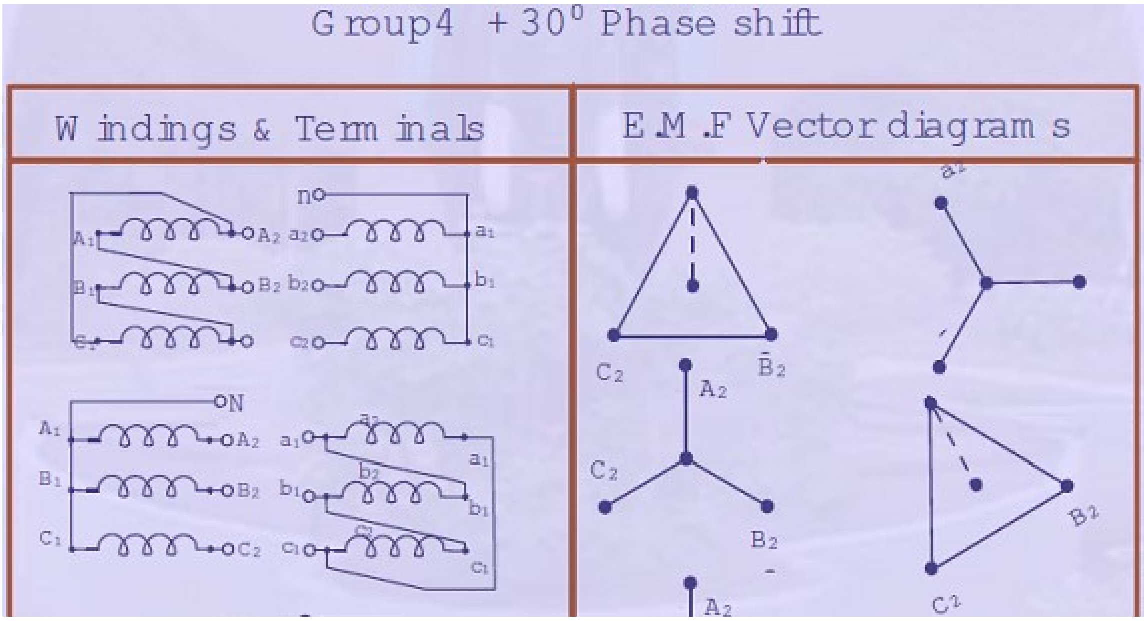
4. Group IV: 30^0lead phase displacement of the secondary with respect to the primary.

A few examples of the physical connections and phasor diagrams are shown in figure corresponding to each group. The angular displacement of secondary with respect to the primary is shown as clock position, 0^0 referring to 12 o'clock position. These vector groups are especially important when two or more transformers are to be connected in parallel.




Group2 180⁰ Phase shift
Windings & Terminals
E.M.F Vector diagrams
N
n
A1
A2
a1
B1
B2
b1
C1
C2
c1
a2
b2
c2


Group3 30⁰ Phase shift
Windings & Terminals
E.M.F Vector diagrams
n
N
A1
A2
a2
a1
B1
B2
b2
b1
C1
C2
c2
c1


Group4 +30⁰ Phase shift
Windings & Terminals
E.M.F Vector diagrams

CONCLUSION: