<u>Jawaharlal Nehru Engineering College</u>

Laboratory Manual

High Voltage Engineering

For

Final Year (EEP) Students

Manual made by

Ms.S.D.Jawale

FOREWORD

This manual is intended for the final year students of **ELECTRICAL, ELECTRONICS & POWER** engineering branch in the subject of High Voltage Engineering (HVE). This manual typically contains practical/Lab Sessions related to HVE covering various aspects related to the subject to enhance understanding.

Students are advised to thoroughly go through this manual rather than only topics mentioned in the syllabus as practical aspects are the key to understanding and conceptual visualization of theoretical aspects covered in the books.

Good Luck for your Enjoyable Laboratory Sessions

Prof. H. H Shinde

PRINCIPAL

MGM`S **JAWAHARLAL NEHRU ENGINEERING COLLEGE,** AURANGABAD.

Department of Electrical Engineering

Vision of JNEC

To create self-reliant, continuous learner and competent technocrats imbued with human values.

Mission of JNEC

1. Imparting quality technical education to the students through participative teaching –learning process.
2. Developing competence amongst the students through academic learning and practical experimentation.
3. Inculcating social mindset and human values amongst the students.

JNEC Environmental Policy

1. The environmental control during its activities, product and services.
2. That applicable , legal and statutory requirements are met according to environmental needs.
3. To reduce waste generation and resource depletion.
4. To increase awareness of environmental responsibility amongst its students and staff.
5. For continual improvement and prevention of pollution.

JNEC Quality Policy:

Institute is committed to:

- To provide technical education as per guidelines of competent authority.
- To continually improve quality management system by providing additional resources required. Initiating corrective & preventive action & conducting management review meeting at periodical intervals.
- To satisfy needs & expectations of students, parents, society at large.

EEP Department

VISION:

- To develop competent Electrical Engineers with human values.

MISSION:

- To Provide Quality Technical Education To The Students Through Effective Teaching-learning Process.
- To Develop Student's Competency Through Academic Learning, Practicals And Skill Development Programs.
- To Encourage Students For Social Activities & Develop Professional Attitude Along With Ethical Values.

SUBJECT INDEX

1. Do's and Don'ts

2. Lab exercise:

1. Quiz on the subject

2. Conduction of Viva-Voce Examination

3. . Evaluation and Marking Systems

1. <u>DOs and DON'Ts:</u>

<u>DO's in Laboratory:</u>

1. Understand the equipment to be tested and apparatus to be used .

2. Select proper type (i.e. A. c. or D. C.) and range of meters.

3. Do not touch the live terminals.

4. Use suitable wires (type and size).

5. All the connection should be tight.

DONT's in Laboratory:

1. Do not leave loose wires (i.e. wires not connected).
2. Get the connection checked before switching 'ON' the supply.
3. Never exceed the permissible values of current, voltage, and / or speed of any machine, apparatus, wire, load, etc.
4. Switch ON or OFF the load gradually and not suddenly.
5. Strictly observe the instructions given by the teacher/Lab Instructor

Instructions for Laboratory Teachers:

1. Submission related to whatever lab work has been completed should be done during the next lab session. The immediate arrangements for printouts related to submission on the day of practical assignments.

2. Students should be taught for taking the observations /readings of different measuring instruments under the able observation of lab teacher.

3. The promptness of submission should be encouraged by way of marking and evaluation patterns that will benefit the sincere students.

Experiment no:-01

Aim: To study Breakdown strength of composite dielectric materials.

Theory:

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 a whole is 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 in fact 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 realised 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.

Properties of Composite Dielectrics

A composite dielectric generally consists of a large number of layers arranged one over the other. This is called "the layered construction" and is widely used in cables, capacitors and transformers. Three properties of composite dielectrics which are important to their performance are given below.

(a) Effect of Multiple Layers

The simplest composite dielectric consists of two layers of the same material. Here, advantage is taken of the fact that two thin sheets have a higher dielectric strength than a single sheet of the same total thickness. The advantage is particularly significant in the case of materials having a wide variation in dielectric strength values measured at different points on its surface.

(b) Effect of Layer Thickness Increase in layer thickness normally gives increased breakdown voltage. In a layered construction, breakdown channels occur at the interfaces only and not directly through another layer. Also, a discharge having penetrated one layer cannot enter the next layer until a part of the interface also attains the potential which can produce an electric field stress comparable to that of the discharge channel.

The use of layered construction is very important in the case of insulating paper since the paper thickness itself varies from point to point and consequently the dielectric strength across its surface is not homogeneous. The differences in the thickness impart a rough surface to the paper which can produce an electric field stress comparable to that of the discharge channel. The rough surface of the paper also helps in better impregnation when tightly wound. On the other hand, the existence of areas with lower thickness in the paper can cause breakdown at these points at considerably lower voltages.

Various investigations on composite dielectrics have shown that (i) the discharge inception voltage depends on the thickness of the solid and solid dielectric, and (ii) the difference in the dielectric constants between the liquid and solid dielectrics does not significantly affect the rate of change of electric field at the electrode edge with the change in the dielectric thickness.

(c) Effect of Interfaces

The interface between two dielectric surfaces in a composite dielectric system plays an important role in determining its pre-breakdown and breakdown strengths. Discharges usually occur at the interfaces and the magnitude of the discharge depends on the associated surface resistance and capacitance. When the surface conductivity increases, the discharge magnitude also increases, resulting in damage to the dielectric.

In a composite dielectric, it is essential to maintain low dielectric losses because they normally operate at high electric stresses. However, even in an initially pure dielectric liquid, when used under industrial conditions for impregnating solid dielectrics, impurities arise, resulting in increased dielectric losses.

Mechanisms of Breakdown in Composite Dielectrics

If dielectric losses are low the cumulative heat produced will be low and thermal breakdown will not occur. However, several other factors can cause short and long time breakdown.

(a) Short-Term Breakdown

If the electric field stresses are very high, failure may occur in seconds or even faster without any substantial damage to the insulating surface prior to breakdown. It has been observed that breakdown results from one or more discharges when the applied voltage is close to the observed breakdown value. There exists a critical stress in the volume of the dielectric at which discharges of a given magnitude can enter the insulation from the surface and propagate rapidly into its volume to cause breakdown.

Experiments with single discharges on an insulating material have shown that breakdown occurs more rapidly when the electric field in the insulation is such that it assists the charged particles in the discharge to penetrate into the insulation, than when the field opposes their entry. Breakdown was observed to occur more readily when the bombarding particles are electrons, rather than positive ions. In addition, there are local field intensifications due to the presence of impurities and variations in the thickness of solid insulation and these local field intensifications play a very important role in causing breakdown under high field conditions; the actual effect being dependent on the field in the insulation before the discharge impinges on it.

(b) Long-Term Breakdown

Long-term breakdown is also called the ageing of insulation. The principal effects responsible for the ageing of the insulation which eventually leads to breakdown arise from the thermal processes and partial discharges. Partial discharges normally occur within the volume of the composite insulation systems. In addition, the charge accumulation and conduction on the surface of the insulation also contributes significantly towards the ageing and failure of insulation.

(i) *Ageing and breakdown due to partial discharges*

During the manufacture of composite insulation, gas filled cavities will be present within the dielectric or adjacent to the interface between the conductor and the dielectric. When a voltage is applied to such a system, discharges occur within the gas-filled cavities. These discharges are called the *'partial discharges" and involve the transfer of electric charge between the two points in sufficient quantity to cause the discharge of the local capacitance. At a given voltage, the impact of this charge on the dielectric surface produces a deterioration of the insulating properties, in many ways, depending on the geometry of the cavity and the nature of the dielectric.

deposited can stay there for very long durations, lasting for days or even weeks. The presence of this charge increases the surface conductivity thereby increasing the discharge magnitude in subsequent discharges. Increased discharge magnitude in subsequent discharges causes damage to the dielectric surface. Experiments using electro-photography and other methods have shown that transverse discharges occur on the faces of the dielectric, and these

discharges cause a large area to be discharged instantaneously. Charges that exist in surface conductivity are due to the discharges themselves such that changes in discharge magnitude will occur spontaneously during the life of a dielectric.

It has been generally observed that the discharge characteristics change with the life of the insulation. This can be explained as follows: for clean surfaces, at the discharge inception voltage V/f the discharge characteristic depends on the nature of the dielectric, its size and shape. The discharge normally consists of a large number of comparatively small discharges originating from sites on the insulator surface where the necessary discharge condition exists. After some time, erosion at these sites causes the discharges to decrease in number as well as in magnitude, and consequently total extinction may occur. With the passage of time, the phenomena involved become complex because the charges from the surface-induced conductivity add to the charge accumulation in the bulk due to partial discharges.

Conclusion:

Experiment No:02

Aim: Study of impulse voltage generator

Theory:

In the field of electrical engineering, high voltages (D.C., A.C. and impulse) are required for several applications. For example electron microscopes and x-ray units require high D.C. voltages of the order of 100 kV or more. Electrostatic precipitators, particle accelerators in nuclear physics, etc. require high D.C. voltages of several kilovolts and even megavolts. High A.C. voltages of one million volts or even more are required for testing power apparatus rated for extra high transmission voltages (400 kV system and above). High impulse voltages are required for testing purposes to simulate over voltages that occur on power system due to lightning or switching action. For electrical engineers, the main concern of high voltage generation is for the insulation design, testing before commissioning and in service testing of various components in power system for different types of voltages namely :

1) high D.C. voltages
2) high A.C. voltages of power frequency
3) high A.C. voltages of high frequency
4) Impulse voltages of very short duration such as lightning over voltages, and
5) transient voltages of longer duration such as switching surges.

Transient over-voltages due to lightning and switching action cause steep build up of voltage on transmission lines and other electrical power apparatus. Experimental investigations show that these waves have a rise time of 0.5 to 10 µs and decay time to 50% of the peak value of the order of 30 to 200 µs. The wave-shapes are arbitrary, but mostly unidirectional. It is shown that lightning over-voltages can be represented as double exponential waves defined by the equation:

$V=V_o [\exp(-at)-\exp(-ßt)]$ ---------------------- (1)

where a and ß are constants of inverse microsecond values. The equation (1) represents a unidirectional wave which usually has a rapid rise to the peak value and slowly falls to zero value. The standard wave-shape is given in figure below.

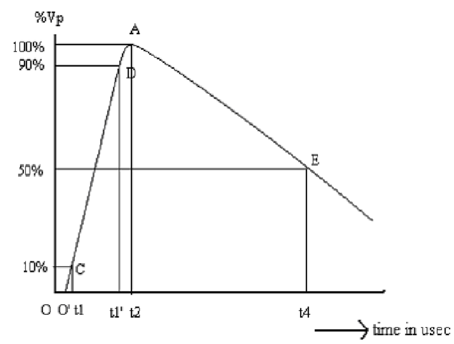


Fig 2.1 Transient wave shape

The impulse waves are specified by defining their rise or front time, fall (or tail time) to 50% peak value, and the value of the peak voltage. Thus 1.2/50 µs, 1000 kV wave represents an impulse voltage wave with a front time of 1.2 µs, fall (or tail) time to 50% peak value of 50 µs and a peak value of 1000 kV. When impulse wave-shapes are recorded, the initial portion of the wave may not be clearly defined or sometimes may be missing. Hence, front and tail times are to be redefined. Referring to the wave shape in figure 1, the peak value A is fixed and referred to as 100% value. The point corresponding to 10% and 90% of the peak values are located on the front portion (points C and D).O' is taken as the virtual origin. 1.25 times the interval between times t1 and t2 corresponding to points C and D is defined as the front time, i.e. 1.25(O't1-O't2). The point E is located on the wave tail corresponding to 50% of the peak value, and it is t4. O't4 is defined as fall or tail time. In case, C is not clear or missing from the wave shape record, the point corresponding to 30% of the peak value is taken on the time axis and then the wave front time in that case will be 1.67 times in place of 1.25. The tolerances that can be allowed on the front and tail times are respectively ±30% and ±20%.The tolerance allowed on the peak value is ±3%.

Transients

When a power device is abruptly switched on or turned off, trapped energy in the circuit stray inductance is dissipated in the switching device, causing a voltage overshoot across the device termed as transient or over voltage. The magnitude of this transient voltage is proportional to the amount of stray inductance and the rate of fall of turn-off current. The time-varying currents and voltages resulting from the sudden application of sources are called transients.

RC transients

The capacitor C is initially charged with charging voltage Vi. When switch is closed at $t=0^+$, the capacitor gets discharged through resistor R, with output voltage, as shown in Fig. 2.1

A capacitor C discharge through resistance R, hence, gives the output equation (2)

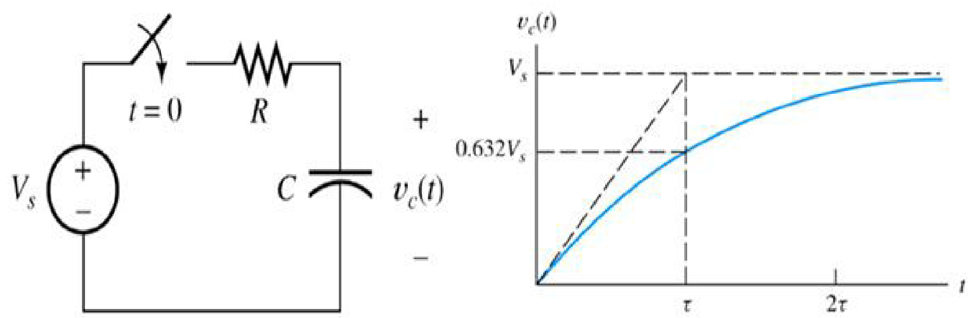


Fig 2.2 : RC Circuit and charging transient

$$\mathbf{Vc(t)=V_i^{-t/RC}} \quad \text{...(2)}$$

RL Transients

For DC circuit analysis, the voltage and current source excitation is constant, so C and L are neglected. The circuit is assumed to be as it is since time t= -∞ to ∞. In practice, no excitation is constant from t= -∞ to ∞.The input DC voltage Vs, which stores the energy in L through a resistor R and gives the output, as shown in Fig2. 3

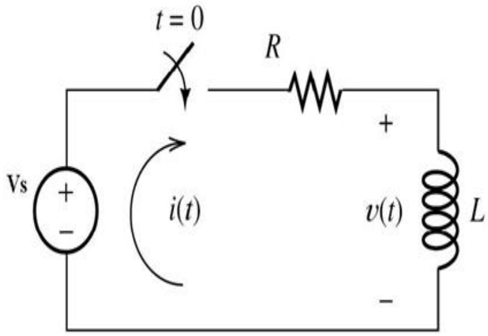


fig 2.3: RL Circuit

$$i(t)=\frac{V_s}{R}\left(1-e^{-\frac{Rt}{L}}\right)$$ ………………………………………….(3)

$$v_t(t)=Ve^{-\frac{Rt}{L}}$$ ……………………………………………..(4)

Vt (t) is the voltage across inductor. In eq. 4, it is noticed that in time L/R seconds, the voltage across the inductor reduces to 1/e of its original value and would go on decreasing by a further factor of 1/e in every L/R seconds thereafter.

Single Stage IVG:

Fig 2.4 shows single stage IVG the inductance Lf represents the loop inductance offered by front resistor that is responsible for overshoot of lighting impulse LI which must be limited to below5 Lt is the inductance offered by the tail resistance of the impulse circuit. impulse voltages are represented as a sum of two exponentials. A double exponential waveshape can be generated by having a circuit with energy storage elements with independent control for rising portion and falling portion of the wave. These circuit elements can either be capacitors or inductors. Since inductors of large ratings are difficult to manufacture owing to their large size and high currents involved, hence a speedy suitable discharge circuit consisting of capacitors could be preferred.

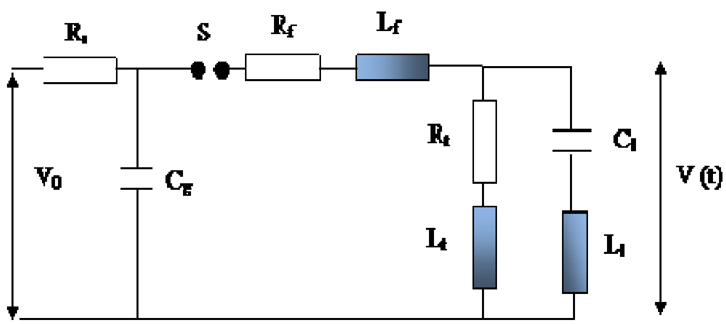


fig 2.4 Single Stage IVG

Procedure to do the Experiment

1. When the page is loaded user will be presented with a circuit representation of IVG on the right frame.
2. The input parameters namely Charging Voltage(V_O),Generator Capacitance(C_g),Tail Capacitance(C_l),Front Inductance(L_f),Load Inductance(L_l),Front Resistance(R_f),Tail Resistance(R_t),Tail Time required(T_d)are displayed with default values on the other frame.
3. The user can conduct the experiment with the default values, however the parameters can also be changed and the experiment performed.
4. Each of these parameters can be changed by using the -- and + buttons along the text box.
5. The setup Generator button is clicked to display the flash version of Experimental setup of IVG.
6. When the experimental setup is loaded, the Trigger Generator button is clicked to trigger the generator.
7. When the generator is triggered the sphere gaps break-down and the impulse waveform so generated is displayed.
8. The salient features of the waveform and the values of output parameters like Peak Voltage, Front Time and Tail Time are displayed in the form of a graph.
9. The end user is given an option to change the previously set input parameter values and to perform the experiment with a new set of input parameters on the same page without going back to previous page.

Observation Table

Sr. No.	Vin	Cg	C1	Lf	L1	Lt	Rf	Rt	Tr	Vp	Tf	Tt

1												
2												
3												
4												

Conclusion:

Experiment No 3

Aim: To study impulse current generator

Objective:

•Exponential impulse current test for verification of current rating.
•Exponential impulse current test for determination of residual voltage like, as surge arresters.

Theory:

Impulse Current Generation:

Generation of impulse current waveforms of high magnitude (~100 kA) find application in test work as well as basic research on non-linear resistors, electric arc studies, and studies related to electric plasmas in high current discharges. Impulse current testing of surge arresters is done to test their ability to withstand lightning impulses. Rectangular impulse testing is done to assess their surge energy absorption ability. As lightning phenomena involves both high voltage impulses and high current impulses on transmission lines, proper measures need to be taken in advance to protect the power apparatus from high impulse currents. Here protective gear like surge arrestors come to our rescue as they can discharge the lightning currents without damage.

Impulse current can have varying wave shapes and magnitudes depending upon their application and occurrence. Often, impulse currents appear as periodic or damped oscillatory currents.

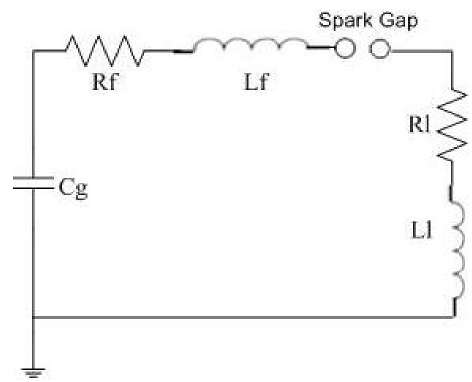


Fig.3.1 Equivalent Circuit

Impulse current waveforms are represented as damped sinusoids given as

I (t) = Io [e-at sin (wt)] ------------------- (1)

Where ‘a’ is damping constant and ‘w’ is the frequency of the sinusoid. The characteristic parameters and the nature of the standard waveform are shown in figure 1. The standard parameters characterizing the waveform are front time (tf), tail time (tt) and peak value of current (Ip). The front time and thetail time are calculated as below.

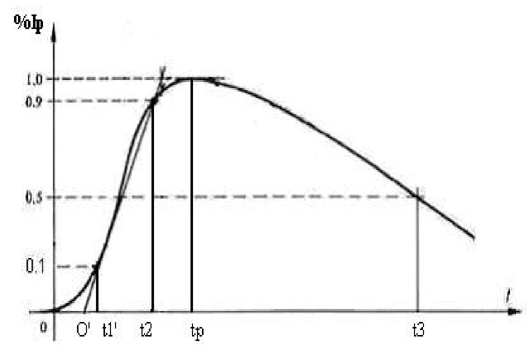


fig 3.2

1) Referring to the wave shape in figure, the peak value is fixed and referred to as 100% value. The points corresponding to 10% and 90% of the peak values are found on the front portion.

2) The line joining these points is extended to cut the time axis at O'. O' is taken as the virtual origin.

3) Now, 1.25 times the time interval between times corresponding to 10% and 90% of peak value of the waveform is defined as the front time (tf).

4) Starting from the virtual origin, the time corresponding to the point on the wave tail for 50% of the peak value of the waveform is known as the tail time (tt).

-- Tolerance that can be allowed both on the front time and the tail time is ± 10%.

-- Tolerance allowed on peak value is +20% and -0%.

Front time tf (µs)	Tail time tt (µs)	Std. notation
1.0 ± 0.1	20.0 ± 2.0	1/20
4.0 ± 0.4	10.0 ± 1.0	4/10
8.0 ± 0.8	20.0 ± 2.0	8/20
30.0 ± 3.0	80.0 ± 8.0	30/80

Table 3.1: Standard impulse current wave shapes

Conclusion:

Experiment No: 4

Aim: Study of Functioning of Voltage Doubler

Theory:

High Voltage DC is used in several applications in industries, in equipments and Research. HV DC is also employed to transmit bulk power. That apart HVDC is used in testing of High Voltage Cables and as a source for charging the Impulse Voltage and Current Generator.

The most usual way of Generating High Voltage DC is through rectification using a) Half wave b) Full wave c) Multiplier Circuits. In all these cases the AC input is taken from a High Voltage transformer.

The DC voltage produced by the half wave rectifier is less than the peak value of the Sine Wave. The size and ratings of the capacitors and transformers become very large if pure high voltage DC is to be produced. Voltage Doublers are used when higher DC voltages are needed. A typical voltage doubler circuit is shown below. The capacitor C_1 is charged through r.

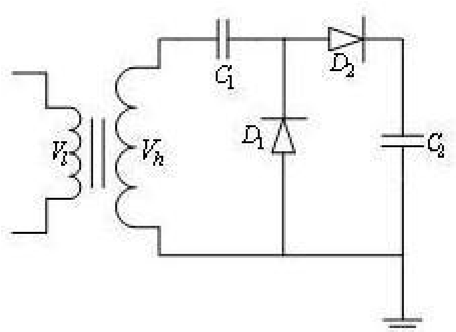


Fig 4.1 Voltage Doubler Circuit

Conclusion:

Experiment No 5

Aim: Study of High Voltage D. C. Test Source

Theory:

High Voltage DC is used in several applications in industries, in equipments and Research. HV DC is also employed to transmit bulk power. That apart HVDC is used in testing of High Voltage Cables and as a source for charging the Impulse Voltage and Current Generator.

The most usual way of Generating High Voltage DC is through rectification using

a) Half wave b) Full wave c) Multiplier Circuits. In all these cases the AC input is taken from a High Voltage transformer.

In a half wave rectifier, the rectifier unit which primarily consists of a set of diode (uni directional conducting devices), the conduction takes place during positive half cycle of the sinusoidal wave form only and it charges a capacitor which stores the energy. The circuit diagram is shown in Figure-1:

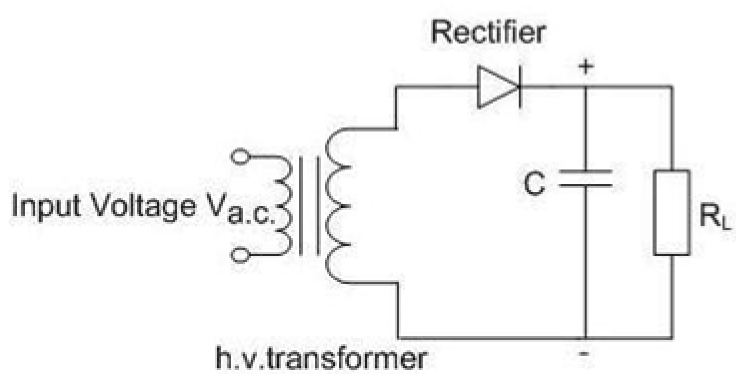


Fig 5.1 Half Wave Rectifier

In a half wave rectifier, the rectifier unit which primarily consists of a set of diode (uni-directional conducting devices), the conduction takes place during positive half cycle of the sinusoidal wave form only and it charges a capacitor which stores the energy. The capacitor too must be rated for the necessary High Voltage and the Peak Inverse Voltage of the rectifier unit must be 2Vmax where Vmax is the maximum voltage of the input AC wave. If the capacitor is connected to a load, then it slowly loses charge and gets replenished only in the next positive half cycle. The output DC voltage thus does not remain constant but fluctuates between a maximum value and a minimum value. The difference between the maximum and minimum value of the voltage is termed as ripple. Larger the value of the capacitor, lesser would be ripple. In addition the ripple voltage also depends on the frequency of the input AC voltage.

In this experiment, the HV DC rectified output from half wave rectifier is used to perform breakdown studies on symmetric sphere gaps.

Below are certain areas in which application of HVDC Test Source (Half wave) finds its place:

High Voltage DC power supply for Impulse Generators.

Used for performing gap breakdown studies of various geometries.

Conclusion:

Experiment No.6

Aim: To study High Voltage withstand test on cables as per IS.

Theory:

Tests on Cables

Cables are tested for withstand voltages using the power frequency a.c., d.c., and impulse voltages. At the time of manufacture, the entire cable is passed through a high voltage test at the rated voltage to check the continuity of the cable. As a routine test, the cable is tested applying an a.c. voltage of 2.5 limes the rated value for 10 min. No damage to the cable insulation should occur. Type tests are done on cable samples using both high voltage d.c. and impulse voltages. The d.c. test consists of applying 1.8 times the rated d.c. voltage of negative polarity for 30 min., and the cable system is said to be fit, if it withstands the test. For impulse tests, impulse voltage of the prescribed magnitude as per specifications is applied, and the cable has to withstand five applications without any damage. Usually, after the impulse test, the power frequency dielectric power factor test is done to ensure that no failure occurred during the impulse test.

Partial Discharges

(a) Discharge Measurement

Partial discharge measurements and the discharge locations are important for cables, since the life of the insulation at a given voltage stress depends on the internal discharges. Also, the weakness of the insulation or faults can be detected with the help of these tests; the portion of the cable if weak may be removed, if necessary.

The equivalent circuit of the cable for discharges is shown in Fig. 6.1, and the cable connection to the discharge detector through the coupling condenser is shown in Figs. 2a and b.

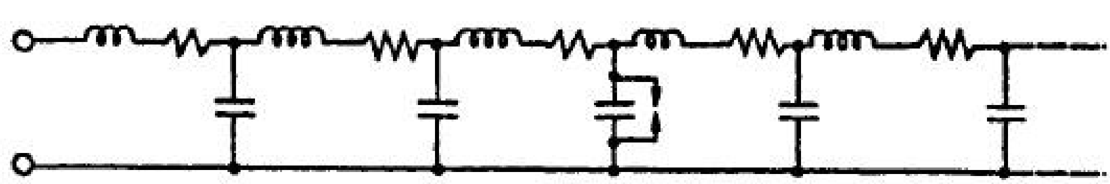


Fig 6.1- Equivalent circuit for cable discharges

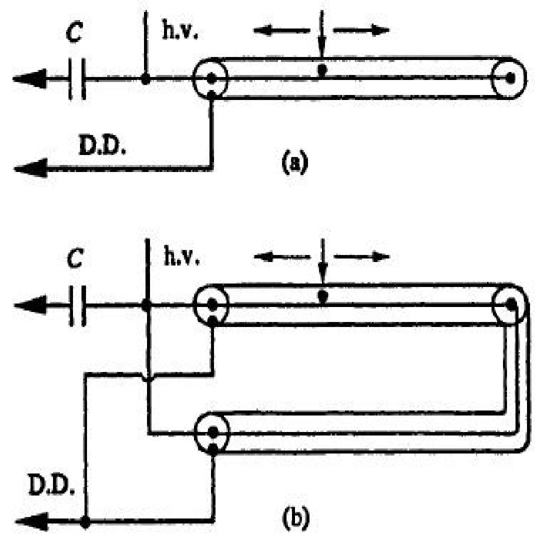


FIg. 6.2- Discharge detector connection to long length of cable D.D.—Discharge detector

If the detector is connected through a coupling capacitor to one end of the cable as in Fig. 2a, it will receive the transient travelling wave directly from the cavity towards the nearer end, and after a short lime, a second travelling wave pulse reflected from the far end is observed. Thus, the detected response is the combination of the above two transient pulses. But, if the connections are made as in Fig. 2b, no severe reflection is involved except as a second order effect of negligible magnitude. Now two transients will arrive at both the ends of the cable, and the superposition of the two pulses is detected. This can be obtained by adding the responses of the two transients. The superpositions of the two responses may give rise to a serious error in the measurement of the discharge magnitude. The magnitude of the possible error may be determined mainly by the shape of the response of the discharge detector.

(b) Location of Discharges

The voltage dip caused by a discharge at a fault or a void is propagated as a travelling wave along the cable. This wave is detected as a voltage pulse across the terminals of the cable ends. By measuring the time duration between the pulses, the distance at which the discharge is taking place from the cable end can be determined. The shapes of the voltage pulses depend on the nature of the discharges. Typical waveshapes are given in Fig. 3. The detection circuits for the pulses are shown in Fig. 10.9, Usually, the pulses detected across the resistor are distorted after passing through the amplifier of the discharge detector.

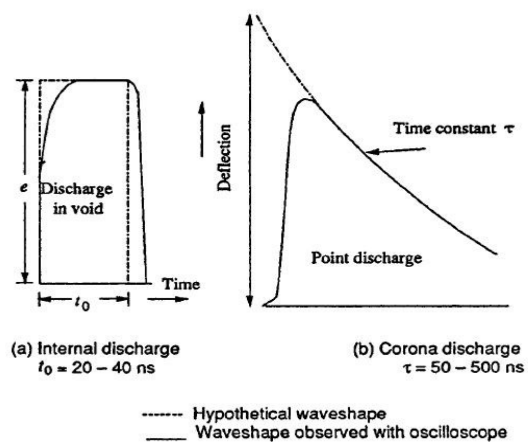


Fig: Typical waveshapes of pulses at the cable ends

(c) Scanning Method

In order to scan the entire cable length for voids or imperfections in manufacture, the bare core of the cable is passed through a high electric field and the discharge location is done. The core of the material is passed through a tube of insulating material filled with distilled water. Four electrodes in the form of rings arc mounted at both ends of tube as well as at the middle, such that they have electrical contact with the water. The middle electrodes are energized with a high voltage, and the other two electrodes and cable conductor are grounded. If a discharge occurs in the portion between the middle electrodes, as the cable is passed between the middle electrodes' portion, the discharge is detected and is located at that length of cable.

This test is very convenient for isolating the defective insulation at the factory site. The manufactured cable, before being rolled on to its former, can be conveniently passed through the test apparatus. "The defective part" can be isolated and cut off from the cable reel before it is sent from the factory.

(d) Life Tests

Life tests are intended for reliability studies in service. In order to determine the expected life to the cable under normal stress, accelerated life tests using increased voltages are performed on actual cable lengths. It is established that the relation between the maximum electrical stress *Em* and the life of the cable insulation in hours *t* approximately follows the relationship

$$E_m = Kt^{-(1/n)}$$

where, *K* = constant which depends on the field conditions and the material, and *n* = life index depending on the material.

By conducting long duration life tests at increased stress (1 hr to about 1000 hr) the expected life at the rated stress may be determined.

Conclusion:

Experiment No: 07

Aim: **Study of Abraham electrostatic voltmeter.**

Theory:

The Abraham voltmeter is the most commonly used electrostatic meter in high voltage testing equipment. In this instrument, there are two mushroom shaped hollow metal discs.

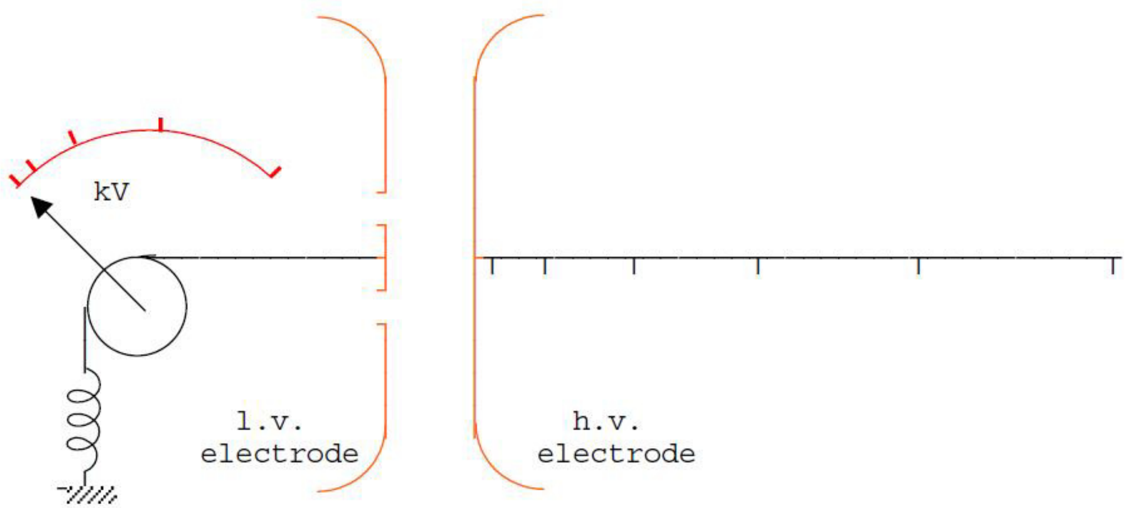


Figure 7. 1 - Abraham electrostatic voltmeter

As shown in figure 7.1 the right hand electrode forms the high voltage plate, while the centre portion of the left hand disc is cut away and encloses a small disc which is movable and is geared to the pointer of the instrument. The range of the instrument can be altered by setting the right hand disc at pre-marked distances. The two large discs form adequate protection for the working parts of the instrument against external electrostatic disturbances. These instruments are made to cover ranges from 3 kV to 500 kV. Owing to the difficulty of designing electrostatic voltmeters for the measurement of extra high voltages which will be free from errors due to corona effects, within the instrument, and to the external electrostatic fields, a number of special methods have been devised for the purpose.

Conclusion:

Experiment No: 08

Aim: To study effects of Extra High Voltage on Humans, animals and Plants

Theory:

By increasing population of the world, towns are expanding, many buildings construct near high voltage overhead power transmission lines. The increase of power demand has increased the need for transmitting huge amount of power over long distances. Large transmission lines configurations with high voltage and current levels generate large values of electric and magnetic fields stresses which affect the human being and the nearby objects located at ground surfaces. This needs to be investigating the effects of electromagnetic fields near the transmission lines on human health.

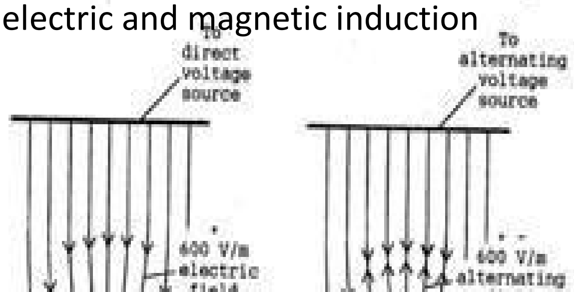
The electricity system produces extremely low frequency electromagnetic field which comes under Nonionizing radiations which can cause health effects. Apart from human effect, the electrostatic coupling & electromagnetic interference of high voltage transmission lines have impact on plants and telecommunication equipments mainly operating in frequency range below UHF.

Extremely high voltages in EHV lines cause electrostatic effects, where as short circuit currents & line loading currents are responsible for electromagnetic effects. The effect of these electrostatic fields is seen prominent with living things like humans, plants, animals along with vehicles, fences & buried pipes under & close to these lines.

1) EMF Effects Human beings:

The human body is a composed of some biological materials like blood, bone, brain, lungs, muscle, skin etc. The permeability of human body is equals to permeability of air but within a human body has different electromagnetic values at a certain frequency for different material.

The human body contains free electric charges (largely in ion-rich fluids such as blood and lymph) that move in response to forces exerted by charges on and currents flowing in nearby power lines. The processes that produce these body currents are called electric and magnetic induction



In electric induction, charges on a power line attract or repel free charges within the body. Since body fluids are good conductors of electricity, charges in the body move to its surface under the influence of this electric force. For example, a positively charged overhead transmission line induces negative charges to flow to the surfaces on the upper part of the body. Since the charge on power lines alternates

from positive to negative many times each second, the charges induced on the body surface alternate also. Negative charges induced on the upper part of the body one instant flow into the lower part of the body the next instant. Thus, power-frequency electric fields induce currents in the body (Eddy Current) as well as charges on its surface.

The currents induced in the body by magnetic fields are greatest near the periphery of the body and smallest at the center of the body.

It is believed that, the magnetic field might induce a voltage in the tissue of human body which causes a current to flow through it due to its conductivity of around them.

The magnetic field has influence on tissues in the human body. These influences may be beneficial or harmful depending upon its nature.

The magnitude of surface charge and internal body currents that are induced by any given source of power-frequency fields depends on many factors. These include the magnitude of the charges and currents in the source, the distance of the body from the source, the presence of other objects that might shield or concentrate the field, and body posture, shape, and orientation. For this reason the surface charges and currents which a given field induces are very different for different Human and animals.

Short term Health Problem

Headaches, Fatigue, Anxiety, Insomnia, Prickling and/or burning skin, Rashes, Muscle pain

Long term Health Problem:

Following serious health Problems may be arise due to EMF effects on human Body.

(1) Risk of damaging DNA.

Our body acts like an energy wave broadcaster and receiver, incorporating and responding to EMFs. In fact, scientific research has demonstrated that every cell in your body may have its own EMF, helping

to regulate important functions and keep you healthy.

Strong, artificial EMFs like those from power lines can scramble and interfere with your body's natural

EMF, harming everything from your sleep cycles and stress levels to your immune response and DNA!

(2) Risk of Cancer

After hundreds of international studies, the evidence linking EMFs to cancers and other health problems is loud and clear. High Voltage power lines are the most obvious and dangerous culprits, but the same EMFs exist in gradually decreasing levels all along the grid, from substations to transformers to homes.

(3) Risk of Leukemia:

Researchers found that children living within 650 feet of power lines had a 70% greater risk for leukemia than children living 2,000 feet away or more.

(4) Risk of Neurodegenerative disease:

"Several studies have identified occupational exposure to extremely low-frequency electromagnetic **fields (EMF) as a potential risk factor for neuro degenerative disease."**

2) EMF Effects on Animals

Many researchers are studying the effect of Electrostatic field on animals. In order to do so they keeps the cages of animals under high Electrostatic field of about 30 kV/m. The results of these Experiments are shocking as animals (are kept below high Electrostatic field their body acquires a charge & when they try to drink water, a spark usually jumps from their nose to the grounded Pipe) like hens are unable to pick up grain because of chattering of their beaks which also affects their growth.

EMF Effects on Plant Life

Most of the areas in agricultural and forest lands where high power transmission lines pass. The voltage level of high power transmission Lines are 400KV, 230KV, 110KV, 66KV etc. The electromagnetic field from high power transmission lines affects the growth of plants.

Gradually increases or decreases and reaches to maximum current or minimum current and thereafter it starts to fall down to lowest current or raises to maximum current or a constant current. Again the current, it evinces with little fluctuations till the next day morning. Current in Power transmission lines varies according to Load (it depending upon the amount of electricity consumed by the consumers). Hence the effect of EMF (due to current flowing in the power lines) upon the growth of plants under the high power transmission lines remains unaltered throughout the year. From various practically study it was found that the response of the crop to EMF from 110 KV and 230 KV Power lines showed variations among themselves. Based on the results the growth characteristics like shoot length, root length, leaf area, leaf fresh weight, specific leaf weight, shoot/root ratio, total biomass content and total water content of the four crop plants were reduced significantly over the control plants.

Conclusion: