DEPARTMENT OF ELECTRICAL ENGINEERING
BENGAL ENGINEERING AND SCIENCE UNIVERSITY, SHIBPUR

HIGH VOLTAGE LABORATORY (EE-853)

The High Voltage Laboratory carries 100 marks under the following three sub-heads:

i. Day to day performance	:30 marks
ii. Report	: 30 marks
iii. Viva-Voce	: 40 marks

GENERAL SAFETY INSTRUCTIONS FOR THE STUDENTS

Read this section carefully before you perform any experiment in the High Voltage Laboratory

1. While performing experiments in the High Voltage Laboratory, you must follow stringent safety rules and precautionary measures for your own safety as well as for safety of your co-workers. Always remember that you are working at voltage levels much higher compared to normal working voltage.

2. Don’t attempt to enter the lab floor except when asked for and accompanied by concerned teachers / instructors.

3. Do not attempt to operate any equipment yourself without permission of the concerned teachers / instructors. You should never be in casual while in the lab floor. Be careful that you don’t operate any button etc. by mistake: it may lead to serious mal operation and hazards.

4. Always maintain sufficient distance from the live objects to avoid electrical shock due to induction.

5. Before taking entry in the lab floor, always double check that all the apparatus and equipment are disconnected from supply and are properly grounded.

6. Use the ground rod to earth all apparatus before putting hands on them.

AC Power Frequency Test on Gaseous Dielectric: Determination of Breakdown Strength of Air under different Electrode Systems

Experiment No: 853/1

Objective:

To determine the breakdown characteristics of air as a dielectric medium, under different types of electrode configurations, such as:

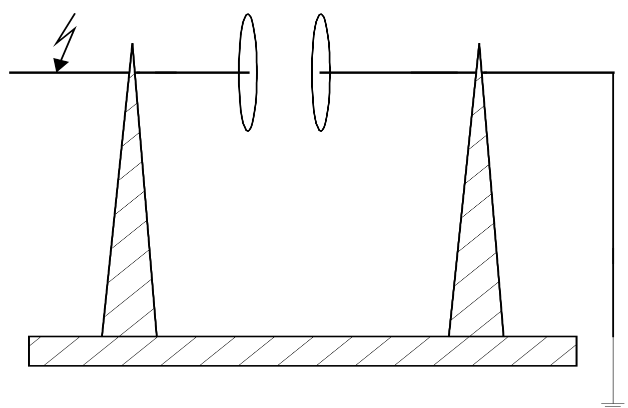
i. Gap between two parallel plate electrodes.
ii. Gap between two uniform spherical electrodes.
iii. Gap between two rod electrodes.
iv. Gap between two pin electrodes.

Theory:

Different Electrode System and their corresponding field distribution:

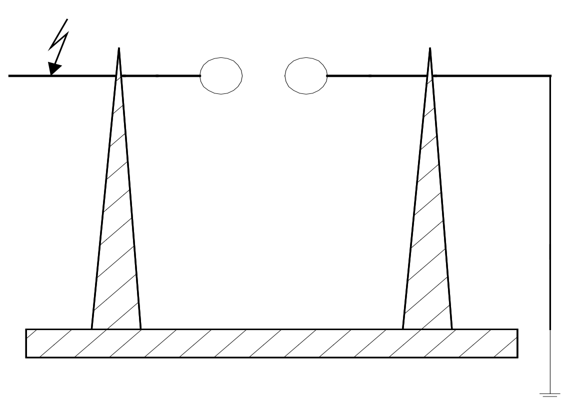
i. Electrode System – I: Parallel Plate Electrodes Configuration:-

The parallel plate system of electrodes is a typical example of almost uniform field provided the gap between the electrodes is small compared to the surface area of the electrodes. In an ideal uniform field, the breakdown voltage increases linearly with gap distance. The breakdown voltage also depends on ambient conditions like temperature, air density and humidity.



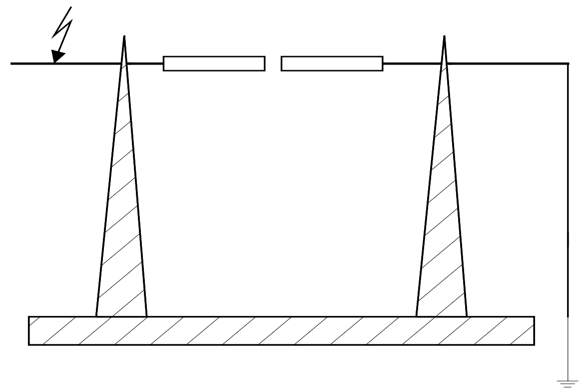
ii. Electrode System – II: Spherical Electrodes Configuration:-

The gap between two spheres is a classical example of weakly nonuniform field or almost uniform field. For smaller distance of separation between the spheres, the field is uniform and the degree of nonuniformity increases in the ratio of distance of separation *s* to the electrode diameter *d.*



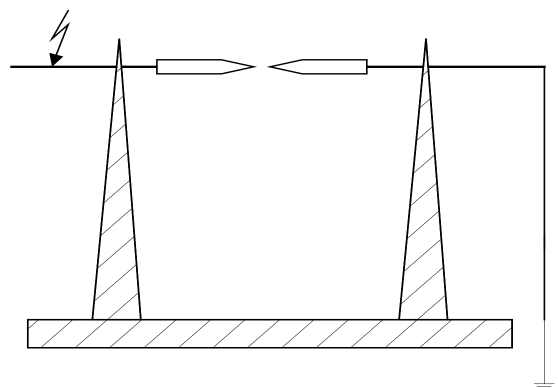
iii. Electrode System – III: Rod – Rod Electrode configuration:-

This is an example of strong onuniform field. In a strongly nonuniform field, the breakdown voltage vs. gap distance curve attains saturation very early. Thus a small increase in break down voltage requires a large separation between the electrodes.



iv. Electrode System – IV: Pin – Pin Electrode configuration:-

This is the worst type of electrode configuration in high voltage systems and field between two pin electrodes is strongly non-uniform in nature. In practical design of H.V. systems, such configuration must be avoided. For a given separation distance between the electrodes, the breakdown voltage is least for pin-pin configuration and also the breakdown voltage vs. gap distance curve attains saturation very fast.



Test Setup:

1. A.C. High Voltage Test set
2. Different electrode configurations like parallel plate electrodes, identical spheres, rod-rod and pin-pin electrodes.
3. Insulating platform for mounting the electrodes.
4. Flexible copper conductor for connection.
5. Ground Rod for earthing.

Procedure:

1. Mount the parallel plate electrode system on an insulated platform as shown in the diagram. Maintain sufficient clearance from other nearby grounded objects to avoid accidental flashover.
2. Connect the left plate electrode to the output terminal of the high voltage testing transformer by means of flexible copper wire.
3. Connect the right plate electrode to ground.

4. Start with a gap distance of 5 mm between the electrodes.
5. Power on the AC High Voltage Test Set and increase the voltage slowly until the air between the electrodes breaks down under the applied voltage stress. Note down the gap distance and the corresponding breakdown voltage. (The unit will automatically trip once breakdown occurs in order to protect the test set and the electrode system).

6. Switch off the High Voltage Test Set. Enter the lab floor and ground the live electrode system properly by means of the ground rod.

7. Increase the gap distance to 10, 15, 20, 25 and 30 mm respectively in 5 steps and repeat the procedures described in step nos. 5-7.

8. Tabulate the readings of breakdown voltage vs. gap distance in every step.

9. Repeat the experiment for Spherical, Rod-Rod and Pin-Pin electrode systems. For Rod-Rod and Pin-Pin electrode systems, start with a gap of 10 mm between the electrodes and increase the separation to 20, 30, 40, 60, 80 and 100 mm respectively in 6 steps.

Report:
1. From the tabulated results draw the graphs showing variation of breakdown voltage of air against gap distance for different electrode configurations and comment on the nature of the curves.
2. From the experimental results, determine the dielectric strength of air under laboratory ambient condition.
3. State a few practical examples of all the 4 types of electrode configurations.

Reference:
1. High Voltage Engineering Fundamentals – E. Kuffel and W. S. Zaengl
2. High Voltage Engineering – C. L. Wadhwa
3. High Voltage Test techniques – Dieter Kind and Kurt Feser

AC Power Frequency Test on Solid Dielectric: Determination of the Flashover Characteristics of 11 kV Pin Insulator

Experiment No: 853/2

Objective:
To determine the AC power frequency surface flashover voltage of a standard 11 kV pin insulator:

1. Under dry, un-polluted condition.

2. Under wet and polluted condition.

Theory:
Pin type insulators are widely used in 11 kV overhead transmission and distribution systems to insulate the overhead conductors from the grounded transmission towers. These insulators are made of porcelain and have a high dielectric strength. The insulators are so designed that flashover along its surface takes place at a much lower voltage compared to the complete breakdown or puncture voltage of the insulating material. This is necessary because surface flashover does not cause permanent damage to the insulator, where as a puncture or breakdown of dielectric renders the insulator completely unusable. At the same time the dry as well as wet creepage lengths of the insulator is designed in such a manner so as to achieve a high surface flashover voltage. The surface flash over voltage is greatly influenced by the surface condition of the insulators. Dirt and moisture reduces the flashover voltage drastically. Thus wet and polluted insulators have significantly lower surface flashover voltage.

Test Setup:

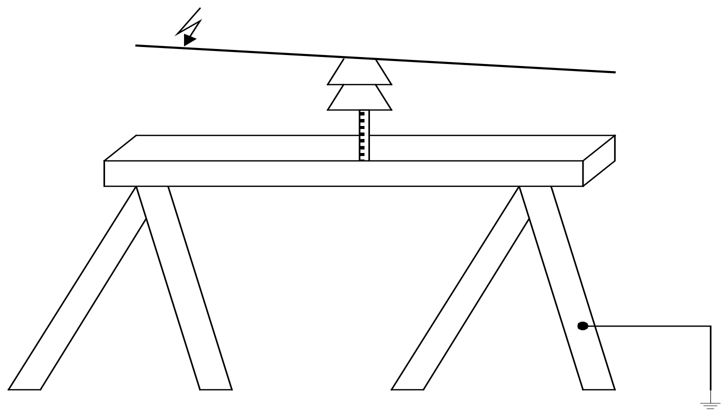
1. A.C. High Voltage Test set
2. 11 kV Pin Insulator
3. Angle Iron Frame for Mounting the Insulator
4. Short length (about 1.5 meter) of solid conductor rod
5. Flexible copper conductor for connection
6. Ground Rod for earthing.

Procedure:

A. Dry Flashover Test:

1. Wipe out the surface of the 11 kV Pin Insulator with a clean, dry cloth to remove all dirt, moisture and grease sticking to the surface of the insulator.
2. Place the Angle Iron Frame at a suitable place in the lab floor maintaining sufficient distance from other objects.

3. Mount the 11 kV Pin Insulator vertically on the Iron Frame and secure it properly by nuts and bolts as shown in the diagram.



4. Place the 1.8 meter length solid conductor on top of the insulator at right angle to the base of the iron frame and tie it with the insulator by means of copper conductor.
5. Connect the output of the AC High Voltage Test Set to one end of the solid conductor placed on top of the insulator. Ensure that the connecting live wire is at sufficient distance from all nearby grounded objects. Otherwise accidental spark over may occur.
6. Ground the Iron Frame properly by connecting the same to earth pit by copper conductor.
7. Power on the AC High Voltage test set and increase the voltage slowly until a flashover occurs over the surface of the Pin Insulator. Note down the flashover voltage.
8. Switch-off the High Voltage Test set, enter the lab floor and ground the live conductor by means of the ground rod.
9. Wipe out the surface of the insulator with a dry, clean cloth to remove any tracking mark.
10. Repeat the experiment at least three times and take the average reading as the surface flashover voltage for the insulator.

B. Wet Flashover Test:
1. Pour water on top of the pin insulator so that its surface becomes wet. Also throw some dirt on the insulator surface to pollute it.
2. Perform wet flash over test following the steps 7 & 8 described earlier (mind that wet flash over voltage shall be significantly lower compared to dry flashover voltage).
3. Repeat the experiment at least three times and take the average reading as the surface flashover voltage of the wet and polluted insulator.

Report:

1. Report the experimentally obtained surface flashover voltage for the 11 kV Pin insulator under i) dry, unpolluted condition and ii) wet, polluted condition.
2. What is dry and wet creepage length of an insulator?
3. Explain why it is necessary to place the 1.8 meter length solid conductor over the insulator.

Reference:

1. High Voltage Engineering Fundamentals – E. Kuffel and W. S. Zaengl
2. High Voltage Engineering – C. L. Wadhwa
3. High Voltage Test techniques – Dieter Kind and Kurt Feser

Studies on the characteristics of Lightning Impulse Voltages

Experiment No. 853/3

Objective:

i. To get familiarized with standard Impulse wave shapes and their mathematical representation.
ii. To study equivalent circuits for production of impulse wave shapes in the laboratory.
iii. To simulate electronic circuits for production of shapes and peak values

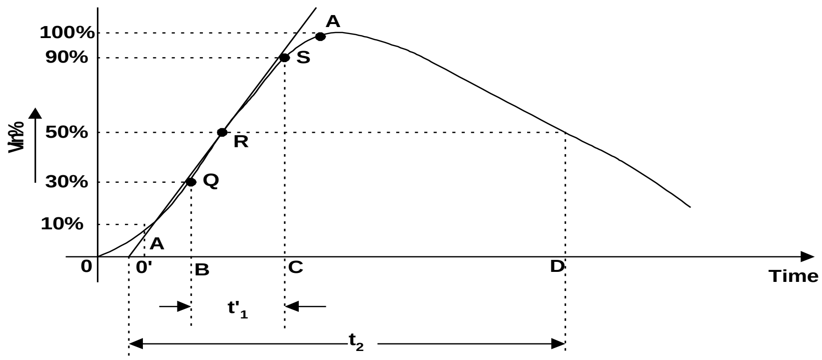
Theory:

Standard Impulse wave shape
Impulse waves are typically characterized by a very first rising wave front, and a relatively slower fall or wav
µsec-10 µsec, and decay on fall time (up to 50% of their peak value) in the range 20 µsec- 200 µsec. The waves are generally unidirectional and can often be represented as double exponential wave shape

(1)

where α and β are constant.

For 1.2/50 μ sec. of unity magnitude $\alpha = -0.0146$, $\beta = -2.467$ and $V_o = 1.04$, when t is expressed μsec, α and β control front and tail time of the wave. A typical lighting impulse voltage wave shape is illustrated in fig.1



Front and Tail time of impulse wave

When impulse wave shapes are recorded in a CRO, the initial portion of the wave may not be clearly recorded all the times or may even be missing. Thus, for an impulse wave, Rise Time (or Front Time) and Fall Time or (Tail Time) are often redefined in the following way:
The peak of the impulse (point A in Fig. 1) is first located and is referred to as 100% or peak value of the wave. The points corresponding to 10% and 90% of the peak values (P and S respectively in the fig.1) are located on the impulse and joining these two points are extended to cut the time Axis at O'. O' is called Virtual origin of the recorded impulse.

The front time is calculated as:

T1 = 1.25 x (time interval to reach from 10% to 90% of peak value)
= 1.25 x [O'C – O'A] (2)

If the point corresponding to 10% is not clearly visible, in that case, 30% and 90% points are chosen, and front time is defined as:

T1 = 1.67 x [Time interval to reach from 30% to 90% of peak value]
= 1.67x [O'C – O'B] (3)

Tail time is defined as the time taken by the wave to fall to 50% of peak value measured from virtual origin.

Thus tail time, T2 = O'D (4)

The tolerances allowed on front and tail times are ± 30% and ± 20% respectively. Tolerance on the peak value is ± 5%.

Production of Impulse Waves

In the high voltage laboratories, impulse voltage generated by multi stage impulse generators called many generators. The basic operating principle and characteristics of impulse generators can be explained by the simple equivalent circuit fig. 2 & fig. 3.

The capacitor C1 previously charged to a particular d.c. voltage is suddenly discharged into the wave shaping network formed by R1, R2 and C2. Analysis of the network in Fig.2 gives output waveform:

$$V_o(t) = \frac{V}{R_1 C_2 (\alpha - \beta)} \left[e^{-\alpha t} - e^{-\beta t} \right] \qquad (5)$$

Where, $\alpha \approx 1/R_1C_2$ and $\beta \approx 1/R_2C_1$

Output of the circuit of Fig. 3 is obtained as:

$$V_o(t) = \frac{V C_1 R_2 \alpha \beta}{(\beta - \alpha)} \left[e^{-\alpha t} - e^{-\beta t} \right] \qquad (6)$$

Control of wave shapes:

Generally, the generator capacitor C1 and output capacitor C2, are fixed by design constraints of the generator and characteristics of the test object. Hence the desired wave shape is obtained primarily by adjusting R1 and R2.

The approximate values of front and tail time can be analytically obtained as:

(7)

and,

$$T_2 = 0.7 (R_1 + R_2) (C_1 + C_2) \qquad (8)$$

Procedure:

1. Simulate the equivalent circuit of an impulse generator shown in fig. 2 using any standard circuit simulation software package like PSpice / EMTP etc.
2. Consider, equivalent generator capacitor C1=0.02 µsec, equivalent load capacitor C2=1000pF, and charging voltage V=100 kv.
3. Theoretically compute the values of series resistance (charging resistance) R_1 and damping resistance (discharge resistance) R_2 needed to produce 1.2/50 µsec impulse wave using formula (7) & (8).
4. Use the compute values of R1, R2 and given values of C1& C2 in your simulation. Run your simulation and Study the waveform generated by the equivalent circuit. Check whether the actual wave form is a 1.2/50 µsec impulse or not.
5. Repeat the above experiment to produce a 10/100 µsec. impulse wave shape.

Report:

1. Vary R_1 and R_2 independently (one at a time, while the other one is kept constant at base value corresponding to 1.2/50 µsec wave) within the range of ±10% in steps of 2.5% of their base value. Analyse how Front and Tail time of the wave respond to variation of R_1 and R_2.
2. Plot various wave shapes on the same graph corresponding to different values of R_1 (while R_2 kept constant).
3. Plot different wave shapes corresponding to various values of R_2 on another graph (while R_1 is kept constant).
4. Comment on which one of the two resistors primarily control front and tail time of the waveforms. Justify your observations by theoretical explanation.

Reference:

1. High Voltage Engineering Fundamentals – E. Kuffel and W. S. Zaengl
2. High Voltage Engineering – C. L. Wadhwa
3. High Voltage Test techniques – Dieter Kind and Kurt Feser