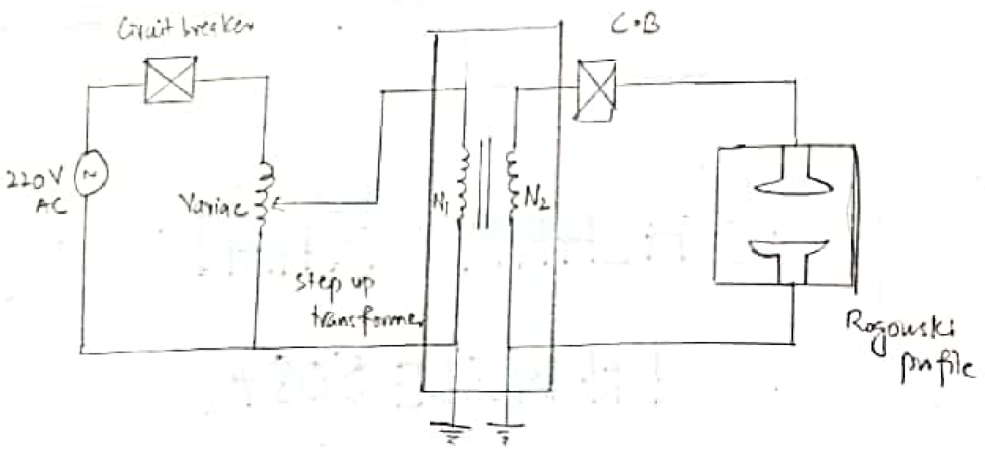
Circuit diagram



Experiment 1

To study the breakdown voltage (BDV) characteristics of uniform field gap under HVAC using rogowski profile.

Apparatus

- 220 V AC supply.
- Rogowski profile.
- HVAC test set.
- step up transformer.
- Scales of different widths.

Objective

- To find the relationship b/w voltage and gap separation for air insulation using rogowski electrodes.
- To find out the behaviour of uniform electric field and its affect on air insulation.

Theory

$$d_n \propto n\,dx$$

$$I = I_0 e^{\alpha d}$$

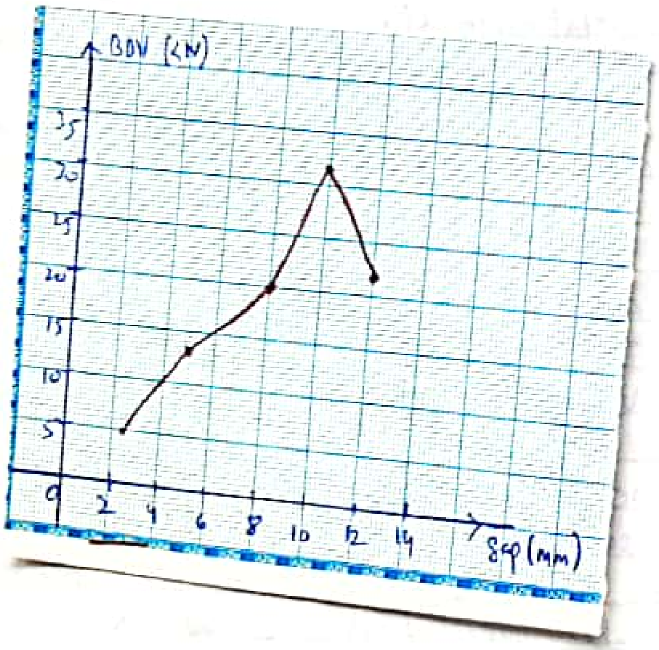
$$V = V_0 e^{\alpha d}$$

Procedure

- Set up the separation b/w the rogowski profile.
- Supply AC source to HVAC test. It steps up voltage using step up transformer maximum upto 60 kV safely when connected in series and upto 30 kV when connected in parallel.

Observations:

Sr No	Gap length (mm)	BDV (kV)
1	2.5	5
2	5	13
3	8	20
4	10	32
5	12	22



- Turn on HVAC set and keep peddle of the set pressed with a foot till end of the experiment.
- Now start varying voltage across rogowski profile using variac.
- Note the voltage at which spark appears and the rogowski profile is short circuited.
- Bring all values of HVAC set to zero before taking further readings.
- Use discharge rod to ground the remnant charges.
- Perform this experiment again for different values of gap separation b/w electrodes.

Conclusion

We can observe that at start there is a linear relationship b/w BDV and gap separation i.e air breakdown at high voltage as separation b/w electrodes increases but the last two readings shows abnormal behaviour b/c air surrounding the electrodes has already been ionized to some extent.

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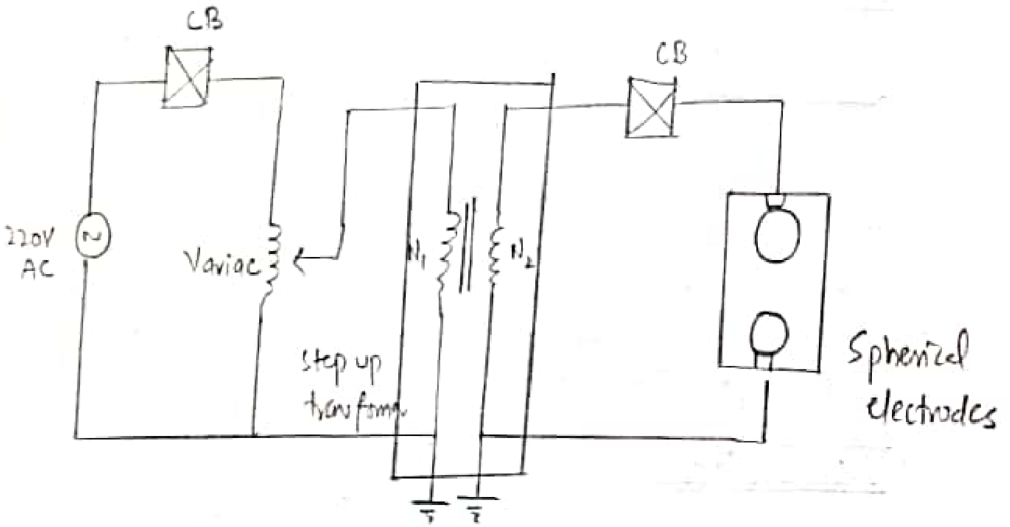
Circuit Diagram



Experiment 2

To study BDV characteristics of uniform field gap under HVAC using spherical electrodes

Apparatus

- HVAC test set.
- Spherical electrodes.
- Discharge rod.
- 220 V AC supply main.
- Connecting wires.

Objective

- To study the uniform electric field generated by spherical electrodes.
- To study the BDV characteristics of air (gaseous insulation) in uniform field gap.

Theory

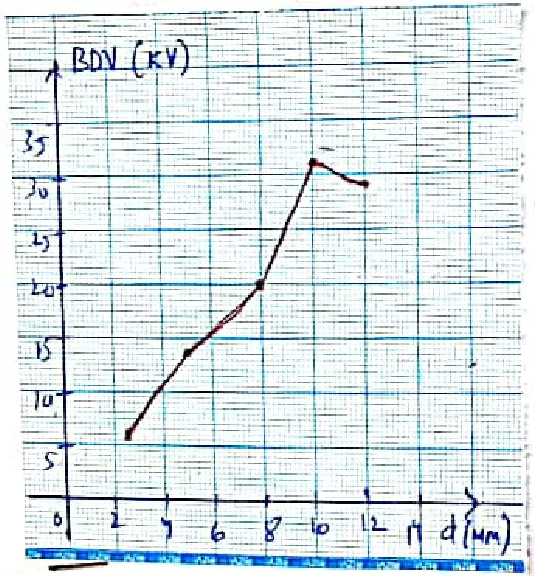
$$dn \propto n\,dx$$
$$I = I_0 e^{\alpha d}$$
$$V = V_0 e^{\alpha d}$$

Procedure

- Make the connections as shown in circuit diagram.
- Adjust the gap distance through proper scale.
- Connect HVAC test set to 220V AC main.
- Turn on the HVAC test set, push the pedal and keep pressing the button at the top left corner.
- Apply the voltage in HVAC test set by slowly

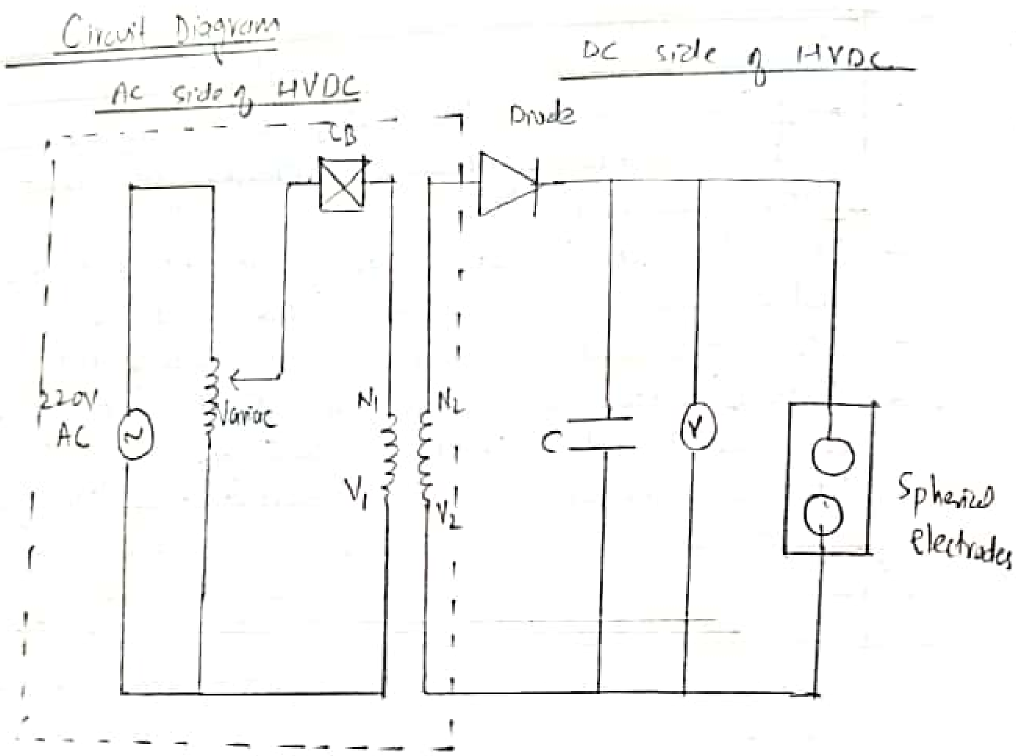
Observations

Sr No	Gap length (mm)	BDV (KV)
1	2.5	5.6
2	5	13
3	8	20
4	10	32
5	12	29



rotating the knob across electrodes.

- keep on increasing the voltage untill a spark occurs b/w the spherical electrodes and short circuit occurs b/w them.
- Note down the value of voltage at the short circuit condition using voltmeter on HVAC test set.
- De energize the apparatus through discharge rod
- Repeat the experiment for different values of gap length and breakdown voltage.
- Dielectric strength can be calculated by dividing voltage over gap length.



Experiment 3

To study the BDV characteristics of uniform field gap under HVDC test set using spherical electrodes.

Apparatus

- AC supply.
- HVDC test set.
- Spherical electrodes
- Earthing rod
- Scales of different widths

Theory

$$dn \propto n\,dx$$

$$I = I_0 e^{\alpha d}$$

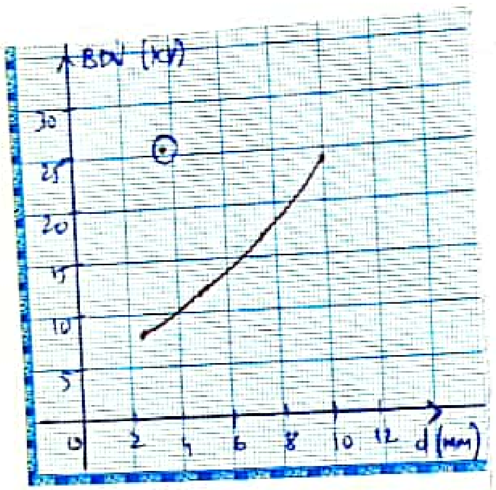
$$V = V_0 e^{\alpha d}$$

Procedure

- Supply 220V to HVDC test set which will step up the voltage using step up transformer and convert it into DC using rectifier arrangements.
- Measure the gap separation b/w electrodes.
- Start increasing the voltage.
- Note down the voltage at which spark appears, indicating the breakdown of air.
- Repeat the experiment for different gap separations.
- Note down and observe the trend of voltage against gap separation.

Observations

Sr. No	Gap separation (mm)	BDV (kV)
1	2.5	7.5
2	5	12.75
3	7.5	17.4
4	3	25.2
5	10	24.6

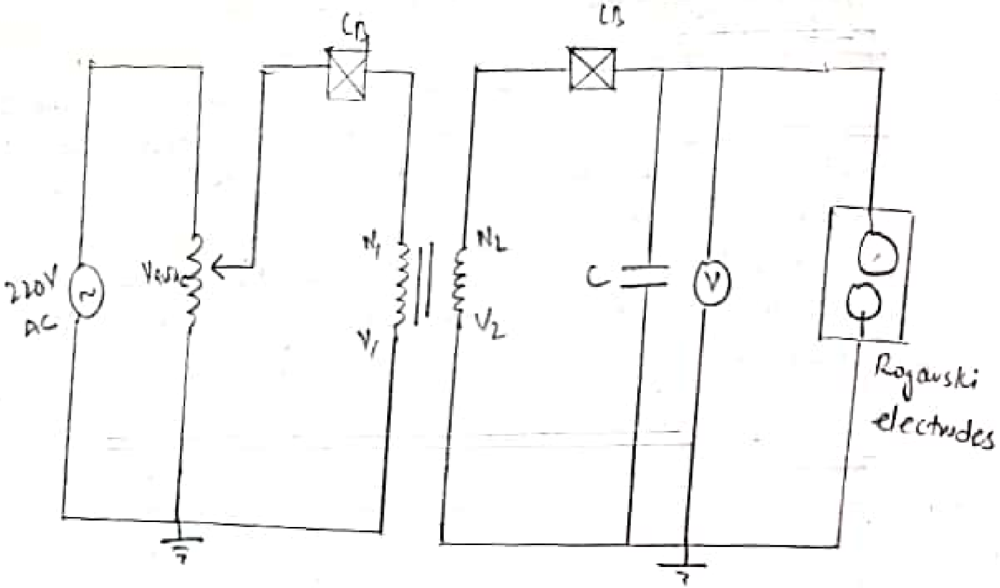


- Ground the apparatus using earthing rod.

Conclusion

Ideally for HVDC set the breakdown of air should achieve early as compared to HVAC test set but due to environmental condition it deviates from ideal values.
Instead of quick as for DC, the graph is also non linear and irregular showing the values for BDV set for real time scenarios.

Circuit Diagram



Experiment 4

To Study the BDV characteristics of uniform field gap under HVDC test using rogowski profile.

Apparatus

- AC supply.
- HVDC test set.
- Rogowski profile.
- Earthing rod.
- Scales of different width.

Procedure

- HVDC set is energized with 220V AC.
- After measuring the gap separation b/w the electrodes, start increasing the voltage with the help of control knob.
- Note down the voltage at which spark appeared across the air gap indicating the breakdown.
- Before taking another reading, equipment should be de energized through discharge rod.
- Repeat the same procedure for different gap separation.

Conclusion

Ideally for HVDC, the breakdown of air should achieve early as compared to HVAC but due to errors and unavoidable environmental conditions, values

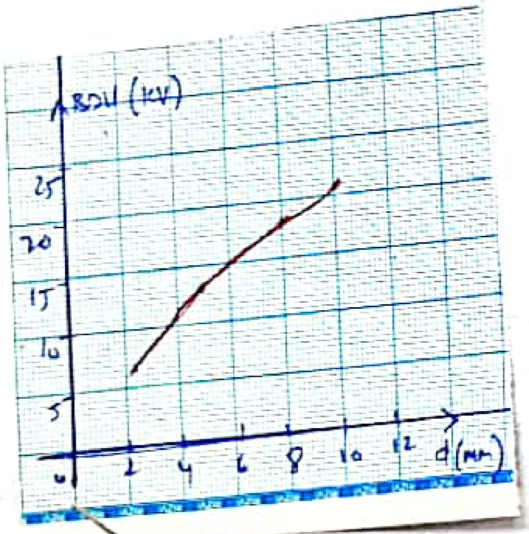
Observations

Sr No	Gap separation (mm)	BDV (kV)	Breakdown strength = V/d
1	2.5	7.2	7.2/0.25 cm = 28.kV/cm
2	5	13.2	13.2/0.5cm = 26.4 kV/cm
3	8	18.6	18.6/0.08 cm = 23.2 kV/cm
4	10	20.4	20.4/0.1cm = 20.4 kV/cm

Average breakdown strength =

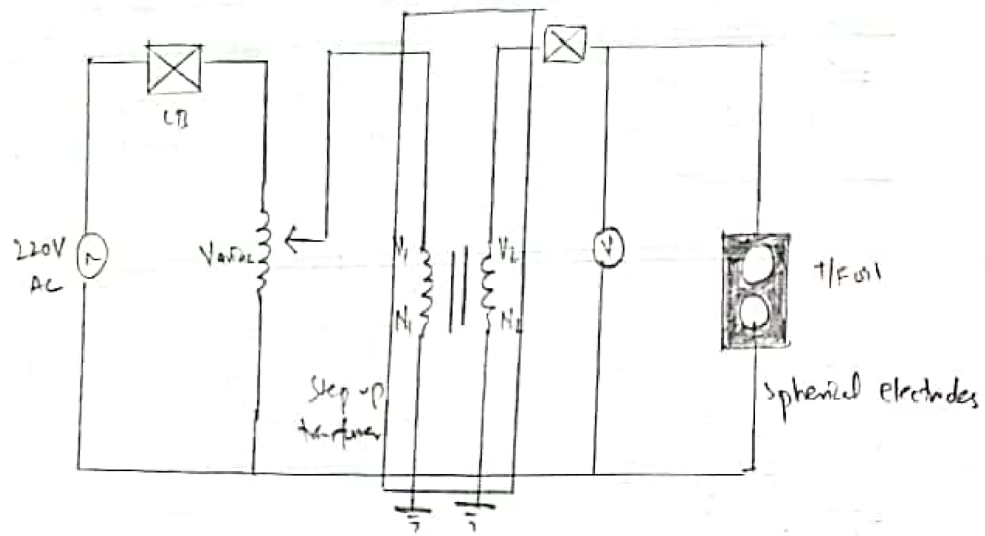
$$\frac{28.5 + 26.4 + 23.2 + 20.4}{4}$$

= 24.7 kV/cm



deviate from ideal situations. The value obtained here is 24.7 kV/cm which is slightly greater than breakdown strength of air ie 21.1 kV/cm. This difference is due to the laboratory's environmental conditions.

Circuit Diagram



Experiment 5

To study breakdown voltage characteristics of liquid insulation (Transformer oil).

Apparatus

- 220V AC supply.
- Portable transformer oil test set.
- Spherical electrodes.
- Transformer oil.
- Earthing rod.

Theory

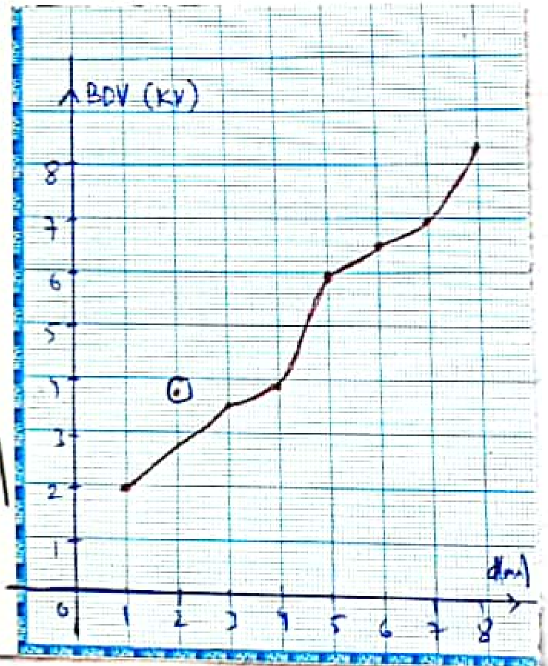
BDV is the maximum voltage an insulator can withstand without allowing any current flow through it.
BDV of liquids is higher compared to gases.

Procedure

- Make the connection according to the circuit diagram.
- Set the gap separation b/w the electrodes with the help of screw gauge.
- Turn on the supply.
- Gradually increase the supply voltage with the help of variac unless the breakdown of the oil occurs which can be observed by the formation of sparks b/w the electrodes.
- Note the value of voltage at which breakdown occured.

Observations

Sr No	Gap separation (mm)	BDV (kV)
1	1	2
2	2	3.8
3	3	3.5
4	4	3.8
5	5	6
6	6	6.5
7	7	7
8	8	8.3

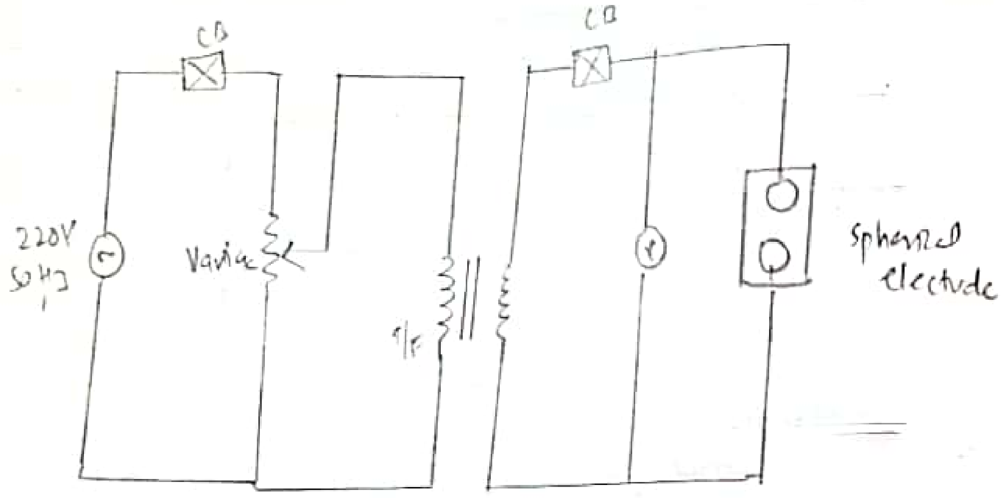


- Bring the variac to zero position.
- Turn off the supply.
- Discharge the apparatus with earthing rod.
- Repeat the experiment to obtain 5 set of readings.
- Plot a graph b/w the BDV and the gap separation to observe the trend of breakdown of transformer oil.

Conclusion

Liquids have higher breakdown voltages compared to gases. Due to multiple breakdown tests of transformer oil, it may loose its dielectric properties and might not give the expected values. Due to presence of impurities, transformer oil may breakdown at lower voltages.

Circuit diagram



Observations

Sr No.	Gap Separation	BDV (kV)
1	8 Stacks of paper	4.5
2	12 Stacks of paper	10
3	16 Stacks of paper	11
4	PVC	20

Experiment 6

To study BDV characteristics of solid insulation under HVAC using spherical electrodes.

Apparatus

- AC supply (220V, 50 Hz)
- Spherical electrode.
- HVAC test set.
- Solids (PVC, paper stacks)
- Earthing rod.

Theory

Solids have higher breakdown strengths than liquids and gases. The Breakdown strength of solids is not recoverable.
Typically it is in the order of 10 MV/cm referred to as intrinsic breakdown strength.

Procedure

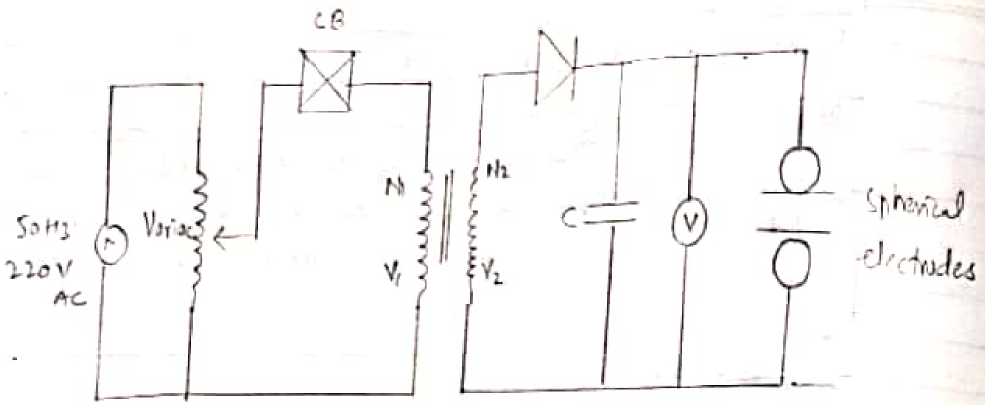
- Make the connections as shown in the circuit diagram.
- Place the solid insulator b/w spherical electrodes.
- Turn on 220V, 50 Hz AC power.
- Turn on the HVAC test set.
- Gradually increase the voltage by rotating the knob on the HVAC test set.
- The voltage at which spark occurs b/w the electrodes shows the breakdown of solid, note down the value of breakdown voltage.

- Bring back the knob to its zero position and turn off the HVAC test set.
- Discharge the test set using earthing rod.
- Repeat the experiment for different samples of solid insulator and note down their respective values breakdown.

Conclusion

It can be concluded that different solid insulators have different values of breakdown voltage. Also, when the thickness of same solid insulator increases, the value of BDV also increases.

Circuit Diagram



Observations

Sr No	gap separation	BDV (kV)
1	1 stack	4-8
2	2 stacks	4-8
3	4 stacks	13-5

Experiment 7

To study the BDV characteristics of solid of uniform gap separation under HVDC test using spherical electrodes.

Apparatus

- AC source
- Spherical electrodes.
- HVDC test.
- Solid insulator.
- Earthing rod.

Procedure

- Make connections according to the circuit diagram.
- Applying AC voltage to the HVDC set that converts AC high DC (0 to 30kV).
- Putting stack of papers in b/w spherical electrodes to note the breakdown voltage.
- Repeat it by increasing the number of stacks and note down the values of breakdown.
- Increase the o/p voltage with the help of variac.
- Sparks will be observed at the BDV b/w the electrodes.
- After each reading, properly discharge the spherical electrodes by using earthing rod. For discharging, first switch off the HVDC set.
- Repeat same procedure for different solid insulators.

Conclusion

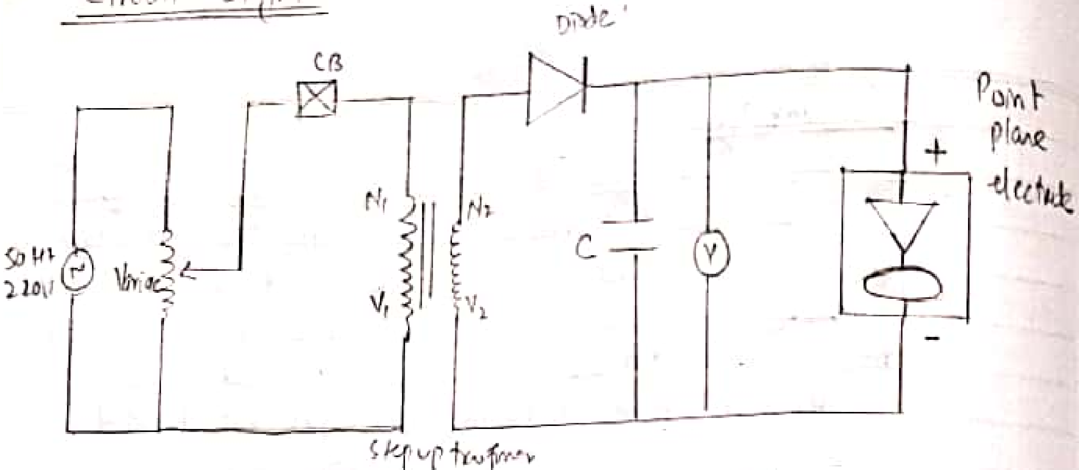
BDV in solids increases with increase in width of solid material used. At the breakdown stage, a hissing sound is produced and after it within a few seconds spark is generated which indicates that breakdown has occurred.

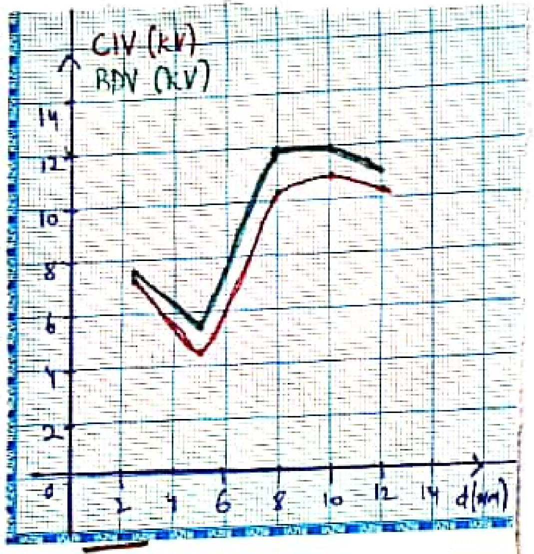
BDV of solid is higher than gas and liquid insulator achieved at very high voltage as compared to liquid and gas.

The BDV of solid is non recoverable.

Positive point Corona

Circuit Diagram





Observations

S.No	Gap (mm) separation	CIV (kV)	BDV (kV)
1	2.5	7.2	7.5
2	5	4.2	5.1
3	8	10.5	12
4	10	10.8	12
5	12	10.5	10.8

Experiment 8

To study the BDV characteristics of air in non uniform electric field (positive and negative corona) under HVDC.

Apparatus

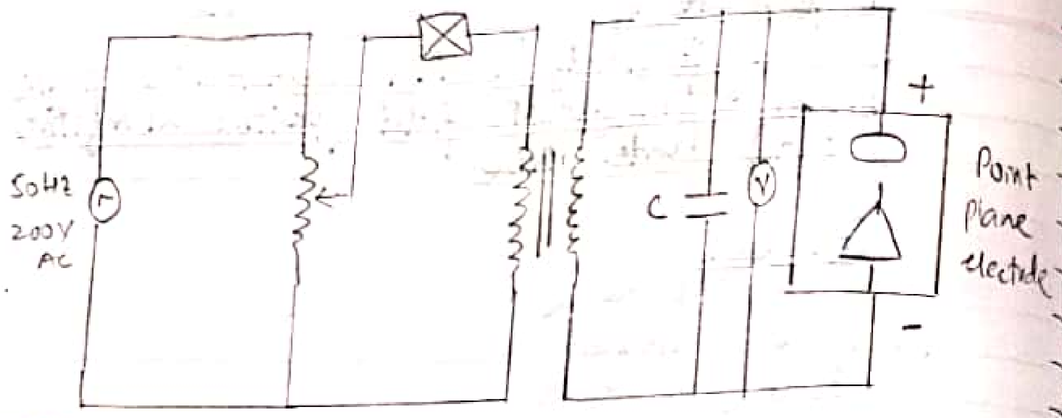
- AC supply source.
- HVDC test set.
- Point plane electrode.
- Earthing rod.

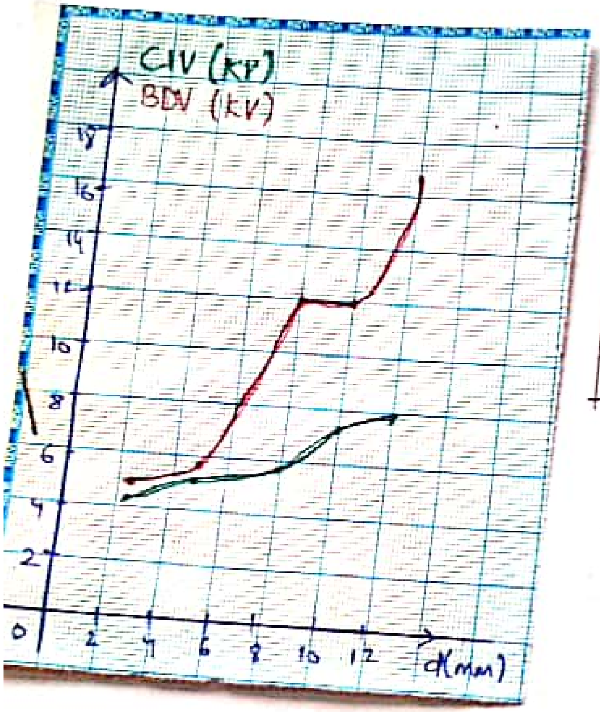
Theory

Corona is partial breakdown of air that occurs due to non uniform electric field. Corona is a luminous, audible discharge of air when there is an excessive localized electric field gradient upon an object that causes the ionization of air adjacent to this point. Corona discharge usually forms at highly curved regions such as sharp corners, projecting points, edges of metal surfaces or smaller diameter wires. There are two types of corona. Positive point corona occurs when the point electrode is connected to positive terminal of power supply w.r.t the other electrode. Negative point corona occurs when the point electrode is connected with negative terminal of power supply w.r.t other electrode.

Negative point Corona

Circuit diagram





Observations

Sr No	d(mm)	CIV (kV)	BDV (kV)
1	2.5	4.2	4.8
2	5	4.8	5.7
3	8	5.7	12
4	10	7.2	12
5	12	7.8	16.8

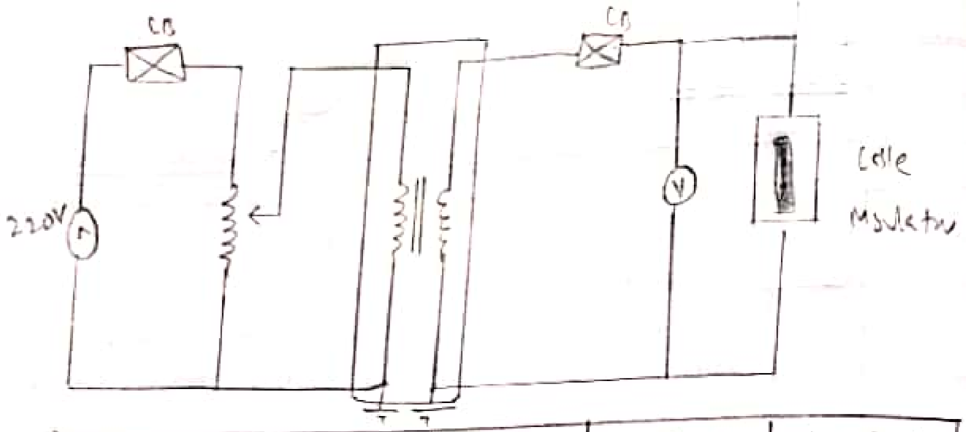
Procedure

- Make the connections according to the circuit diagram.
- Supply AC source to HVDC set. It is step up by step up transformer and is converted to DC through rectifier arrangement.
- Increase the supply voltage slowly and gradually through variac untill we hear a hissing sound, which is audible corona.
- Observe the voltage at which the spark occurs, that is corona inception voltage (CIV). Note down the value of CIV which is achieved.
- Keep on increasing supply voltage through variac untill BDV is observed at which complete breakdown of air occurs. Note down the values.
- Repeat the experiment for different values of gap separation and note down the values of CIV and BDV.
- Ground the nominal charges by using earthing rod after each reading.

Conclusion

The -ve and +ve point corona is only generated when non uniform electric field is applied across the electrodes. CIV has no sharp value due to environmental conditions. BDV increases with gap separation but due to ionization of surrounding air, the BDV is achieved at low voltages as compared to theoretical values.

Circuit diagram



Nominal system line voltage (kV)	Insulation class	AC factory test (kV)	Max field applied AC test	Max field applied DC test
1.20	1.20	10.00	6.00 kV	8.50 kV
2.40	2.50	15.00	9.00	12.70
4.80	5.00	19.00	11.40	16.10
8.32	8.70	26.00	15.60	22.10
14.40	15.00	34.00	20.40	28.80
18.00	18.00	40.00	24.00	33.90
25.50	25.0	50.00	30.00	42.40
34.50	35.00	70.00	42.00	59.40
46.00	46.00	95.00	57.00	80.60
69.00	69.0	140.00	84.00	118.80

Experiment 9

Testing of Cable Insulation

Apparatus

- 220V AC supply.
- HV AC test set.
- Cable insulator.
- Earthing rod.

Theory

Dielectric strength is the maximum voltage that can be applied to a given material without causing it to breakdown, usually expressed in volts or kilovolts per unit of the thickness.

Breakdown voltage of an insulator is the minimum voltage that causes a portion of insulator to become electrically conductive.

A test is performed called as 2 minute 2 kV test. It is known as terminal testing, voltage test gauge measure and current measurer.

Procedure

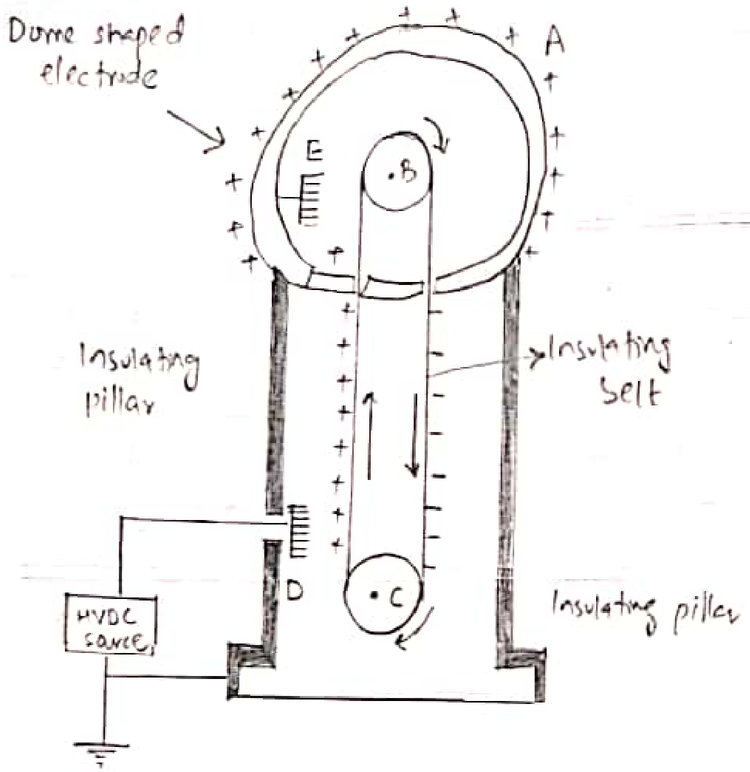
- Make the circuit according to the diagram.
- Apply AC voltage to HV AC test set.
- Set the timer initially at 2 minutes.
- Connect the positive terminal of the tester to the conductor and the negative terminal to the insulator.
- Rotate the knob of the test set slowly and finally

set it to 2 kV.

- After 2 minutes is set up, an alarm will ring which indicates that voltage test is passed.
- This experiment is repeated for different types of insulation.

Conclusion

Testing is in b/w insulation of cable and conductor so insulation must not damage during the testing otherwise cable is not safe for any commercial purpose or home appliances because it cannot sustain maximum voltage this damage the cable as well as the appliance.



Van De Graff generator HVDC source

Experiment 10

To produce high electro static charge using VAN DE GRAFF generator.

Apparatus

- HVDC source (10 kV – 30 kV)
- Van De Graff generator.
- Discharge rod.

Theory

A Van De Graff generator is an electrostatic generator which uses a moving belt and accumulates electric charge on a hollow metal globe on the top of an insulated column, creating very high electric potentials. It produces very high HVDC electricity at low current levels. The potential difference achieved by modern Van De Graff generators can be as much as 5 MV. The VDG generator was developed as a particle accelerator for physics research, its high potential is used to accelerate subatomic particles to great speeds in an evacuated tube.

Procedure

- Connect the components as shown in circuit diagram.
- VDG generator consists of large hollow metallic dome and an insulated belt run by two pulley.
- The upper pulley is idle and the lower pulley is ~~the~~ driven by electric motor.

- At the top and bottom of the column are two electrodes E_1 and E_2 which terminate in row of sharply pointed corona combs.
- At lower electrode, high voltage is applied w.r.t earth by a HVDC source.
- At the tip of E_1, the electric field becomes very high which ionize the air thus injected positive ions.
- These ions are sprayed from E1 to moving belt at E2.
- These charges are removed by another row of corona points.
- Thus the +ve charge carried by the belt induces -ve charge on the point at E2 and thus +ve charge is transferred to the metallic sphere through which E_2 is connected and the charge gradually increase as the belt goes around the upper and lower pulley.
- The charge transfer on the metallic sphere increases its potential w.r.t earth.
- As the process of charging continues a very high potential difference is created b/w the metallic sphere and the earth of the order of megavolts.
- This high potential difference when applied across a spark gap may cause breakdown under favorable condition.

Mathematical equation

As we know that voltage depends upon current and resistance.

$$V = IR$$

The resistance R is in order of 10^{12} ohms. The current I depend upon the velocity of the belt, current density and width of the belt.

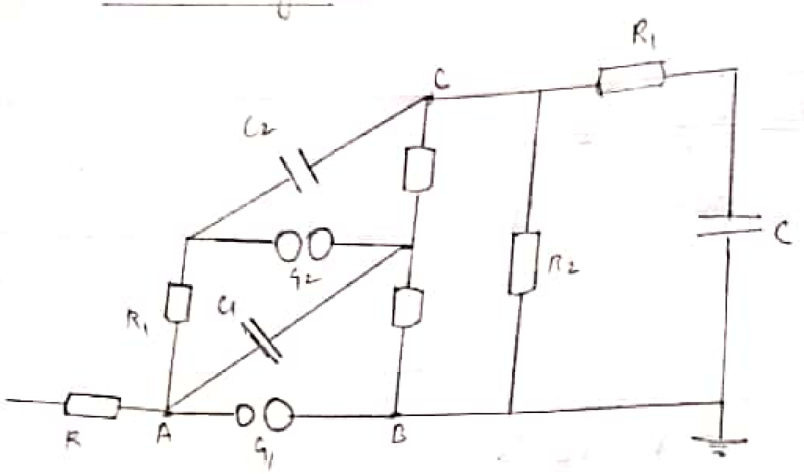
$$V = vb\sigma R$$

$v \rightarrow$ speed of belt.
$b \rightarrow$ width of belt
$\sigma \rightarrow$ current density.

Conclusion

we see that charge is gradually increased on metallic sphere wrt earth as the belt goes around the upper and lower pulley.

Circuit diagram



Observations

220 V = 100 kV ⇒ 1 V = 0.45 kV

Input voltage (V)	output voltage (kV)
50	22.5
55	25

Experiment 11

To study multi stage impulse generator.

Apparatus

- HVAC test set.
- HVDC set.
- Discharge rod.
- Two stage impulse generator.
- Impulse test control unit
- Connecting wires.

Objectives

- To generate impulse voltage for testing insulation.
- To study breakdown of air by applying impulse voltage.

Theory

An impulse generator is an electrical apparatus which produces impulse voltages which is a unidirectional voltage that rapidly rises to a peak value and then gradually decays to zero. Most transient overvoltages encountered in power system due to lightning and switching surges are impulsive in nature. For most testing purpose specifications, the term impulse spark over voltage, impulse withstand voltage and basic impulse level is employed. The standard wave shape is 1.2 by 50 μs wave reaching peak value in approximately 1.2 μs and decaying to 50% of peak value in 50 μs from the beginning of the wave

Procedure

- First make connections according to the circuit diagram.
- Switch on the AC supply which is stepped up to given HVAC.
- Convert HVAC to HVDC then supply to impulse generator.
- The capacitor starts ~~discharging~~ charging through resistor and when we close the spark gaps manually through control unit, an impulse voltage is appeared across air gap which results in short circuit of an insulation.

Mathematical form

output voltage; $E = nE_0$

output energy; $E_0 = \frac{1}{2} CV^2$

Conclusion

Using two stage impulse generator we can generate twice the impulse voltage at output. High impulse voltages are used to test the strength of electrical power equipped against lightning and switching surges.

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