"Study of Corona Discharge and AC Breakdown Voltage for Different Electrode-Gap Geometry"

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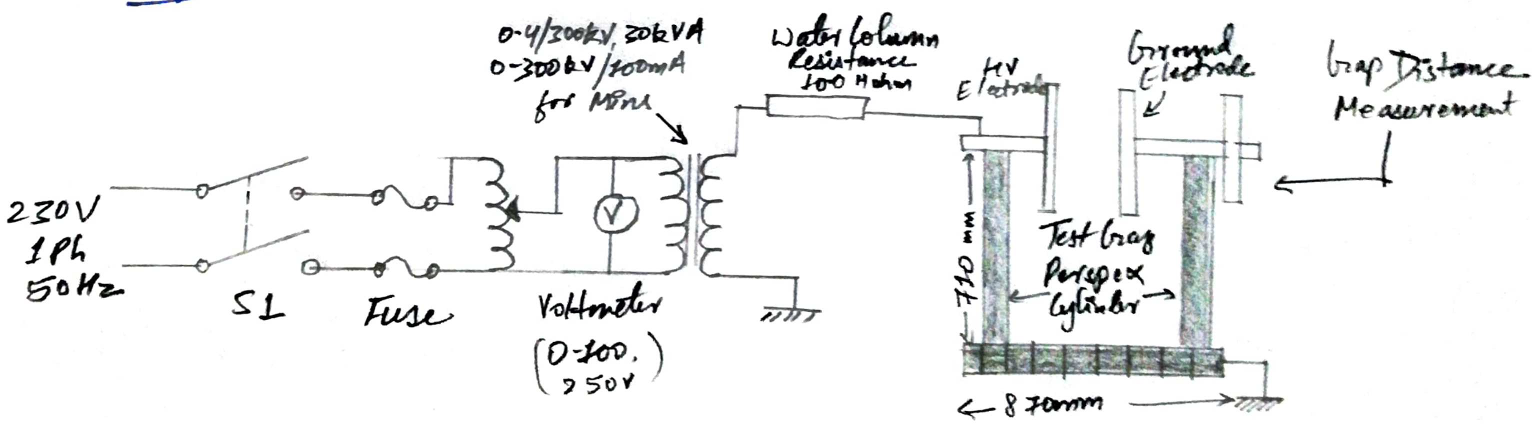
OBJECTIVES:

1. Breakdown studies of uniform field and non-uniform field gaps under AC excitation
   - Point Plane (non-uniform field gap) and
   - Sphere-Sphere (nearly uniform field gap)
2. Observation of Corona Inception and Corona Extinction Voltage

Experimental Setup:



Schematic for Experimental Setup

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OBSERVATION TABLE:

(a) Point-Plane Electrode

Sr. No.	Gap Distance (mm)	Corona Inception Voltage (kV)	Visible Corona Inception Volt (kV)	Corona ~~Incept~~ Extinction Voltage (kV)	BDV (kV)
1	10	-	-	-	4
2	20	8	11	5	13
3	30	10	14	6	19
4	40	11	17	9	21
5	50	12	18	10	24

(b) Sphere-Sphere Electrode

Sr. No.	Gap Distance (mm)	Corona Inception Voltage (kV)	Visible Corona Inception Volt (kV)	Corona Extinction Voltage (kV)	BDV (kV)
1	10	-	-	-	5
2	20	20	-	-	17
3	30	34	-	27	36
4	40	35	-	30	50
5	50	40	-	32	63

Temperature & Humidity Measurement

Dry Bulb Temp: 33°C

Wet Bulb Temp: 30°C

Atmospheric Pressure: 755 mm Hg

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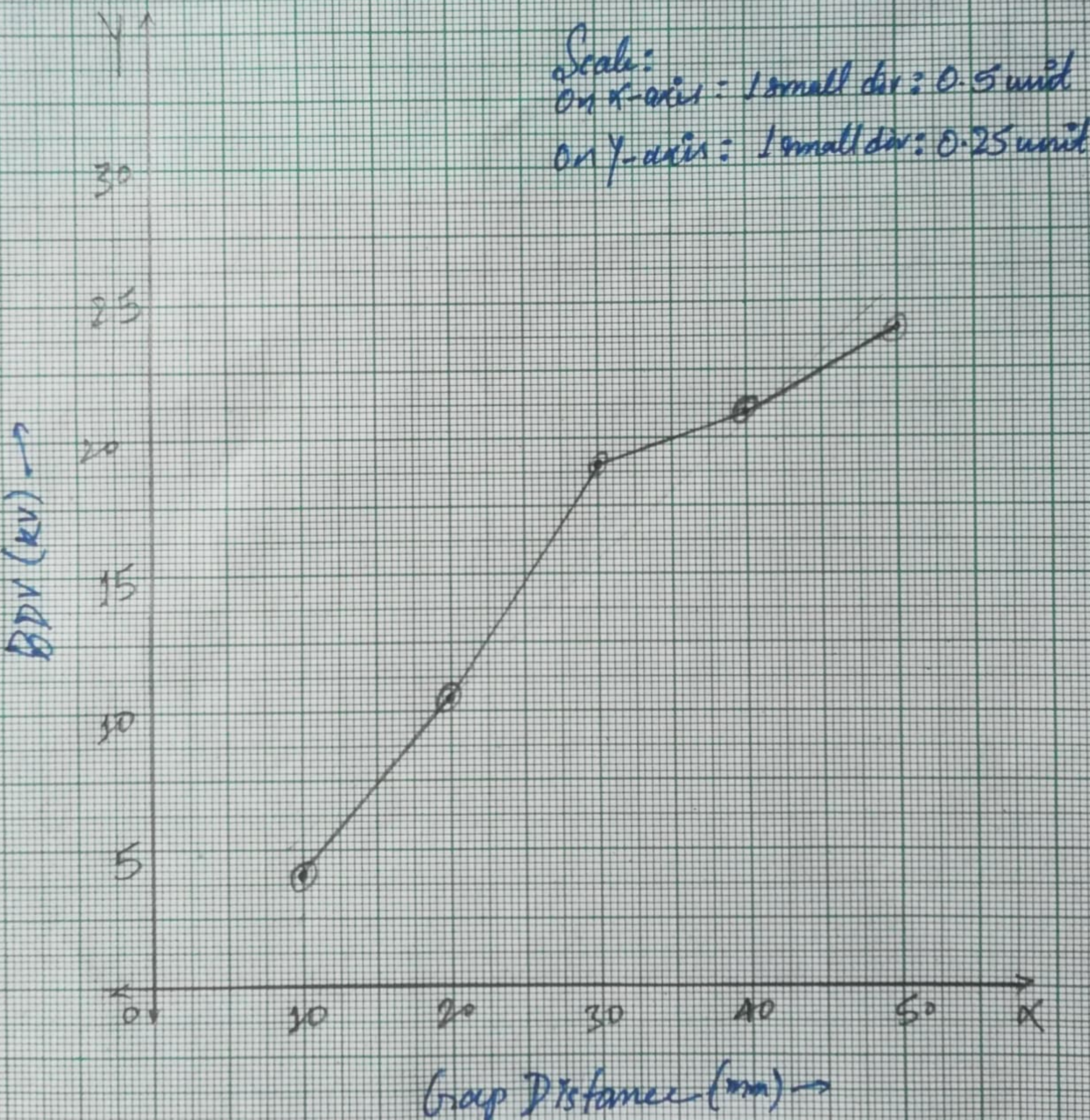
BDV vs Gap Distance (Point-Plane Electrode)



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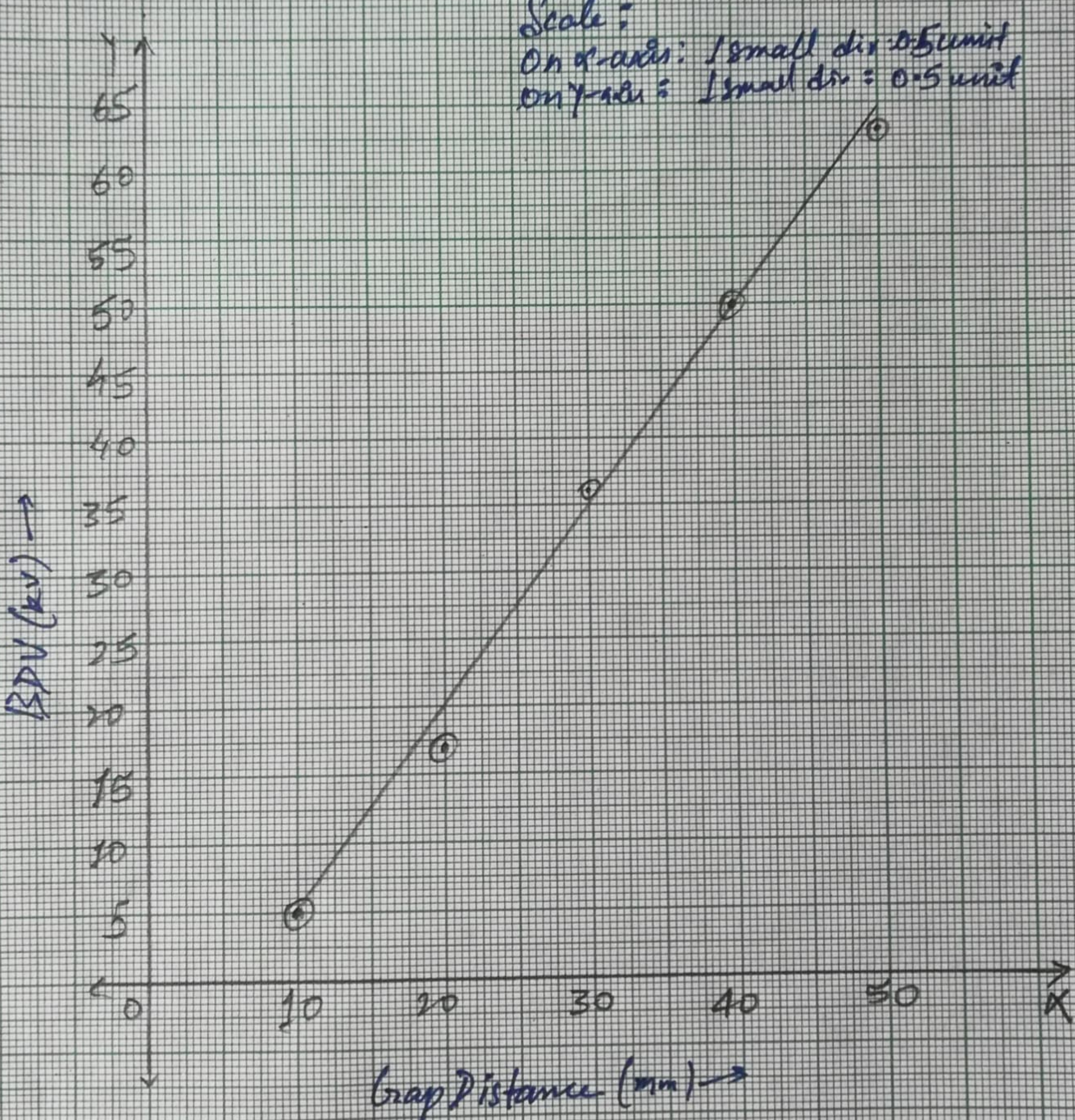
BDV vs Gap Distance (Sphere-Sphere Electrode)



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Calculations :

Air density correction factor : $k_1 = \frac{P}{P_0}\left(\frac{273+t_0}{273+t}\right)$

$$P = \frac{1.013\times10^5}{760}\times(1 - 1.8\times10^{-4}\times t)\times(\text{Mercury height in mm})$$

$$= \frac{1.013\times10^5}{760}\times755(1-1.8\times10^{-4}\times33)$$

$$\boxed{P = 1.00357\times10^5\ Pa}$$

$t_0 = 20^\circ C \qquad P_0 = 1.013\times10^5\ Pa$

$$k_1 = \frac{1.00357\times10^5}{1.013\times10^5}\times\left(\frac{273+20}{273+33}\right) = 0.94522$$

Dry Bulb Lamp Temp :- $33^\circ C$
Wet Bulb Lamp Temp :- $30^\circ C$
Relative humidity = 80.2

Absolute Humidity at 755 mmHg and $33^\circ C$
$= 28.56\ g/m^3$

k (Humidity Correction factor) for ac voltage from the graph given in manual,
$\simeq 0.83$

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(a) Point - Plane Electrode

$k_d = k_t = 0.94522$

$k_h = (k)^1 = 0.83$

~~Vactual~~ ~~Vapp~~ $V_{actual} = \frac{V_{measured}}{k_d/k_h} = 0.88\, V_{measured}$

(b) Sphere - Sphere Electrode

$k_d = k_t = 0.94522$

$k_h = (k)^0 = 1$

$V_{actual} = \frac{V_{measured}}{k_d/k_h} = 1.057\, V_{measured}$

Corrected Observation Table:

(a) Point - Plane Electrode:

Sr. No.	Gap Distance (mm)	Corona Inception Voltage (kV)	Visible Corona Inception Volt (kV)	Corona Extinction Voltage (kV)	BDV (kV)
1	10	-	-	-	3.52
2	20	7.04	9.68	4.4	11.44
3	30	8.8	12.32	5.28	16.72
4	40	9.68	14.96	7.92	18.48
5	50	10.56	15.84	8.8	21.12

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(b) Sphere-Sphere Electrode

Sr. No.	Gap Distance (mm)	Corona Inception Voltage (kV)	Visible Corona Inception Voltage (kV)	Corona Extinction Volt (kV)	BDV (kV)
1	10	-	-	-	5.285
2	20	21.14	-	-	17.97
3	30	35.938	-	28.539	38.05
4	40	36.995	-	31.71	52.85
5	50	42.28	-	33.824	66.59

ANSWER THE FOLLOWING QUESTIONS:

1. Why no humidity correction for Sphere-Sphere gap?

→ from the observation table data of Sphere-Sphere gap Breakdown Voltage, it is evident that the breakdown voltage changes linearly with gap spacings over short ranges. Also the effect of humidity for such low gap is around 0.3% change in Breakdown voltage per 1gm/m³. Also breakdown voltage erratically changes in case of highly humid atmosphere and large gap between spheres.

In normal use of spheres, surface becomes rough. The surface should be rubbed with ~~high~~ fine abbrassive paper and resulting dust, oil or grease is removed. Moisture may condense on the surface of sparking points in conditions of high relative humidity causing measurement to become erratic. So spheres are made with their surfaces smooth and curvature as uniform as possible.

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2. What is unique about High Voltage Testing Transformer?

→ The main advantage of HV Testing Transformer is its current rating. Since we use high voltage rating, we get low current rating. For ex: 30kVA, 300kV ⟹

$I_{rating} = \frac{30kVA}{300kV}$ = 100 mA which is too low. So even if a fault occurs or there is a breakdown in path, the current doesn't blow up to high values. The current value will be in bounds of human constraints and is highly advantages for transmission stepping.

3. Is corona useful at all?

→ Corona discharge has a number of commercial applications. It is used in removal of unwanted electric charges from surface of aircraft in flight and thus avoids effect of uncontrolled electric discharge pulses. It is used in manufacturing ozone, photocopying, air ionisers, EHD thrusters, Nitrogen laser and static neutralization.

4. Why corona extinction voltage is less than the corona inception voltage?

→ The answer can be found by the following the mechanism of Corona discharge in a non-uniform electric field (as in real life) increase in voltage leads to ionization of air surrounding conductors and there comes a voltage when continuous corona discharge starts and it is corona inception voltage. To make corona disappear voltage is reduced from high values to low values, as the air medium has got ionized and has less strength as compared to pre-ionized state the voltage

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has to be lowered as compared to inception voltage. So this voltage, corona extinction voltage is always lower than inception voltage.

5. Why is corona inception voltage not voltage for small gap distances for both electrode gaps?

→ Before visible corona discharge begins, i.e. visual corona inception voltage appears, corona inception takes place with a hissing sound and the voltage is disruptive critical voltage or can be referred to as corona inception voltage also.
Breakdown strength of air is 30kV/cm or $E_{rms} = \frac{30}{\sqrt{2}}$ 21.2 kV/cm
Disruptive critical voltage is given as $E_{0,rms} = 21.2\, m_0 r \log_e(d/r)$ to neutral. From the mathematical expression we can easily infer if the distance d falls below radius of conductors r or bridges ~~small corona~~ the conductors and the stress is insufficient to ionize air and so the corona inception voltage is not observed.

6. Why BDV is more for sphere-sphere gap compared to point-plane gap?

→ This can be observed from the analysis of the mathematical expression $E_{0rms} = 21.2\, \delta\, m_0 r \log_e(d/r)$. To obtain Breakdown voltage, we see that the effective conductor radius of point-plane gap case is much less compared to sphere gap. So, breakdown is achieved earlier in point-plane gap.

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Mathematically,

$$\frac{E_{0rms}(\text{sphere-sphere gap})}{E_{0rms}(\text{point-plane})} = \frac{21.2\,\delta m_0 r_1 \log_e(d/r_1)}{21.2\,\delta m_0 r_2 \log_e(d/r_2)}$$

r_1 = sphere-sphere
r_2 = point-plane

As $r_1 > r_2$, E_{0rms}(sphere-sphere) > E_{0rms}(point-plane)

7. How the BDV will vary for a 30mm gap if point-point electrodes are used instead of point-plane gap?

→ The inception of the corona takes place when the E_{0rms} becomes just more than 21.2 kV/cm, so in point-point electrodes the effective radius increases as compared to point-plane. so breakdown voltage has to increase to cause corona discharge. So As we see for point-phase electrode gap the BDV is 17.17 kV after humidity correction, so it will increase from that in point-point.