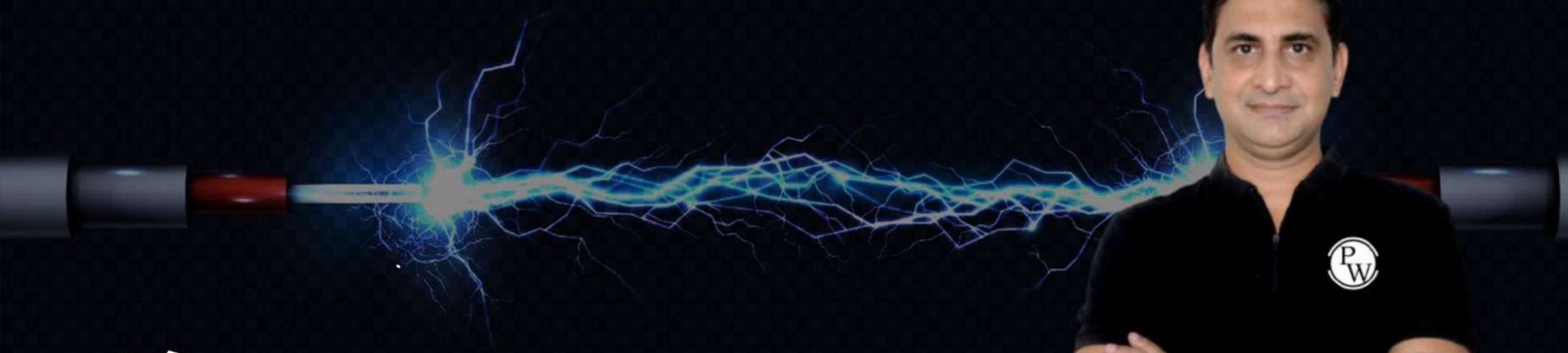
# Electrical Engineering

## Power System



Lecture No.-1

Corona

By- Ajay Gupta Sir

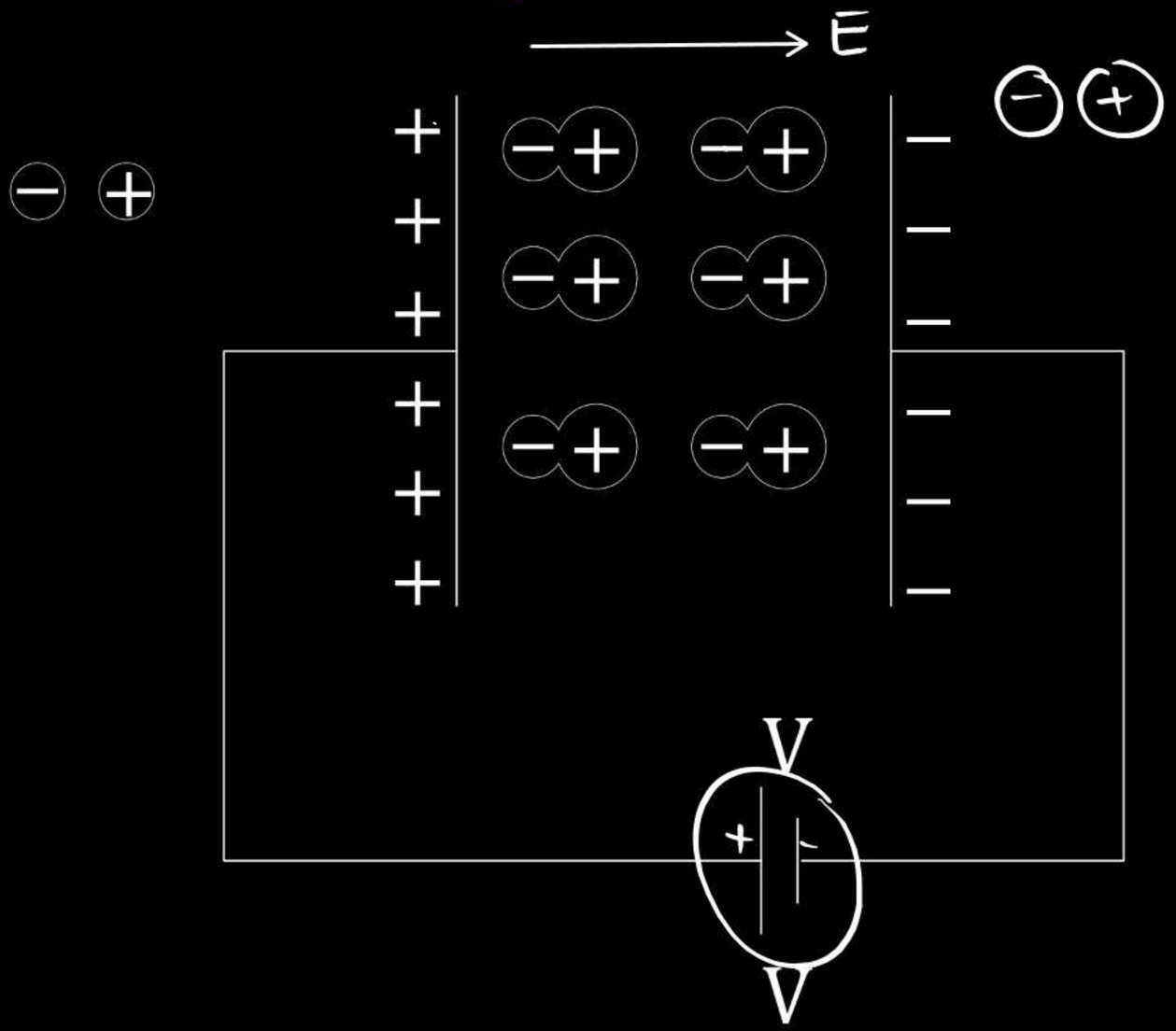
1. Propagation constant
2. Phase constant
3. Surge impedance loading
4. improvement in SIL

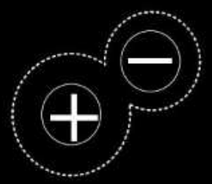
- ✓ 1. corona
- ✓ 2. Critical disruptive voltage
- ✓ 3. Visual critical voltage
- 4. corona

@AJAYGUPTASIRPW

# CORONA

## Dielectric Strength & Breakdown Voltage:



$V\uparrow \rightarrow$

$\downarrow$

$E\uparrow \rightarrow$

$\downarrow$

$F\uparrow \; qE\uparrow$

$F = \oplus E$

$F = \ominus E$

$\underline{F} = q\underline{E}$

$\underline{F} = \oplus \underline{E}$

$F = \ominus E$

## Dielectric strength and breakdown voltage:

- If voltage is increased
- The electric stress E would also increase.
- Due to electric fields the force is exerted on the charge F=qE.
- If charge is positive the force would be in the direction of E.
- If charge is negative the force would be opposite to the direction of E

- At a particular electric fields, the force on positive charge (nucleus) and negative electron is become so high that
- The nucleus is not able to hold electron, and electron is separate out from nucleus.
- Now free electron is available for conduction and material is no longer a dielectric material .
- The electric field E at which dielectric material lose its dielectric property is called dielectric strength of dielectric material
- And the voltage this breakdown is occur is called breakdown voltage

➢ The electrical field at which the insulating material is converted into conducting material is called it dielectric strength (V/cm).

40 kv/cm 30 kv/cm

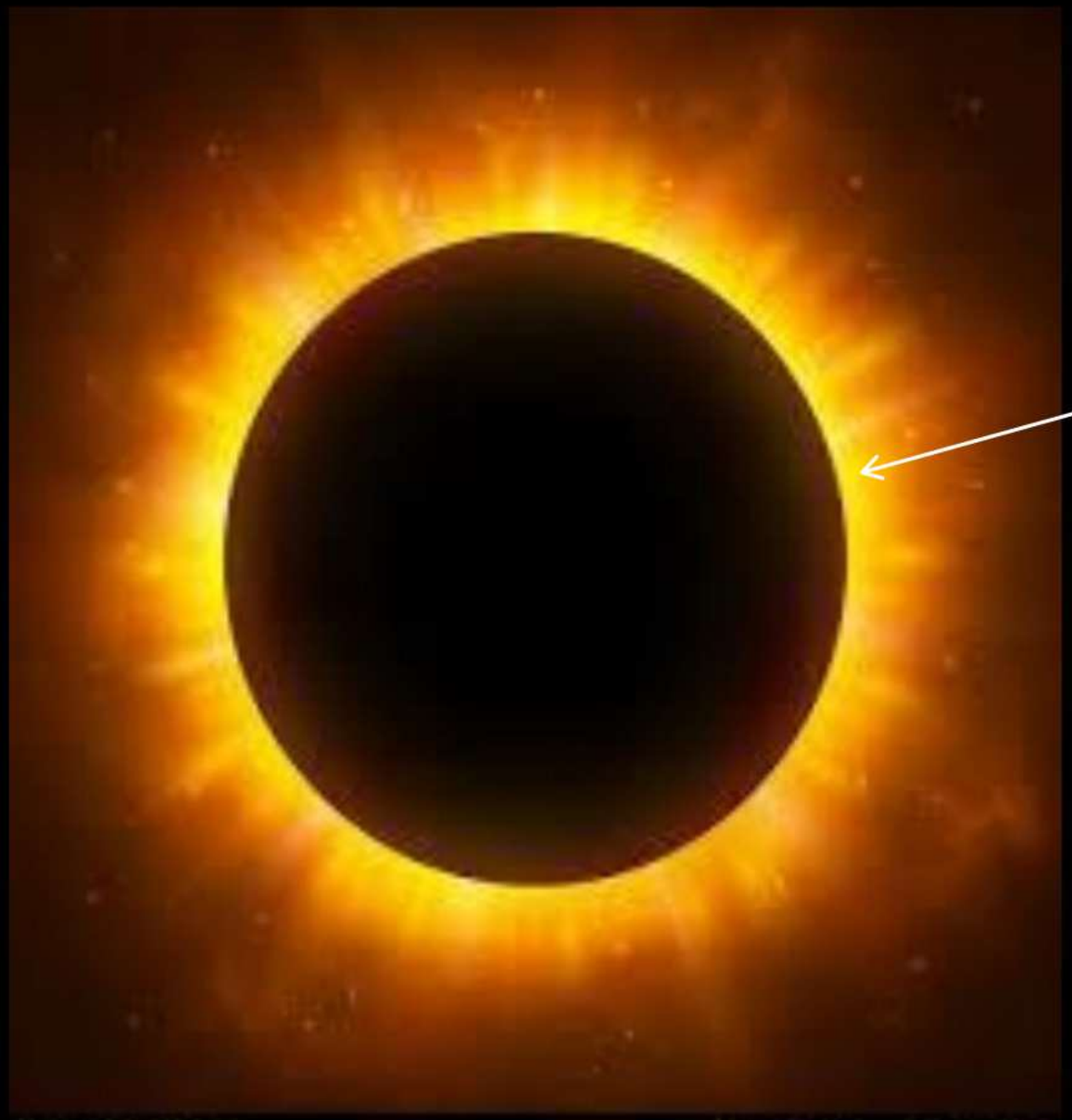
⇒ If Applied electrical field > dielectric strength of material

it converts into conductor

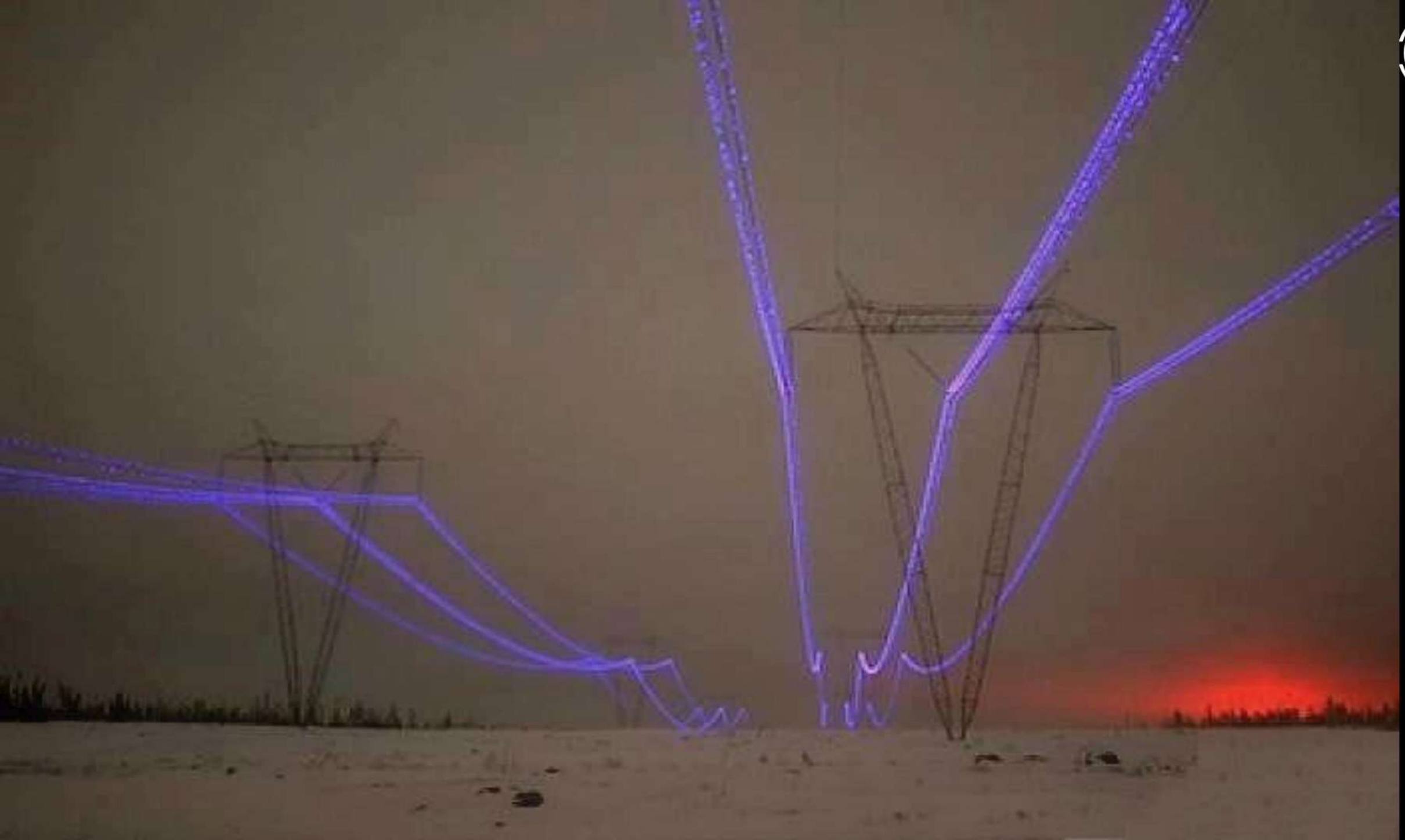
20 kv/cm 30 kv/cm

⇒ If Applied electrical field < dielectric strength of material

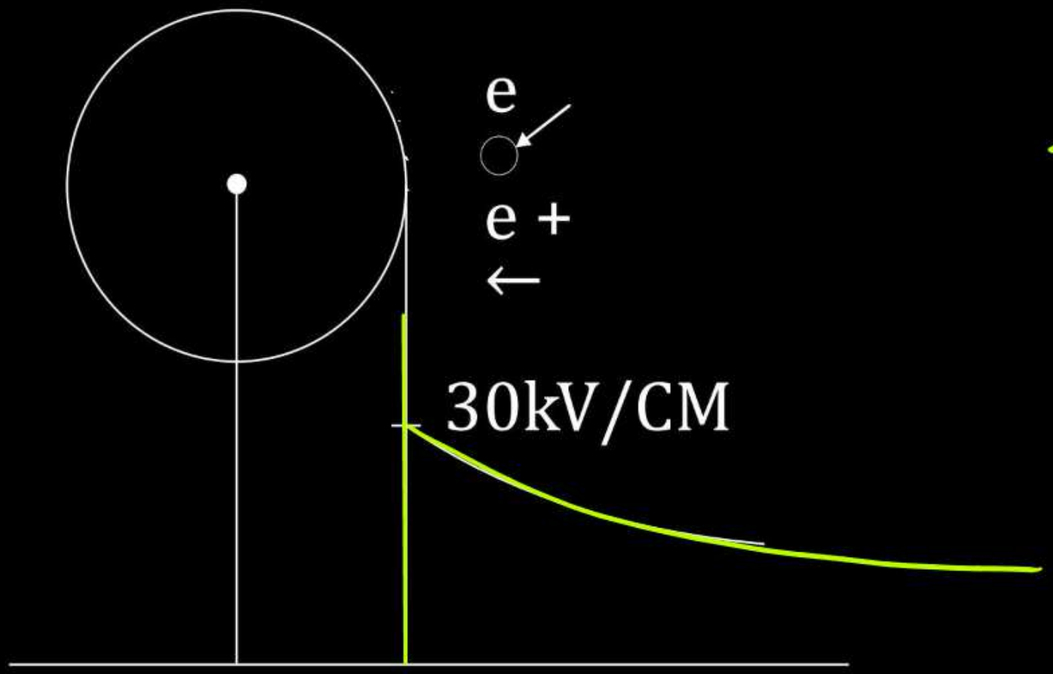
it will be insulator

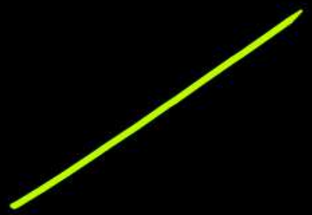



Corona



The voltage at which breakdown of insulating material occur is the Break down voltage.



$$E = \frac{q}{2\pi\epsilon r}$$

# Corona effect on transmission line

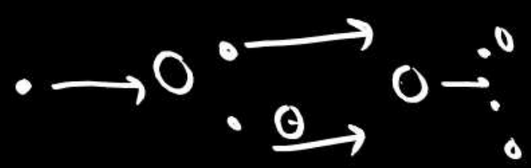
1. Corona is an Ionization of air surrounding power conductor.
2. Due to ultraviolet rays from sun & cosmic rays, radioactivity of soil some ions and charges are still present in air.
3. When electrical field at the surface of conductor is become more than 30 kV/cm (Peak)
4. A force exerts an electron & electron start moving with high velocity.

5. These electrons now collide with air molecules so dislodge electrons and positive ions from air molecules.

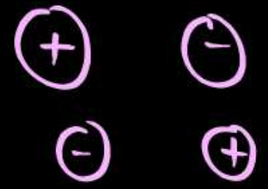
6. Now these newly born electrons also start moving due to electrical field & further dislodge air molecule.

7. This will ultimately result in electronic Ions avlanches

8. This Ionization is accompanied by a luminous (violet) in A.C around the conductor & hissing sound is heard & smell of ozone gas is detected.

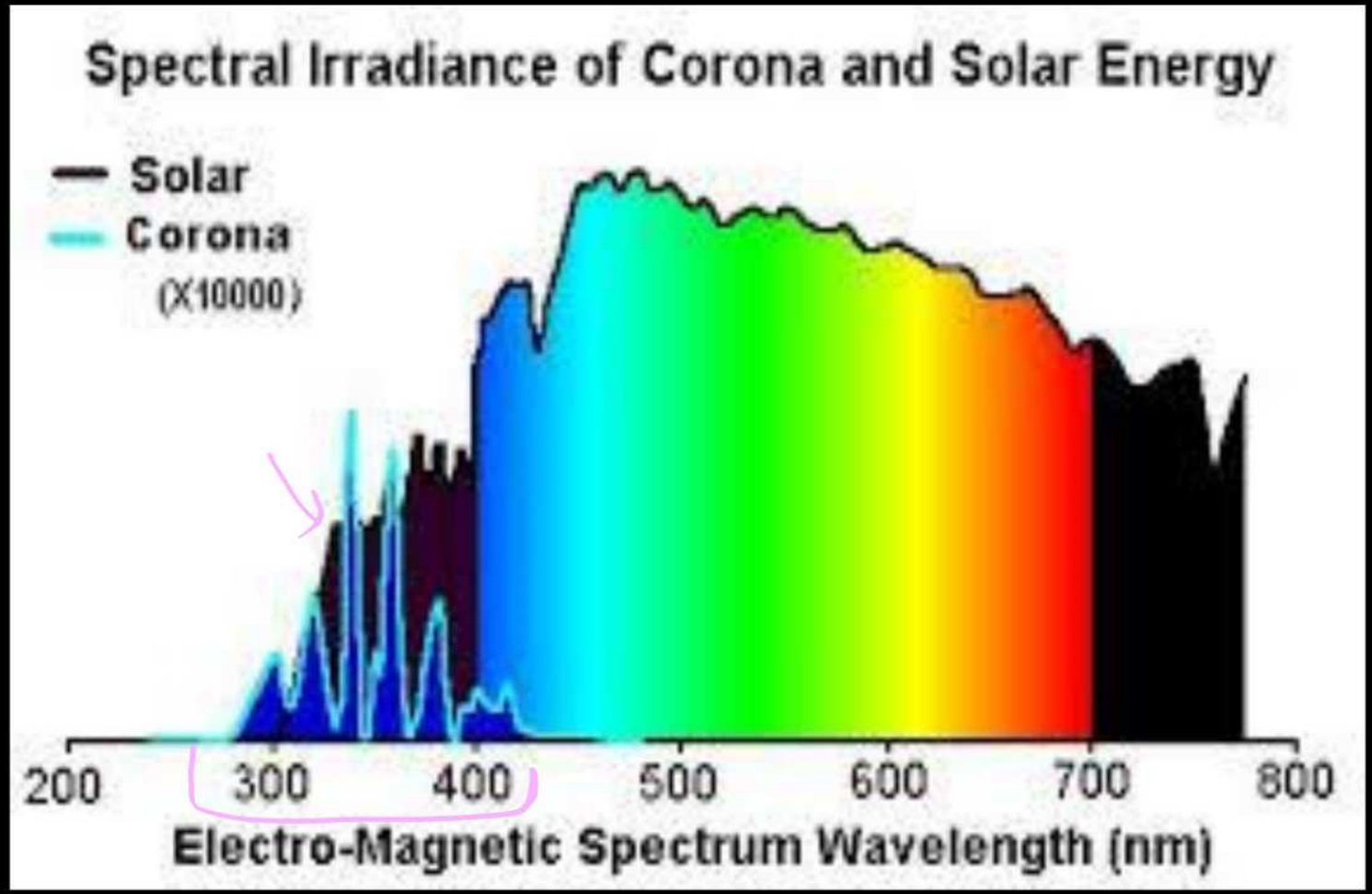


$O + O + O = O_3$



9. In D.C transmission the positive wire has uniform bluish white blow, but negative wire has reddish tufts & beads (non-uniform)

10. Corona is a low temperature and low-density electrical discharge. The corona discharge is slightly warmer than ambient air. The bluish-purple light is emitted by excited nitrogen molecule. As they return to lower energy state, they liberate light in blue and near ultraviolet spectrum with most peak falling between 300 and 400 nm.


Spectral Irradiance of Corona and Solar Energy
Solar
Corona
(X10000)
200
300
400
500
600
700
800
Electro-Magnetic Spectrum Wavelength (nm)

Corona is associated with:

- Light (Violet) around conductor ✓
- Hissing sound ✓
- Odour due ozone gas ✓

# Critical Disruptive Voltage

- The potential at which electrical field at the surface of conductor is become more than 30 kV/cm (peak) at (NTP) normal temperature and pressure and generate corona is called critical disruptive voltage.
- Corona begin when electrical field intensity (Potential gradient) at the surface of conductor is become more than dielectric strength of air.

$g_0$ = 30 kV/cm (Peak Value)

$$g_{0\,(\text{RMS})} = \frac{30}{\sqrt{2}} kV = 21.2 \text{kV/cm (RMS)}$$

at normal temperature & pressure (at 25°C & 76 mm Hg pressure)

- Dielectric strength depends on air density
- The air density proportional to pressure and inversely proportional to temperature.
- At any other temperature & pressure $g = g_0 \delta$

$\delta$ = air density factor $\delta = \frac{P}{(273+\theta)} \cdot \frac{(273+25)}{76}$

$$g = g_0 \times \frac{P \times (273+25)}{76(273+\theta)}$$

$$g = g_0 \times \frac{3.92P}{273+\theta}$$

$$\text{Dielectric strength} \propto \text{air density} \propto \frac{\text{Pressure}}{\text{Temperature}}$$

$$\text{Dielectric strength} = K \frac{\text{Pressure}}{\text{Temperature}}$$

$$K = \frac{\text{Dielectric strength} \times \text{Temperature}}{\text{Pressure}} = \text{Constant}$$

At 25° & 76 mm Hg Pressure Dielectric strength $= g_0 = 30\ \text{kv/cm}$

At T temperature and P pressure $= g$

$$\frac{g_0 \times (273+25)}{76} = \frac{g\,(273+T)}{P}$$

$$g = g_0 \frac{(273+25)}{(273+T)} \times \frac{P}{76}$$

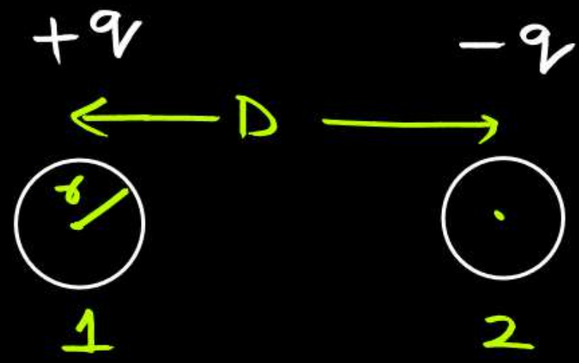
$$g = g_0 \frac{3.92\,P}{273+T}$$

$$\boxed{g = g_0 \times \delta}$$

$\delta$ = Air density factor

# Critical disruptive voltage for 1 phase line:

The electric field intensity at the surface of conductor.




$$E = \frac{q}{2\pi\varepsilon_0 r} \quad \text{... (1) (q = charge per unity length)}$$

potential difference between two conductors separate by a distance D.

$$V_{12} = \frac{q}{2\pi\epsilon_0}\ln\frac{D}{r} + \frac{(-q)}{2\pi\epsilon_0}\ln\frac{r}{D}$$

$$V_{12} = \frac{q}{2\pi\epsilon_0}\left[\ln\frac{D}{r} - \ln\frac{r}{D}\right] = \frac{q}{2\pi\epsilon_0}\ln\left(\frac{D}{r}\right)^2 = \frac{q}{2\pi\epsilon_0}\cdot 2\ln\frac{D}{r}$$

$$V_{12} = \frac{q}{\pi\epsilon_0}\ln\frac{D}{r}$$

From equation (1),

$$\frac{q}{\pi\epsilon_0} = 2\gamma E$$

Put this value in equation (2)

$$V = 2\gamma E \ln\frac{D}{\gamma}$$

When E is become equal to dielectric strength of air E = g, then breakdown occur
So, critical disruptive voltage

$$V_d = 2\gamma g \ln\frac{D}{\gamma}$$

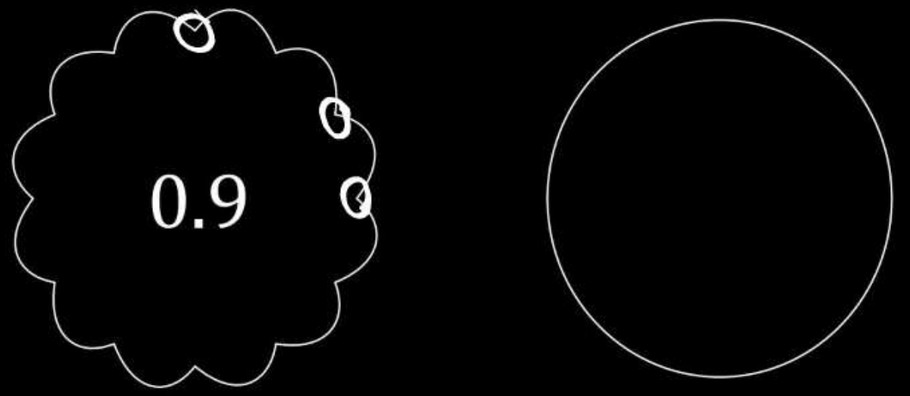
$$V_d = 2\gamma(g_0\delta) \ln\frac{D}{\gamma}$$

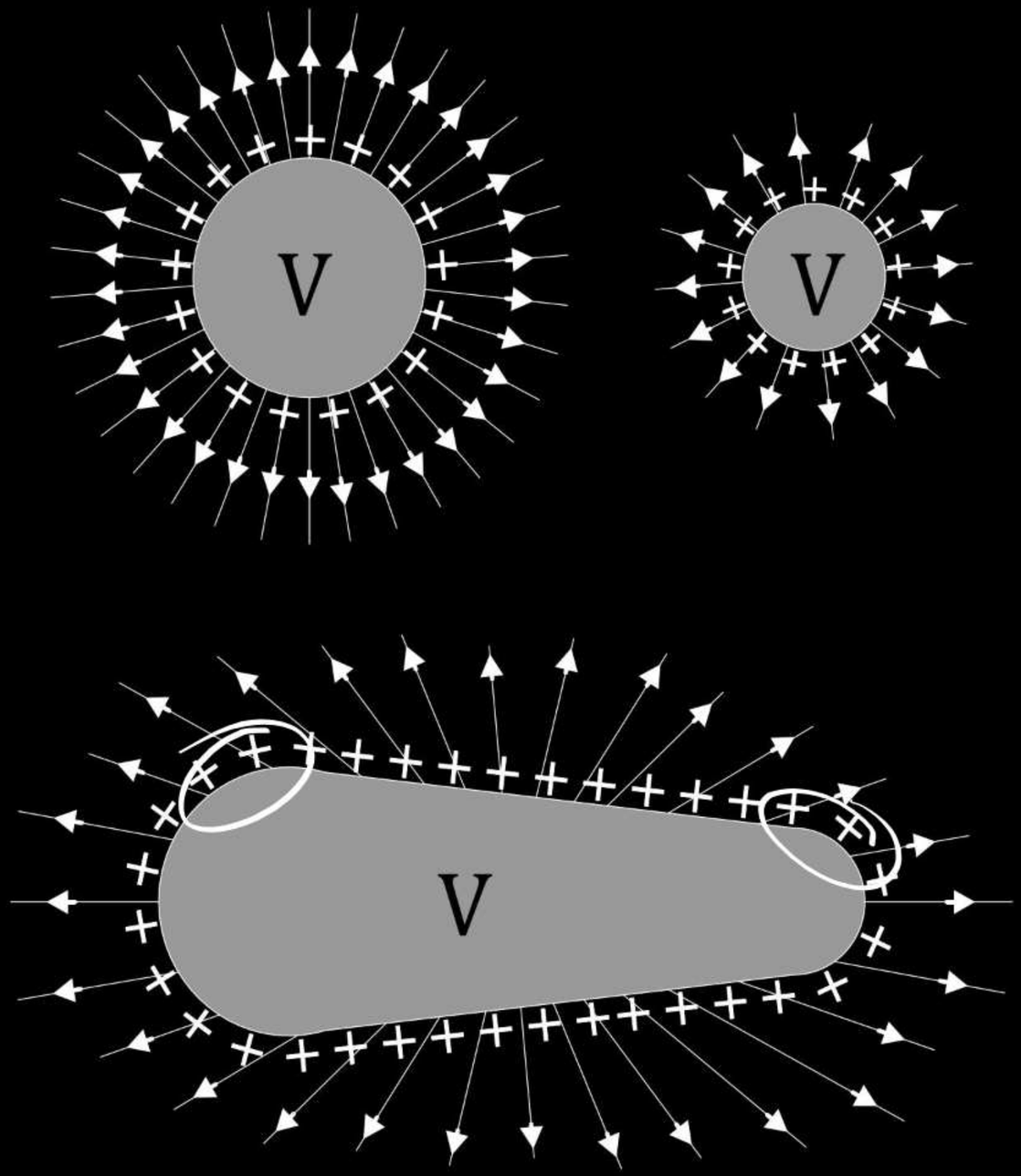
- If conductor is having rough surface or we use stranded conductor then electrical field is disturbed (not uniform). So, at the edges and corners the potential gradient is become more than other region so localized corona occurs. So, we can say, in these conductors, critical disruptive voltage is less than that of normal smooth conductor.

  So, to take care about roughness & smoothness of conductor. We take a factor $m_0$ (smoothness factor) $m_0 \leq 1$

$$V_d = 2r\, g_0\, \delta m_0 \ln\left(\frac{D}{r}\right)$$

for 1-phase, 2 wire line




V
V
V

$g_0$ = dielectric strength of air at normal temperature and pressure

= $3 \times 10^6$ V/m (or) = $\frac{3\times10^6}{\sqrt{2}}$ (RMS) $\frac{30\text{kV}}{\sqrt{2}\ \text{cm}}$

$m_0$ = smoothness factor.

$m_0$ = 1 for smooth conductor

$m_0$ = 0.92 – 0.98 (Rough conductor)

$m_0$ = 0.82 – 0.88 (Stranded conductor)

# Critical disruptive voltage for 3 phase line:

$$V = \frac{q}{2\pi\epsilon_0} \ln\frac{D}{r}$$

per phase

$$E = \frac{q}{2\pi\epsilon_0 r}$$

Now put the value of $\frac{q}{\pi\epsilon_0} = 2rE$

$$V = \frac{2rE}{2} \ln\frac{D}{r} \Rightarrow V = rE \ln\frac{D}{r}$$

When $E = g$ the break down will occur

$$V_d = r(g) \ln\frac{D}{r}$$

So critical disruptive voltage, $V_d = r(g_0 \delta) \ln \frac{D}{r}$

For rough & stranded conductor

$$V_d = r\, go\, \delta\, \underline{m_0}\, \ln\left(\frac{D}{r}\right)$$ ⟶ For 3ϕ line (Critical Voltage per phase)

$$go = \frac{3\times10^6}{\sqrt{2}} rms$$

# Visual Critical Voltage:

- Experiment show that visual corona occurs when electrical field intensity is become $E_V$, which is slightly higher than 30kV/cm

So, we add a factor $\left(1+\frac{0.3}{\sqrt{\delta r}}\right)$ in critical disruptive voltage formula.

$$E = go\,\delta r\left(1+\frac{0.3}{\sqrt{\delta r}}\right) kV/m$$

$\gamma$ = Cm

$\left(1+\frac{0.03}{\sqrt{\delta r}}\right)$ ← $r$ = metre

So visual critical voltage

$$V_v = r\,g_0\,\delta\left(1+\frac{0.3}{\sqrt{\delta r}}\right)\ln\frac{D}{r}$$

$$V_v = 2\pi g_0 \delta m_v \left(1 + \frac{0.3}{\sqrt{\delta r}}\right) \ln \frac{D}{r}$$ for 1$\phi$ line

$$V_v = \pi g_0 \delta m_v \left(1 + \frac{0.3}{\sqrt{\delta r}}\right) \ln \frac{D}{r}$$ For 3$\phi$ line (Per phase)

$m_v$ = smoothness factor for visual corona

$m_v$ = 1 for smooth conductor

= 0.72, for stranded conductor

= 0.82 for decided corona for standard conductor

$$\delta = \frac{3.92P}{273 + \theta}$$

**Q.** Find out critical disruptive voltage on a 3-phase overhead T.L. consisting of 3 standard Cu conductor spaced 2.5 m apart at the equilateral triangle. Air temperature and pressure is 21°C & 73.6 Hg. The conductor diameter = 10.4 mm. Irregularity factor = 0.85

A. 56.5 kV

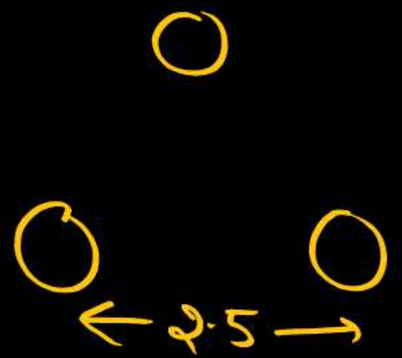
B. 97.8 kV

C. 114.4 kV

D. 120 kV

$$r = \frac{10.4}{2} = 5.2\,mm = 0.52\,cm$$

$$m_0 = 0.85$$




$$\delta = \frac{3.92P}{273+T} = \frac{3.92 \times 73.6}{273+21} = 0.9813$$

$$D = 2.5\,m = 250$$

$$V_d = \gamma (g_0 \delta) m_0 \ln \frac{D}{\gamma}$$

$$V_d = (0.52 \text{ cm}) \left( \frac{30}{\sqrt{2}} \frac{\text{kV}}{\text{cm}} \right) \times 0.9813 \times 0.85 \ln \frac{250 \text{ cm}}{0.52 \text{ cm}}$$

$$V_d = 57.487 \text{ (Per phase)}$$

$$V_d = \sqrt{3} \times 57.487$$

$$V_d = 99.57 \text{ (line)}$$

**Q.** Find out visual critical voltage for local corona & decided corona. Surface factor for local corona = 0.7 & = 0.8 for decided corona

A. 114.4

B. 120.3

C. 124.7

D. 152.9

Local Corona :-

$$V_v = \gamma(g_0\delta)\, m_v \left(1+\frac{0.3}{\sqrt{\delta r}}\right) \ln\frac{D}{r}$$

$$V_v = (0.52\ \text{kV/cm})\left(\frac{30\ \text{kV}}{\sqrt{2}\ \text{cm}}\right) \times 0.9813 \times 0.7 \times \left(1+\frac{0.3}{\sqrt{0.9813\times 0.52}}\right) \ln\frac{250}{0.52}$$

$V_v = 66.81$ kV per phase

$V_v(\text{line}) = 66.81 \times \sqrt{3}$

$= 115.7$

For decided Corona

$$115.7 \times \frac{0.8}{0.7} = 132.25$$

- **Corona Loss:** The positive & negative charges produced by corona move around the conductor. For this movement energy is taken from conductor. So, we can say this energy as a corona loss.
    - The energy is dissipated in form of heat, light, sound & chemical action.
    - As per "peek" empirical formula

$$P = 241 \times 10^{-5} \frac{(f+25)}{\delta} \sqrt{\frac{r}{D}} (V_P - V_D)^2 \quad \text{kW / km / ph}$$

$f$ = frequency

$\delta$ = air density factor

r = radius

D = Distance

$V_D$ = Disruptive critical voltage (Per phase)

$V_P$ = Actual per phase voltage of line

kV

# Peek formula is valid only is

(a) if corona loss is predominating

(b) $25 < f < 120$

(c) $\frac{V_P}{V_D} > 1.8$

(d) Radius of conductor > 0.25 cm

if $\frac{V_P}{V_D} < 1.8$, then Peterson formula give more accurate result than Peek formula

$$P_C = \frac{21 \times 10^{-6} f V^2}{\left(\log_{10}(D/r)\right)^2} \times F$$

Where, F is a factor

| $V_P/V_D$ | 0.6 | 0.8 | 1 | 1.2 | 1.4 | 1.6 | 1.8 | 2 | 2.2 |
|---|---|---|---|---|---|---|---|---|---|
| F | 0.012 | 0.018 | 0.05 | 0.08 | 0.3 | 1.0 | 3.5 | 6 | 8 |

- In foul weather condition, we take $V_D$ as a 80% of fair weather value.

Note → if $V_D > V_P$ 160 kV

$\frac{220}{\sqrt{3}} = 127$

So No corona occur ($P_c = 0$)

**Q.** What will be corona loss for a 3-phase line operating at 110 kV. Which has conductor of 2.5 cm diameter arranged in a 3.05 m distance. Assume air density factor of 1.07 & dielectric strength of air is 21 kV/cm.

($\delta$ = 1.07, $g_0$ = 21 kV/cm)

A 0

B 10

C 11.2

D 12.4

$$V_d = \gamma (g_0 \delta) m \ln \frac{D}{\gamma}$$

$$V_D = 1.25\,\text{cm} \times 21\,\frac{\text{kv}}{\text{cm}} \times 1.07 \times 1 \ln \frac{305}{1.25}$$

$$V_D = 154.4\ \text{kv (Per phase)}$$

$$V_d (\text{line}) = 267.42\ \text{kV}$$

$V_d > V_p$

No Corona

Corona loss = 0

# 2 Minutes Summary

→ Corona

→ Critical disruptive voltage

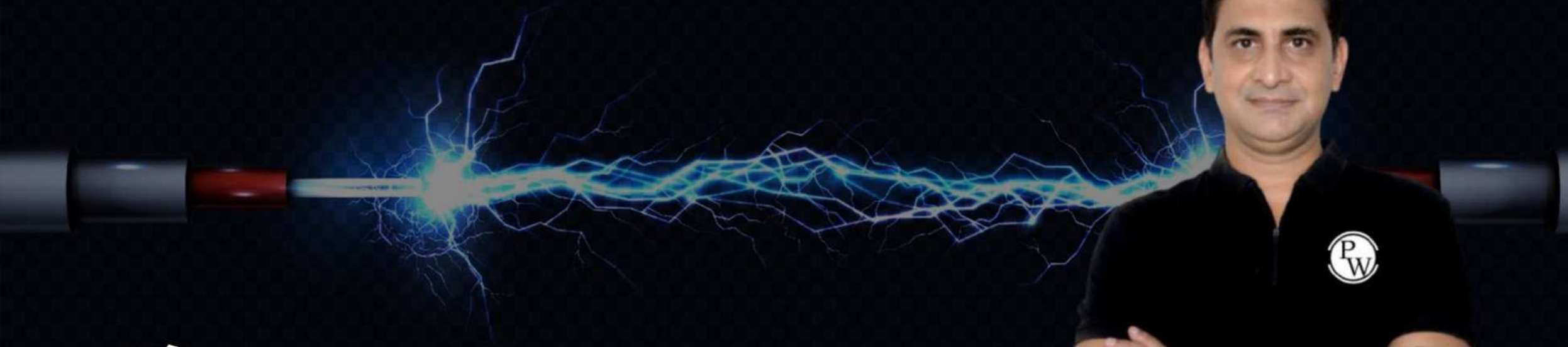
→ Visual critical voltage

→ Corona loss

# Thank you GW *Soldiers !*

# Electrical Engineering

## Power System



Lecture No.-2

Corona

By- Ajay Gupta Sir

1. corona
2. Critical disruptive voltage
3. Visual critical voltage
4. corona

1. Factor affecting Corona
2. Advantage of corona
3. Disadvantage of corona
4. Corona QUESTIONS

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**Q.** What will be corona loss for a 3-phase line operating at 110 kV. Which has conductor of 2.5 cm diameter arranged in a 3.05 m distance. Assume air density factor of 1.07 & dielectric strength of air is 21 kV/cm.

A 0

B 10

C 11.2

D 12.4

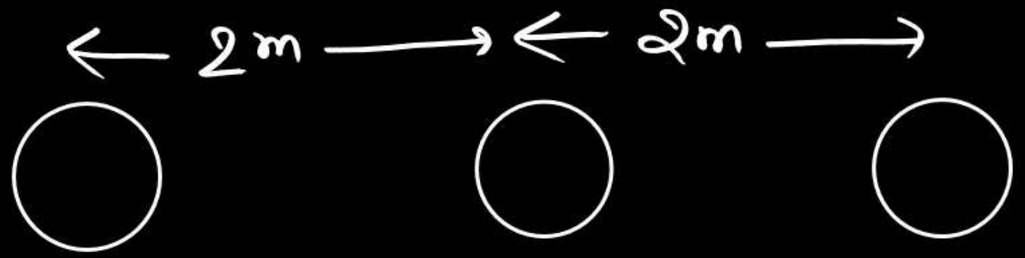
$V_D > V_P$

$\Rightarrow$ No Corona

$=$ Corona loss $= 0$

**Q.** A 3-phase overhead transmission line consist of 3 conductors in horizontal spacing with 2 meter spacing. The conductor diameter is 1.00 Cm and surface factor is 0.80. The air pressure and temperature is 74 cm hg pressure and 21-degree cent. The critical disruptive voltage is? The dielectric strength of air at 30 kV/cm (Peak) at 76 cm pressure and 25-degree cent. (Give ans in kV)

76 cm = 760 mm




$r = \frac{1}{2} = 0.5$ cm

$$D_{eq} = \sqrt[3]{D_{12} \cdot D_{23} \; D_{31}}$$

$$= [2 \times 2 \times 4]^{1/3}$$

$$= 2.52 \text{ meter}$$

$$\delta = \frac{3.92P}{273+T} = \frac{3.92 \times 74}{273+21} = 0.9866$$

$$V_d = \gamma(g_0 8)\, m_0 \ln \frac{Deq}{\gamma}$$

$$V_d = (0.5\,cm)\left(\frac{30\,kV}{\sqrt{2}\,cm}\right) \times 0.9866^{\times 0.8} \ln \frac{252}{0.5}$$

$$V_d = \quad 65.11 \times 0.8 = 52.088$$

$$V_d(line) = 65.11 \times \sqrt{3} \times 0.8$$

$$= 90.22\ kV$$

**Q.** A 3-phase overhead transmission line consist of 3 conductors in equilateral spacing with 2.44 meter spacing. The conductor diameter is 1.04 Cm and surface factor is 0.85. The air pressure and temperature is 74 cm hg pressure and 21.1-degree cent. The visual critical disruptive voltage is? The dielectric strength of air at 30 kV/cm (Peak) at 76 cm pressure and 20-degree cent.

A. 137.95 kV/phase

B. 79.65 kV/Phase

C. 76.30 kV/Phase

D. 68.12 kV/Phase

$$g \propto \frac{P}{273+T}$$

$$\gamma = \frac{1.04}{2} = 0.52$$

$$\frac{g \times (273+T)}{P} = \text{Constant}$$

$$\frac{g_0\,(273+20)}{76} = \frac{g\,(273+21.1)}{74}$$

$$g = g_0 \times 0.97 = g_0\delta$$

$$V_V = \gamma(g_0\delta)\, m_v \left(1+\frac{0.3}{\sqrt{\delta\gamma}}\right) \ln\frac{D}{\gamma}$$

$$= 0.52\,\text{cm} \times \frac{30\,\text{kv}}{\sqrt{2}\,\text{cm}} \times 0.97 \times 0.85 \left(1+\frac{0.3}{\sqrt{0.97\times 0.52}}\right) \ln\frac{244}{0.52}$$

$$= 9.05 \times 1.422 \times 6.151$$

$$= 79.15 \text{ kv (Per phase)}$$

**Q.** A 3-phase 220 Kv, 50 Hz , 250 Km, overhead transmission line consist of 3 conductors in equilateral spacing with 6 meter spacing. The conductor diameter is 22.26 mm and surface factor is 0.84. The air pressure and temperature is 73 cm hg pressure and 25-degree cent. What is total corona loss using peek formula.

A 322 KW

B 400 KW

C 505 KW

D 450 KW

$$P = 241 \times 10^{-5} \left(\frac{\delta + 25}{\delta}\right) \sqrt{\frac{\gamma}{D}} (V_P - V_D)^2 \quad \text{KW/km/phase}$$

$$\delta = \frac{3.92P}{273+T} = \frac{3.92 \times 73}{273+25} = 0.96$$

$$\gamma = \frac{22.26}{2} = 11.13$$

$$= 1.113 \text{ cm}$$

$$V_d = r(g_0 \delta)\, m_0 \ln \frac{D}{r}$$

$$V_d = 1.113 \times \frac{30\ kV}{\sqrt{2}\ cm} \times 0.96 \times 0.84 \ln \frac{600}{1.113}$$

$$V_d = 119.75 \text{ (Per phase)}$$

$$V_P = \frac{220}{\sqrt{3}} = 127.01$$

$V_P > V_D \Rightarrow$ Corona will occur

$$P_c = 241 \times 10^{-5} \left(\frac{50+25}{0.96}\right) \sqrt{\frac{1.113}{600}} (127.01 - 119.75)^2 \text{ kW/km/ph}$$

$$P_c = 241 \times 10^{-5} \times 78.125 \times 0.043 \times 52.70$$

$$P_c = 0.4266 \text{ kW/km/phase}$$

$$P_c = 0.4266 \times 250 \times 3$$

$$P_c = 319.9 \text{ kW}$$

**Q.** What will be total corona loss for a 3 phase 220 kV, 200 km long line having D/r ratio 650. Take factor F as 0.05. Use Peterson formula?

A. 64.2 kW

B. 21.4 kW

C. 56.8 kW

D. 112.4 kW

$$P_c = \frac{21 \times 10^{-6}\, f\, V_r^2}{\left[\log_{10}\left(\frac{D}{r}\right)\right]^2} \times F \quad \text{kw/km/ph.}$$

$\frac{220}{\sqrt{3}} = 127$

$$P_c = \frac{21 \times 10^{-6} \times (127)^2 \times 50}{\left[\log_{10}(650)\right]^2} \times 0.05$$

$$P_c = 0.107 \text{ kw/km/ph}$$

$0.107 \times 3 \times 200$

$= 64.2 \text{ kw}$

# FACTOR AFFECTING CORONA

## 1. Frequency:

$$P_C \uparrow \propto (f \uparrow +25)$$

So, corona loss increases with frequency. In D.C Corona loss will be less.

## 2. System voltage:

$$P_C \uparrow \propto (V_P \uparrow - V_D)^2$$

$(201-200)^2 = 1$ $(300-200)^2$

$(210-200) = 100$ $= 10000$

When voltage is large as compared to $V_D$. The $P_C$ will increase with faster rate.

## 3. Atmosphere Factor:

$\delta \propto \frac{\text{Pressure} \downarrow}{\text{Temp.}}$

$P_C \uparrow \propto \frac{1}{\delta \downarrow}$

At hilly region atmosphere pressure reduce, so $\delta$ decrease and corona loss increase.

## 4. Dust, Rain, Snow:

Due to formation of Dust, Rain drops & Snow the roughness of conductor increase. Which distort the E so at the sharp edges potential gradient is become high so critical disruptive voltage is reduce & corona loss increase

$$V_d \downarrow \propto m_0 \downarrow$$

$$P_C \uparrow \propto \left(V_P - V_D \downarrow\right)^2$$

# 5. Diameter of Conductor:

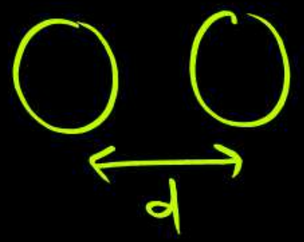
$$\downarrow P_C \propto \sqrt{\frac{r\uparrow}{D}}\left(V_P - V_D \uparrow\right)^2\downarrow$$

$$V_D\uparrow = r\uparrow\left(g_0\delta\right)m\ln\frac{D}{r\uparrow}$$

$$V_D \uparrow \propto r \uparrow$$

So, by increasing radius corona loss is decreased

- When we use bundle conductor it increases effective radius of conductor so corona loss is reduced




$GMR = \sqrt{r'd}$

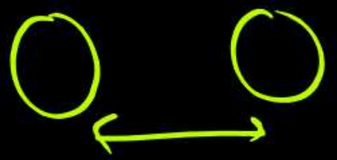
## Number of conductors per Phase

$GMR\uparrow = \text{self GMD}\uparrow \rightarrow V_D\uparrow \rightarrow P_C\downarrow$

**Heating:** During foul weather condition water droplet, fog and snow exist at conductor surface. Due to heating it will be removed from surface so surface is become smoother & corona loss reduced.

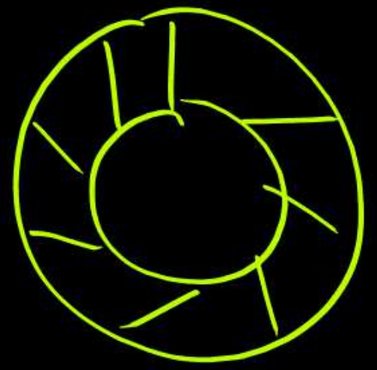
## Increasing Distance Between Conductor:

If distance between conductors is increased the potential gradient at surface of conductor reduce so corona loss reduces.



# Method to reduce corona:

- Large diameter conductor ✓
- Bundled conductors ✓
- Hollow conductors ✓



# Advantage of corona (IMP)

- Due to corona effective diameter is increase

  C ↑

  ↑T = RC ↑

$$C \uparrow = \frac{0.02412}{\downarrow \mu \log \frac{D}{\gamma \uparrow}}$$

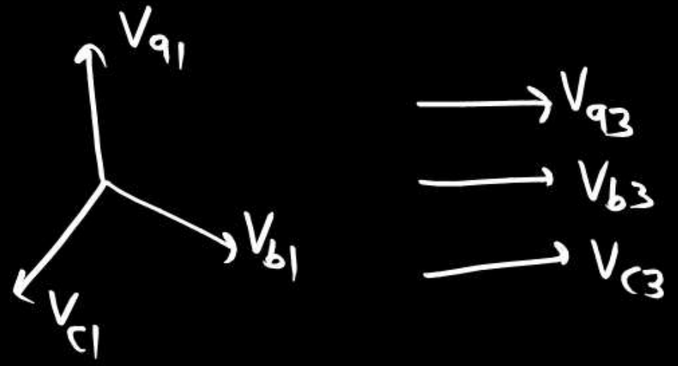
So, steepness of voltage surge is reduced due to lightning & switching, it act as a safety valve.

- It partially dissipated the surges as a corona loss.

## Disadvantage:

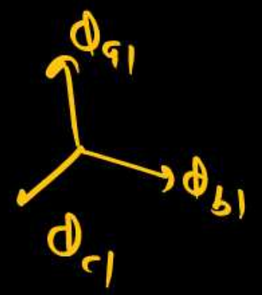
1. It creates energy loss so efficiency of system reduces.
2. Due to formation of ozone the corrosion occurs at the conductor.
3. Due to corona effective diameter increase → C will increase → it increases charging current
4. Due to corona third harmonic current create & it create third harmonic voltage drop. So, it creates interference with communication line

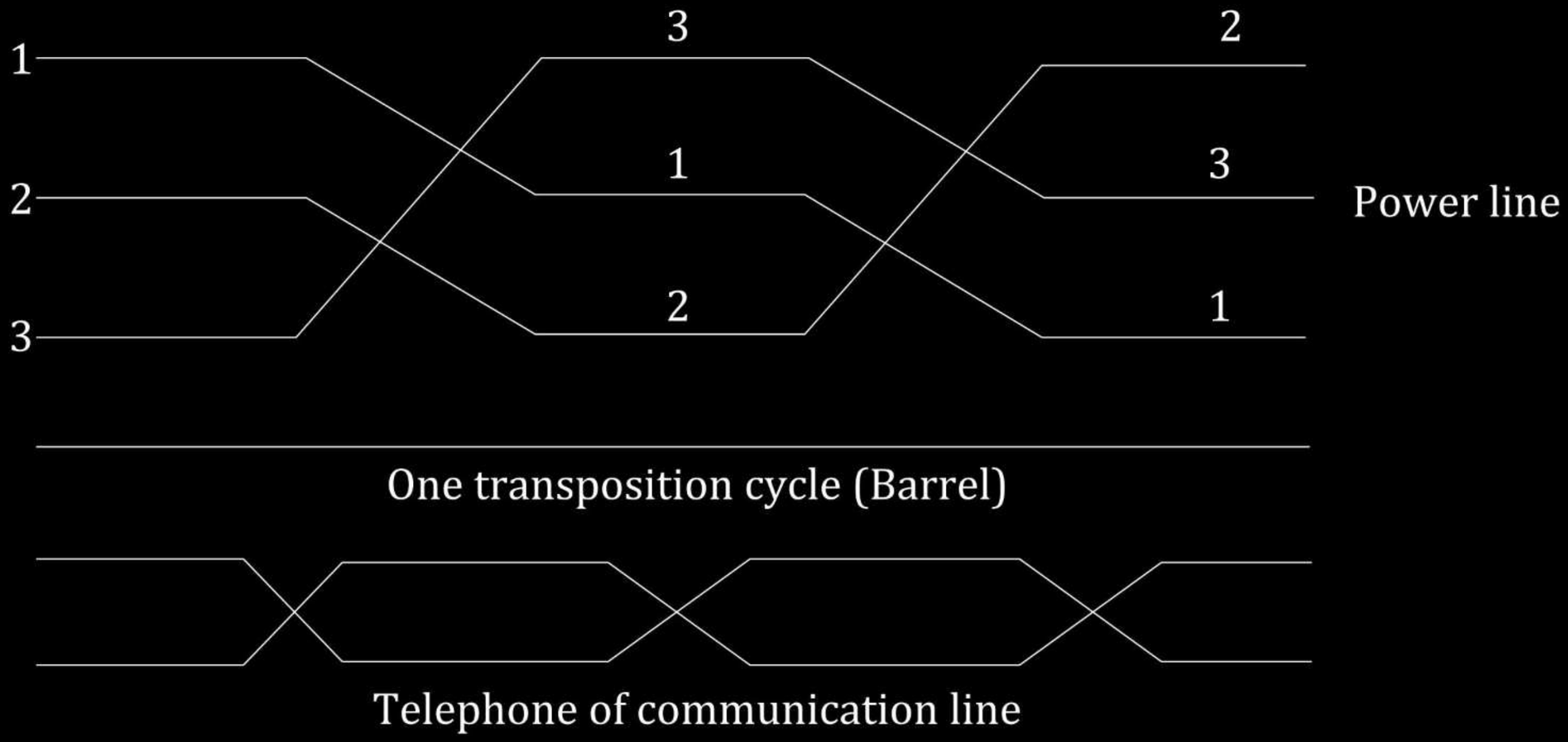
IMP



$\phi_{r1} + \phi_{b1} + \phi_{c3} = 0$

$\phi_{r3} + \phi_{b} + \phi_{c3} \neq 0$




1
2
3
3
1
2
2
3
1
Power line
One transposition cycle (Barrel)
Telephone of communication line

**Q.** The good effect of corona on overhead lines is to **[ESE-2001]**

**A** increase the line carrying capacity due to conducting ionized air envelop around the conductor

**B** increase the power factor due to corona loss

**C** reduce the radio interference from the conductor

**D** reduce the steepness of surge fronts

**Q.** What is the approximate breakdown strength of atmospheric air at N.T.P.? **[ESE-2007]**

**A** 0.3 kV/cm

**B** 1.0 kV/cm

**C** 3 kV/cm

**D** 30 kV/cm

**Q.** The corona loss on a particular system at 50 Hz is 1 kW/km per phase. What is the corona loss at 60 Hz in kW/km per phase? **[ESE-2005]**

**A** 0.83

**B** 1.0

**C** 1.13

**D** 1.12

$$P_c \propto (f + 25)$$

$$\frac{P_{c1}}{P_{c2}} = \frac{f_1 + 25}{f_2 + 25}$$

$$\frac{1}{P_{c2}} = \frac{50 + 25}{60 + 25}$$

$$P_{c2} = \frac{85}{75} = 1.13$$

**Q.** Which one of the following statements is correct? Corona loss increases with **[ESE-2004]**

**A** decrease in conductor size and increase in supply frequency.

**B** increase in both conductor size and supply frequency.

**C** decrease in both conductor size and supply frequency.

**D** increase in conductor size and decrease in supply frequency.

$P_c \uparrow \propto (f \uparrow + 25)$

$V_d \uparrow \propto \gamma \uparrow$

$P_c \downarrow \propto \sqrt{\frac{\gamma \uparrow}{d}} (V_p - V_D \uparrow)^2$

$\gamma \downarrow \Rightarrow P_c \uparrow$

#Q. Which one of the following is correct regarding reduction of corona loss?

[ESE-2024]

**A** Corona losses can be reduced by using large dia conductors, hollow conductors and bundled conductors

**B** Corona losses can be reduced by using small dia conductors, hollow conductors and bundled conductors

**C** Corona losses can be reduced by using large dia conductors, hollow conductors and single conductors

**D** Corona losses can be reduced by using large dia conductors, solid conductors and single conductors

#Q. Which one of the following statements is not correct? [ESE-2023]

**A** The corona loss on the middle conductor is more as compared with the two outer conductors.

**B** The corona loss is less in hilly areas than in plain areas. ✗

**C** The rains increase the corona loss in transmission lines.

**D** The height of the conductors from the ground has its effect on corona loss.

#Q. Which of the following factors affect Corona?

1. Atmospheric conditions, temperature, humidity, moisture, ice and fog
2. Current of conductor
3. Waveform
4. Condition of surface of conductors, smoothness and dust [ESE-2020]

**A** 1, 2 and 3 only

**B** 1, 3 and 4 only

**C** 1, 2 and 4 only

**D** 2, 3 and 4 only

#Q. Radio Influence Voltage (RIV) generated on a transmission line conductor surface is not affected by [ESE-2019]

A System voltage ✓

B Corona discharges on the conductors ✓

C Rain ✗

D Nearby radio receivers ✓

#Q. Which one of the following does not have an effect on corona? [ESE-2017]

A Spacing between conductors ✓ D

B Conductor size ✓

C Line voltage ✓

D Length of conductor ✗

#Q. Consider the following statements regarding corona :

1. It causes radio interference.
2. It attenuates lightning surges.
3. It causes power loss.
4. It is more prevalent in the middle conductor of a transmission line employing flat conductor configuration.

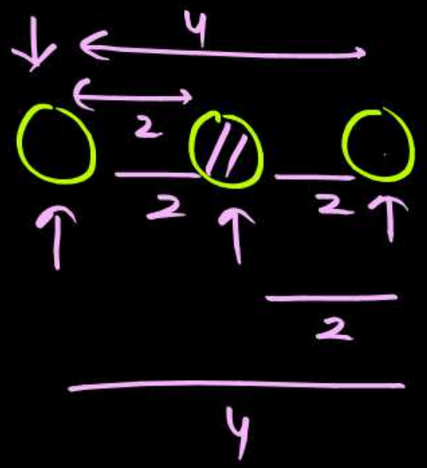
Which of the above statements are correct? [ESE-2017]

**A** 1, 2 and 3 only

**B** 1, 2 and 4 only

**C** 1, 2, 3 and 4

**D** 3 and 4 only




$\sqrt{\frac{r}{D}}$

# 2 Minutes Summary

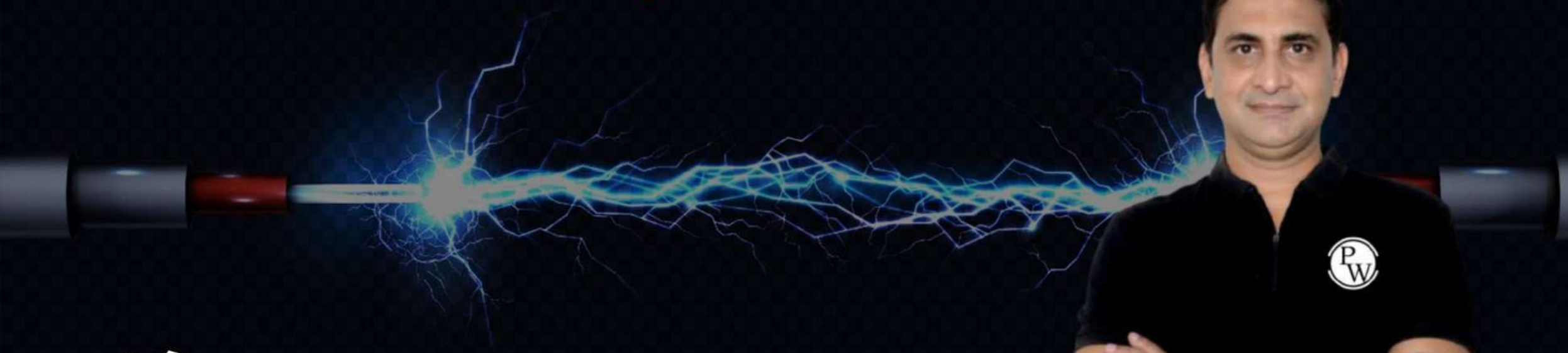
→ Corona — Advantage
\ Disadvantage

→ Question.

# Thank you GW *Soldiers !*

# Electrical Engineering

## Power System



Lecture No.-3

Corona

By- Ajay Gupta Sir

1. corona
2. Factor affecting corona
3. Advantage and disadvantage

1. Electromagnetic induction
2. Electrostatic induction
3. rectification
4. questions

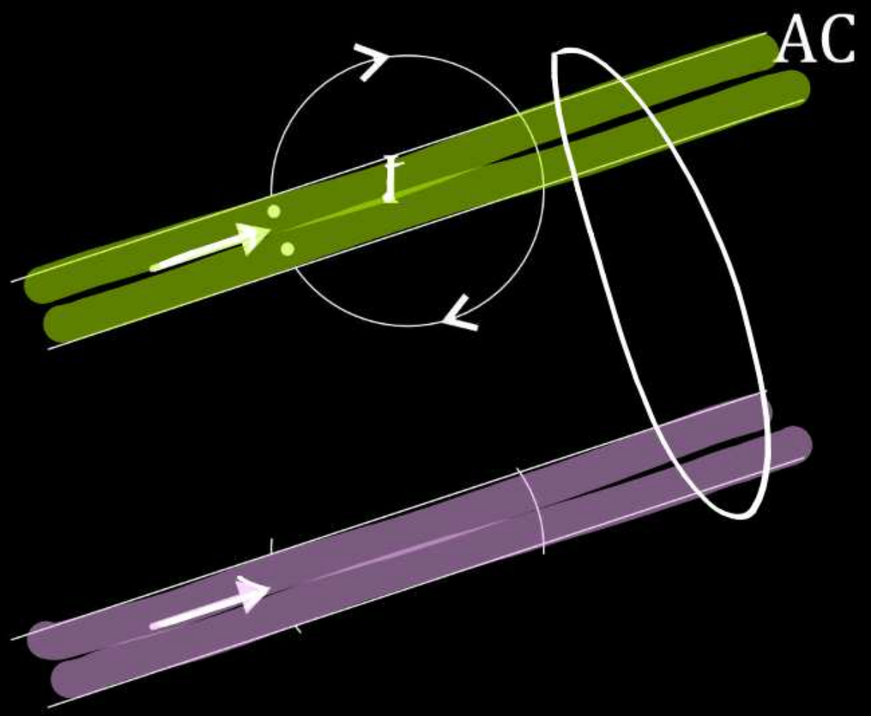
@AJAYGUPTASIRPW

# Interference Between Power & Communication Line

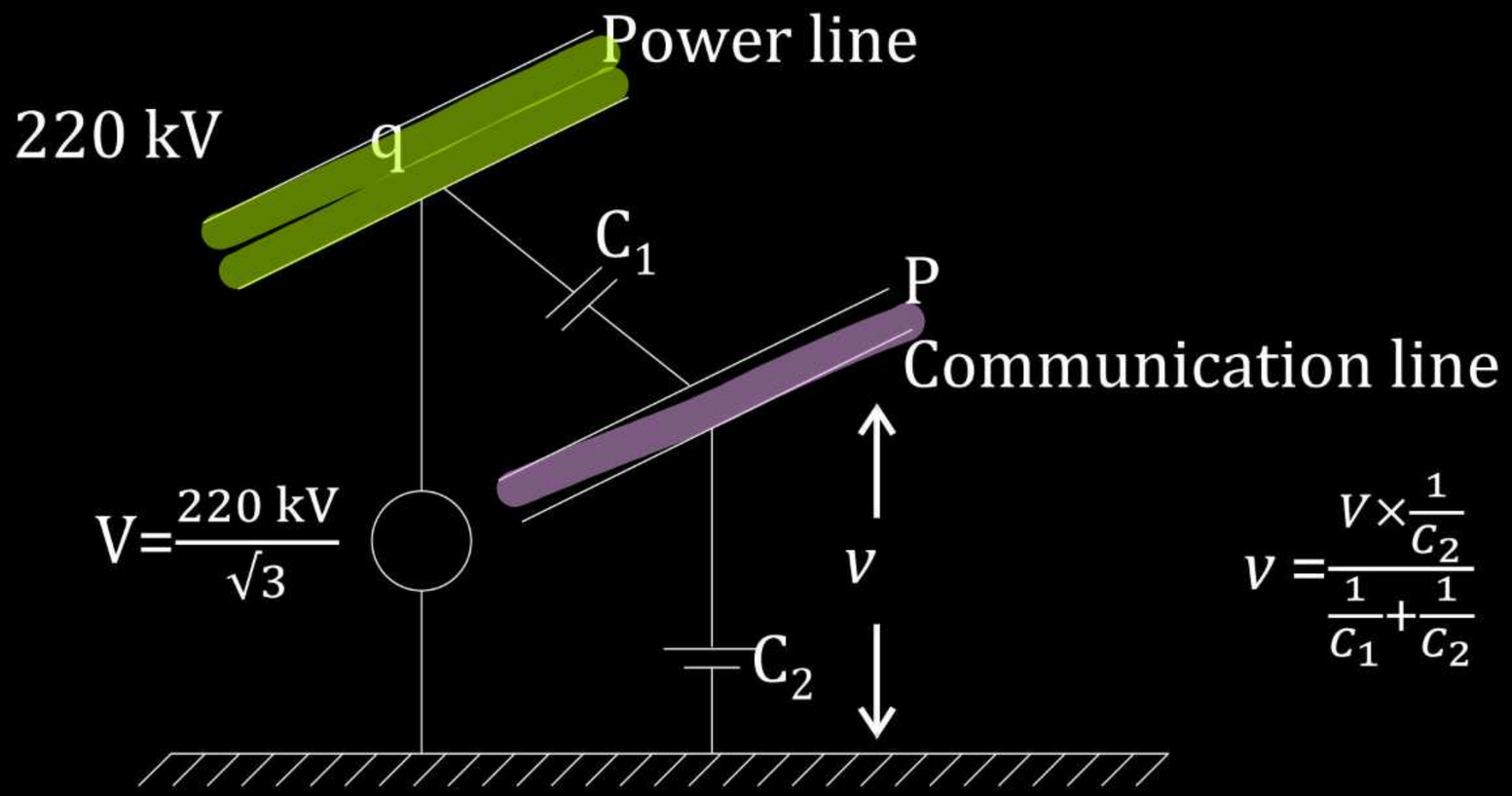
- Normally power & communication line exist in close proximity, so power line create interference with communication.

- Interference occur due to
  - Electromagnetic Induction (Due to Magnetic field)
  - Electrostatic Induction (Due to electric field)

- Electromagnetic induction induce current in communication line. The current superimposed with speech current (Signal) and create disturbance.

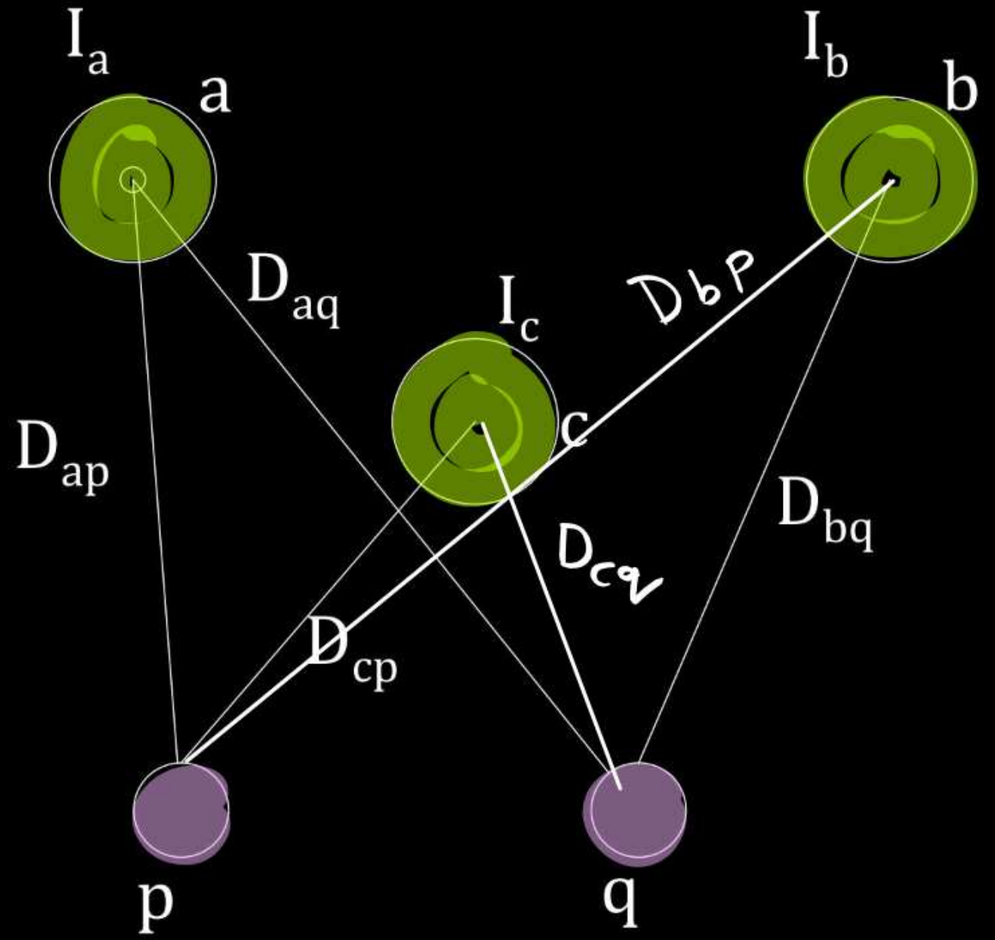


- Electrostatic induction raise the potential of communication line, thereby endangering equipment & users.




$$v=\frac{V\times\frac{1}{C_2}}{\frac{1}{C_1}+\frac{1}{C_2}}$$

# Electromagnetic Induction:




$$I_a + I_b + I_c = 0$$

When current flow in T. L.

↓

A time varying magnetic Flux is Inducted around the power line.

↓

This magnetic field induced the EMF in the communication line and due to this emf, The Induced current start flowing in communication line

$$\psi_j = 2\times10^{-7}\sum_{k=1}^{n} I_k \ln\frac{1}{D_{jk}}$$

# Flux linkage of conductor P (Communicated line)

$$\psi_p = 2\times10^{-7} I_a \ln\frac{1}{D_{ap}} + 2\times10^{-7} I_b \ln\frac{1}{D_{bp}} + 2\times10^{-7} I_c \ln\frac{1}{D_{cp}}$$

$$\psi_p = 2\times10^{-7}\left[ I_a \ln\frac{1}{D_{ap}} + I_b \ln\frac{1}{D_{bp}} + I_c \ln\frac{1}{D_{cp}}\right] \quad -(1)$$

FLUX LINKAGE of CONDUCTOR Q

$$\psi_q = 2\times10^{-7}\left[ I_a \ln\frac{1}{D_{aq}} + I_b \ln\frac{1}{D_{bq}} + I_c \ln\frac{1}{D_{cq}}\right] \quad -(2)$$

Flux linkage between P and q Conductor

$$\psi = \psi_p - \psi_q$$

$$\psi = 2\times10^{-7}\left[ I_a \ln\frac{1}{D_{ap}} - I_a \ln\frac{1}{D_{aq}} + I_b \ln\frac{1}{D_{bp}} - I_b \ln\frac{1}{D_{bq}} + I_c \ln\frac{1}{D_{cp}} - I_c \ln\frac{1}{D_{cq}}\right]$$

$$\psi_p - \psi_q = \psi = 2\times10^{-7}\left[ I_a \ln\frac{D_{aq}}{D_{ap}} + I_b \ln\frac{D_{bq}}{D_{bp}} + I_c \ln\frac{D_{cq}}{D_{cp}}\right]$$

- Since flux linkage is changing w.r.t time, so as per faraday law, EMF is induced.

$$e = -\frac{d\psi}{dt}$$

$$e = \frac{-d}{dt}[\psi_m \sin \omega t]$$

$$e = -\psi_m \omega \cos \omega t = \psi_m \omega \sin\left(\omega t + \frac{\pi}{2}\right)$$

$$\text{RMS value} = E = \frac{\psi_m \omega}{\sqrt{2}}$$

$$E = 2\pi f \frac{\psi_m}{\sqrt{2}} \qquad \psi = \frac{\psi_m}{\sqrt{2}}$$

$$E = 2\pi f \psi$$

# Induced EMF in p and q conductor

$$E_{pq} = E_p - E_q$$

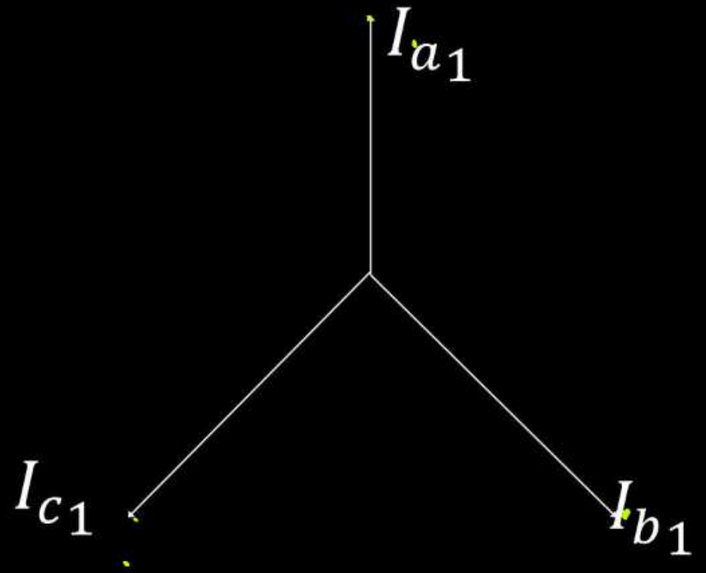
$$= 2\pi f \psi_p - 2\pi f \psi_q$$

$$E_{pq} = 2\pi f [\psi_p - \psi_q] = 2\pi f \psi$$

$$\boxed{E_{pq} = 2\pi f \psi}$$

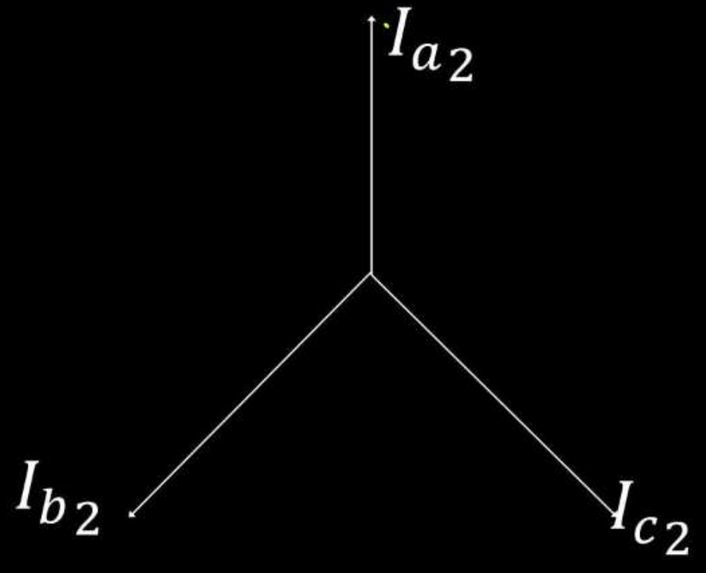
Where $\psi = 2 \times 10^{-7} \left[ I_a \ln \frac{D_{aq}}{D_{ap}} + I_b \ln \frac{D_{bq}}{D_{bp}} + I_c \ln \frac{D_{cq}}{D_{cp}} \right]$

## Balance Current:




Positive sequence

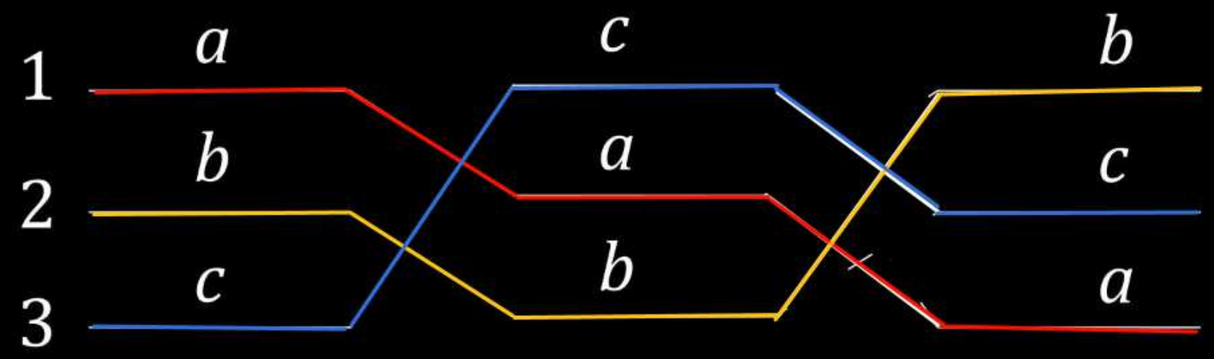
$$I_{a_1} + I_{b_1} + I_{c_1} = 0$$

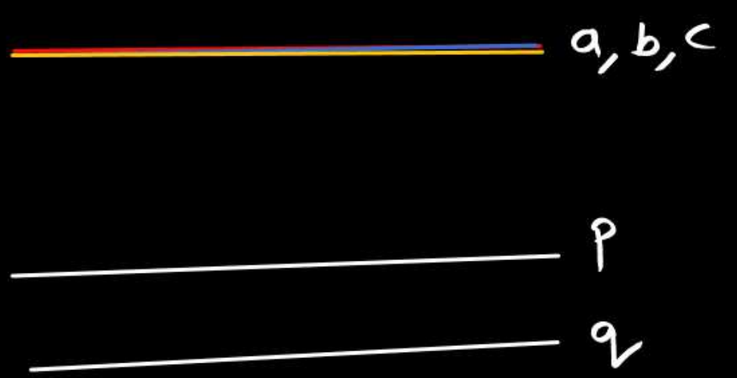



Negative sequence

$$I_{a_2} + I_{b_2} + I_{c_2} = 0$$

- In case of balance current the net flux linkage is very small (almost zero)




In complete transposition

$$D_{ap} = D_{bp} = D_{cp}$$

$$D_{aq} = D_{bq} = D_{cq}$$

$$\ln\left(\frac{D_{aq}}{D_{ap}}\right) = \ln\left(\frac{D_{bq}}{D_{bp}}\right) = \ln\left(\frac{D_{cq}}{D_{cp}}\right) = K$$

$$\psi = 2\times10^{-7}\left[I_a \ln\frac{D_{aq}}{D_{ap}} + I_b \ln\frac{D_{bq}}{D_{bp}} + I_c \ln\frac{D_{cq}}{D_{cp}}\right]$$

$$\psi = 2\times10^{-7}\left[I_a K + I_b K + I_c K\right]$$

$$\psi = 2\times10^{-7} K\left[I_a + I_b + I_c\right]$$

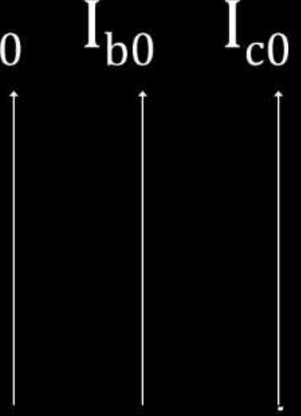
For positive and negative seq. $(I_a + I_b + I_c)$

$$\psi = 0$$

$$E = 2\pi f \psi = 0$$

# Unbalance Current

- But during unbalancing condition like (L – G) fault or due to corona the 3rd harmonic current flow(zero seq)




$$I_{a0} = I_{b0} = I_{c0}$$

Even if power line is transposed,

$$\psi = 2 \times 10^{-7} \, k \, [I_{a0} + I_{b0} + I_{c0}]$$

$$\psi = 2 \times 10^{-7} \, k \, (3 I_{a0})$$

$\psi = 3\psi$ (3 time of 1$\phi$ flux)

$E = 2\pi f \psi$

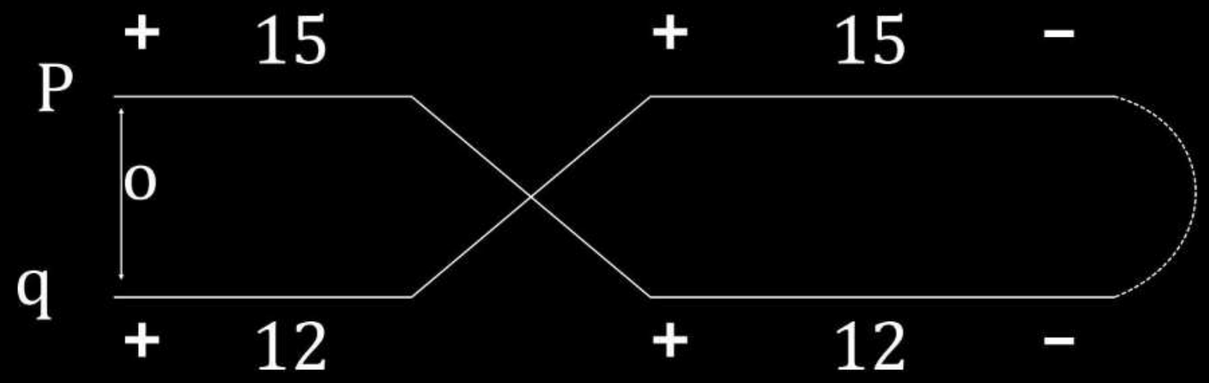
$E = 2\pi (3f)(3\psi)$

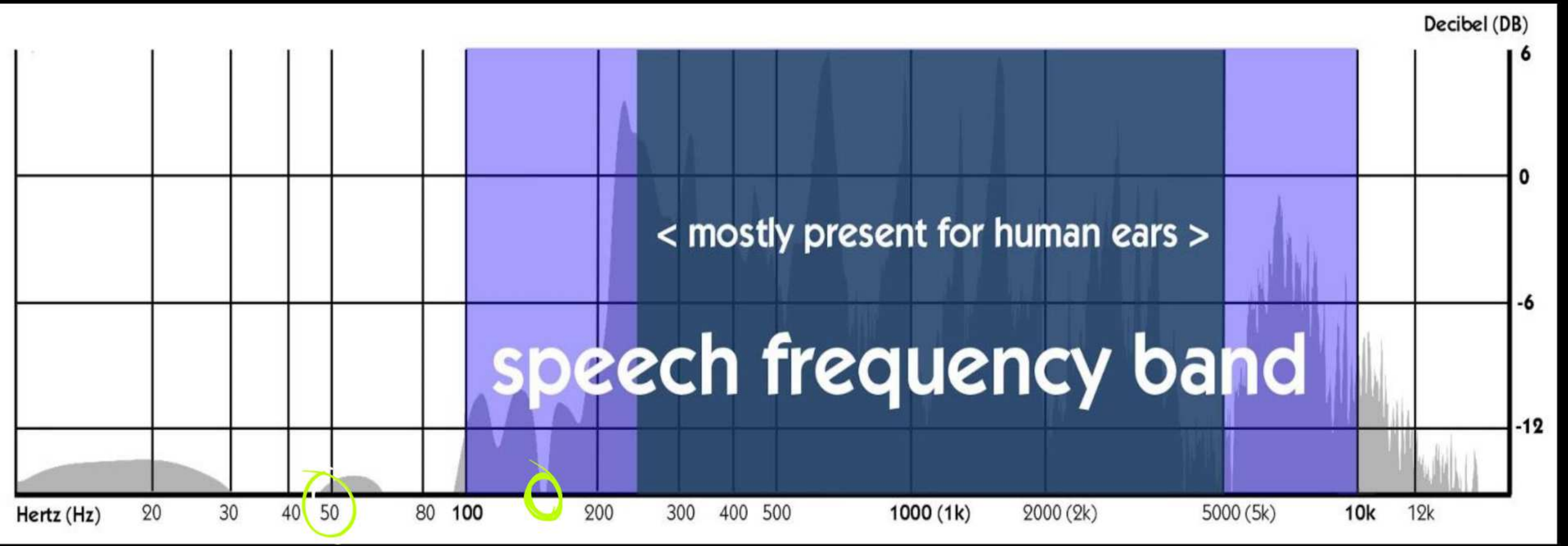
$E = 9$ times of $1\phi$

$50\,Hz \times 3 = 150\,Hz$

The high frequency is also in audible range, so it should be eliminated.

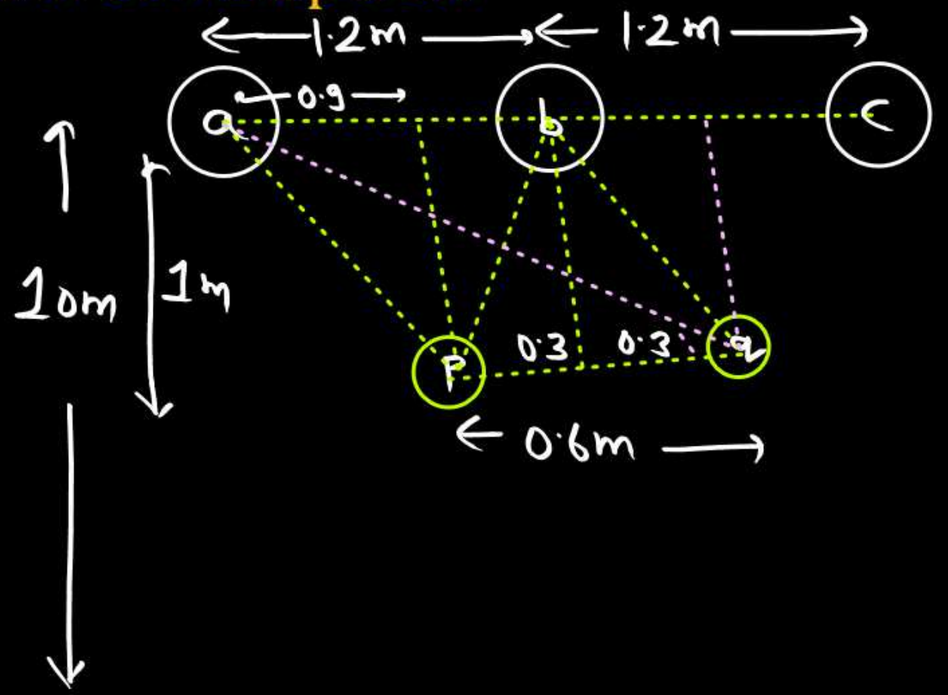
- So to eliminate current due to unbalance current the communication line should also transposed.




Decibel (DB)
6
0
-6
-12
< mostly present for human ears >
speech frequency band
Hertz (Hz)
20
30
40
50
80
100
200
300
400
500
1000 (1k)
2000 (2k)
5000 (5k)
10k
12k

**NAT**

#Q. A 3 phase 11 kV 50 Hz feeder has horizontal configuration with 1.2 m between adjacent conductors. The height of the conductors above ground is 10m. A telephone line is run on the same supports. The horizontal distance between the telephone wires is 0.6m. The vertical distance between the power line and the telephone line is 1m. Find the magnitude of the voltage induced in the telephone circuit due to electromagnetic induction if the power line carries a balanced current of 300 amperes.




$$D_{ap} = D_{cq} = \sqrt{1^2 + 0.9^2} = 1.345$$

$$D_{bp} = D_{bq} = \sqrt{1^2 + 0.3^2} = 1.044$$

$$D_{aq} = D_{cp} = \sqrt{1.5^2 + 1^2} = 1.803$$

$$\psi = 2\times10^{-7}\left[I_a \ln\frac{D_{aq}}{D_{ap}} + I_b \ln\frac{D_{bq}}{D_{bp}} + I_c \ln\frac{D_{cq}}{D_{cp}}\right]$$

$$\psi = 2\times10^{-7}\left[(300\angle 0)\ln\frac{1.803}{1.345} + (300\angle -120)\ln\frac{1.044}{1.044} + (300\angle -240)\ln\frac{1.345}{1.803}\right]$$

$\ln 1 = 0$

$$\psi = 2\times10^{-7}\left[(300\angle 0)(0.293) + (300\angle -240)(-0.293)\right]$$

$$\psi = (304.55\angle -30)\times10^{-7}$$

$$E = 2\pi f \psi$$

$$E = 100\pi (304.55\angle -30) \times 10^{-7}$$

$$E = 9.57 \times 10^{-3} \text{ V}$$

**NAT**

#Q. Calculate the voltage induced due to electromagnetic induction in the telephone line of last question under the condition of a single line to earth fault on phase *a* if the fault current is 2000 amperes.

$$I_a = 2000 \quad I_b = I_c = 0$$

$$\psi = 2\times10^{-7} I_a \ln \frac{D_{aa'}}{D_{ap}}$$

$$\psi = (2\times10^{-7})(2000) \ln \frac{1.803}{1.345}$$

$$\psi = 1172.23\times10^{-7}$$

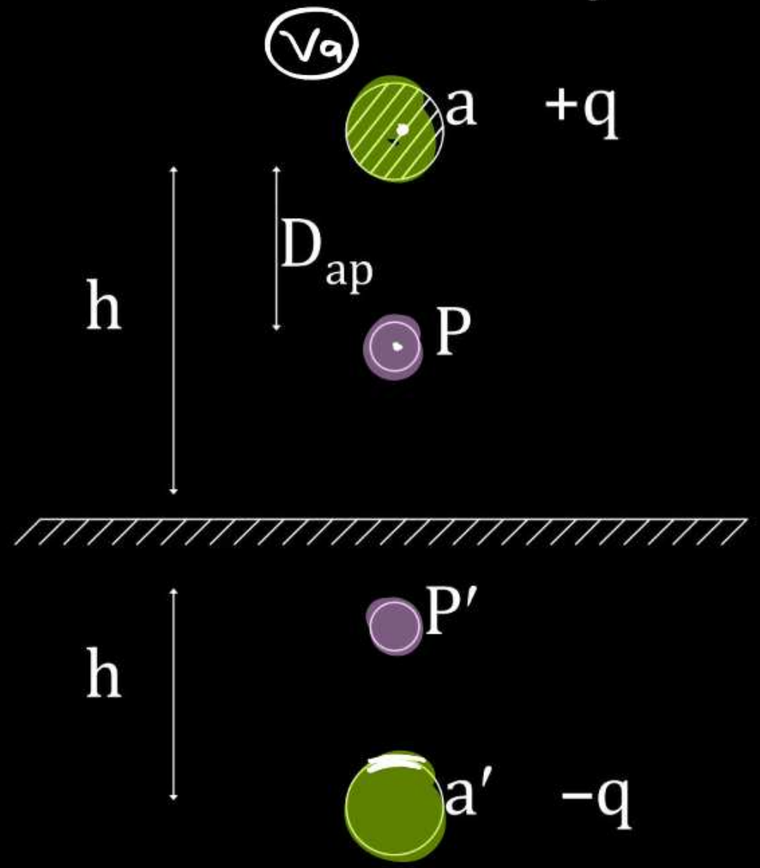
$$E = 2\pi f \psi$$

$$= 100\pi \times 1172.23\times10^{-7}$$

$$E = 0.0368 \ V/m$$

# Electrostatic Induction:

The charge is induced in a nearly conducting material due to electrical field.



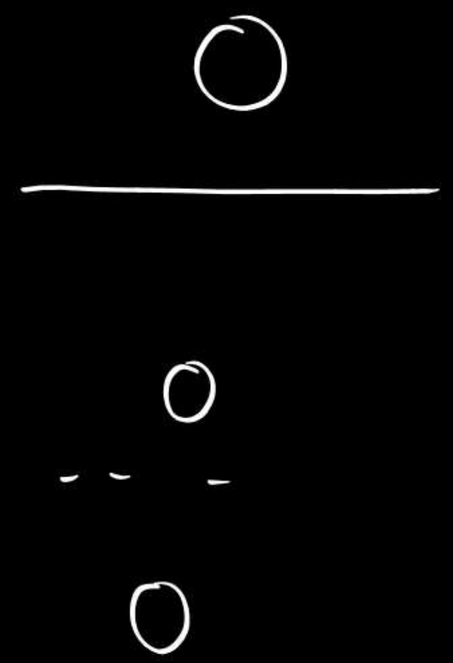
The potential of a with respect to ground

$$V_{ag} = \frac{q}{2\pi\epsilon} \ln \frac{h}{r} + \frac{(-q)}{2\pi\epsilon} \ln \frac{h}{(2h-r)}$$

$$V_{ag} = \frac{q}{2\pi\epsilon} \ln \frac{h}{r} \cdot \frac{(2h-r)}{h}$$

$$V_{ag} = \frac{q}{2\pi\epsilon} \ln \frac{(2h-r)}{r}$$

$$\frac{q}{2\pi\epsilon} = \frac{V_a}{\ln\left(\frac{2h-r}{r}\right)} \quad -(1)$$



The potential of P with respect to ground

$$V_{Pg} = \frac{q}{2\pi\epsilon} \ln \frac{h}{Dap} + \frac{(-q)}{2\pi\epsilon} \ln \frac{h}{2h-Dap}$$

$$V_P = \frac{q}{2\pi\epsilon} \left[ \ln \frac{h}{Dap} - \ln \frac{h}{2h-Dap} \right]$$

$$V_P = \frac{q}{2\pi\epsilon} \ln \frac{h}{Dap} \cdot \frac{2h-Dap}{h} = \frac{q}{2\pi\epsilon} \ln \frac{2h-Dap}{Dap}$$

$$V_{P(a)} = V_a \frac{\ln\left(\frac{2h - D_{ap}}{D_{ap}}\right)}{\ln\left(\frac{2h - r}{r}\right)}$$

Voltage Induced in P Conductor due to phase a Conductor

— Similarly voltage induced in P conductor due to phase b conductor

$$V_{P(b)} = V_b \frac{\ln\left(\frac{2h - D_{bp}}{D_{bp}}\right)}{\ln\left(\frac{2h - r}{r}\right)}$$

— Voltage induced in p conductor due to c phase

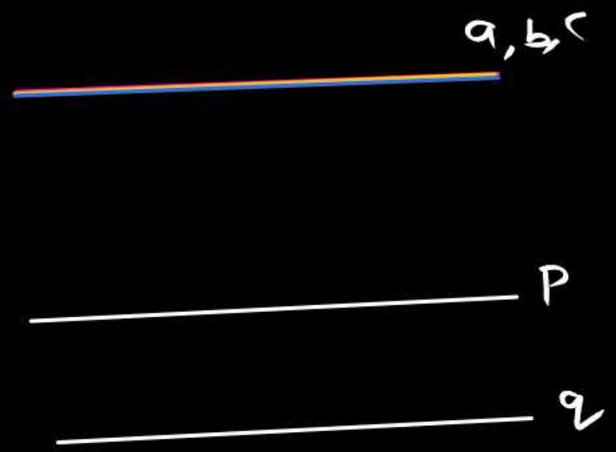
$$V_{P(c)} = V_c \ln\left(\frac{2h - D_{cp}}{D_{cp}}\right) \Big/ \ln\left(\frac{2h - r}{r}\right)$$

So total potential of P

$V_P = V_{P(a)} + V_{P(b)} + V_{P(c)}$

- The transposition of power line neutralized the unbalance in capacitance. So electrically induced voltage are neutralized in complete set of transposition.

$$D_{aP} = D_{bP} = D_{cP}$$



$$\frac{\ln\left(\frac{2h-D_{aP}}{D_{aP}}\right)}{\ln\left(\frac{2h-r}{r}\right)}=\frac{\ln\left(\frac{2h-D_{bP}}{D_{bP}}\right)}{\ln\left(\frac{2h-r}{r}\right)}=\frac{\ln\left(\frac{2h-D_{cP}}{D_{cP}}\right)}{\ln\left(\frac{2h-r}{r}\right)}=k$$

$$V_P = V_{P(a)} + V_{P(b)} + V_{P(c)}$$

$$V_p = V_a k + V_b k + V_c k$$

$$= k\left[\bar{V}_a + \bar{V}_b + \bar{V}_c\right]$$

$$V_P = 0$$

- However, a voltage due to electrostatic induction will still exist between communication line & ground, so insulator of communication line should be able to with stand it.

**NAT**

#Q. A 3 phase 11 kV 50 Hz feeder has horizontal configuration with 1.2 m between adjacent conductors. The height of the conductors above ground is 10m. A telephone line is run on the same supports. The horizontal distance between the telephone wires is 0.6m. The vertical distance between the power line and the telephone line is 1m. Find the magnitude of the voltage induced in the telephone circuit due to electrostatic induction if the diameter is 14.15 mm each

$$V_{P(a)} = V_a \frac{\ln\left(\frac{2h-D_{ap}}{D_{ap}}\right)}{\ln\left(\frac{2h-r}{r}\right)} = \frac{11000}{\sqrt{3}}\angle 0 \frac{\ln\left(\frac{20-1.345}{1.345}\right)}{\ln\left(\frac{20-0.7075\times10^{-2}}{0.7075\times10^{-2}}\right)} = 2101\angle 0$$

Similary $V_{P(b)} = 2317\angle -120$

$V_{P(c)} = 1847\angle -240$

$V_P = V_{P(a)} + V_{P(b)} + V_{P(c)}$

$= 2101\angle 0 + 2317\angle -120 + 1847\angle -240$

$= 404.47\angle -87.32$

# 2 Minutes Summary

→ Interference with Communication line
- Electromagnetic
- Electrostatic

# Thank you GW *Soldiers !*