HIGH VOLTAGE
Breakdown phenomena

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Corona

- Literal meaning of corona is «light crown»

- Physical meaning of corona is partial discharge occurring around regions with small curvature radius (sharp edges, corners, needles, ...)

![Diagram of corona phenomena: a corner, a rod electrode, and a needle with lightning symbols and arrows indicating the discharge path.](image-url)
Corona

• In a uniform electric field, a gradual increase in voltage across a gap produces a breakdown of the gap in the form of a spark without any preliminary discharges.

• On the other hand, if the field is non-uniform, an increase in voltage will first cause a localised discharge in the gas to appear at points with the highest electric field intensity, namely at sharp points or where the electrodes are curved or on transmission line conductors.

• This form of discharge is called a corona discharge and can be observed as a bluish luminance.
Characteristic properties of corona

Corona has a specific

- Light
- Sound
- Smell ($O_3$)
Waveform of corona current
• The shunt current in a line is almost purely capacitive under normal conditions, and leads the applied voltage by 90°, and there is no power loss in the line under no-load conditions.

• When the applied voltage is increased and corona is formed, the air is rendered conducting, and power loss occurs.

• The shunt current would no longer be leading the voltage by 90°. Thus the current waveform would consist of two components.

• The lossy component would be non-sinusoidal and would occur only when the disruptive critical voltage is exceeded in either polarity.
Mechanism of corona

• The stress surrounding the conductor is a maximum at the conductor surface itself, and decreases rapidly as the distance from the conductor increases.
• Thus when the stress has been raised to critical value immediately surrounding the conductor, ionisation would commence only in this region and the air in this region would become conducting.
• The effect is to increase the effective conductor diameter while the voltage remains constant.
This has two effects:

1. an increase in the effective sharpness of the conductor would reduce the stress outside this region,
2. this would cause a reduction of the effective spacing between the conductors leading to an increase in stress.

Depending on which effect is stronger, the stress at increasing distance can either increase or decrease. If the stress is made to increase, further ionisation would occur and flashover is inevitable.
• Under ordinary conditions, the breakdown strength of air can be taken as 30 kV/cm.
• Corona will of course be affected by the physical state of the atmosphere.
• In stormy weather, the number of ions present is generally much more than normal, and corona will then be formed at a much lower voltage than in fair weather.
• This reduced voltage is generally about 80% of the fair weather voltage.
Current voltage characteristic
**Visual corona**

- Visual corona occurs at a higher voltage than the disruptive critical voltage. For the formation of visual corona, a certain amount of ionization, and the raising of an electron to an excited state are necessary.

- The production of light by discharge is not due to ionisation, but due to excitation, and subsequent giving out of excess energy in the form of light and other electromagnetic waves.

- To obtain the critical voltage for visual corona formation, the disruptive critical voltage has to be multiplied by a factor dependant on the air density and the conductor radius.
Power loss due to corona

• The formation of corona is associated with a loss of power.

• This loss will have a small effect on the efficiency of the line, but will not be of sufficient importance to have any appreciable effect on the voltage regulation.

• The more important effect is the radio interference.
Corona voltage

\[ U_c = U_0 \times m \times \delta \times \left( 1 + \frac{0.301}{\sqrt{r \times \delta}} \right) \]

\[ m = 1 - 0.8 \]

\[ \delta = \frac{p}{p_0} \cdot \frac{T_0}{T} = \frac{p}{760[mmHg]} \cdot \frac{273 + 20^\circ C}{273 + \theta^\circ C} = 0.386 \frac{p[mmHg]}{273 + \theta^\circ C} \]
For an overhead line

- Single phase:
  \[ U_c = 21.2 \times m \times r \times \delta \times \left(1 + \frac{0.301}{\sqrt{r \times \delta}}\right) \times \ln \frac{d}{r} \]

- Three phase:
  \[ U_c = \sqrt{3} \times 21.2 \times m \times r \times \delta \times \left(1 + \frac{0.301}{\sqrt{r \times \delta}}\right) \times \ln \frac{d}{r} \]
Corona loss (Peak formula)

\[ P_c = \frac{243}{\delta} \times (f + 25) \times \sqrt{\frac{r}{d}} \times (U - U_0)^2 \times 10^{-5} \left(\text{kW/km.phase}\right) \]