Chapter Six

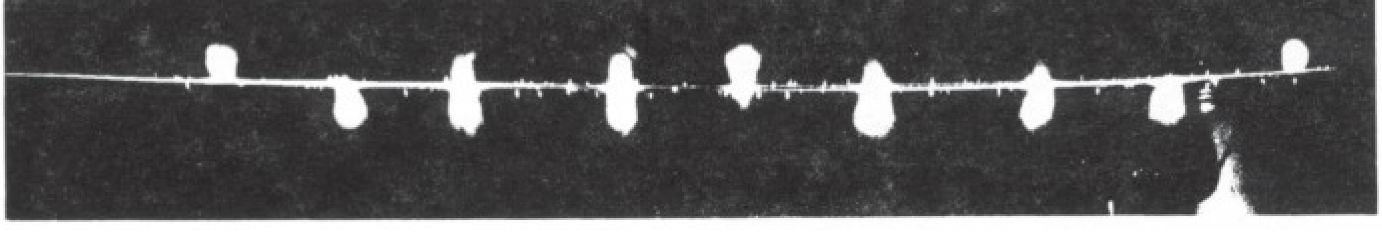
Corona:

When an alternating potential difference is applied across two conductors whose spacing is large as compared to their diameters, there is no apparent change in the condition of atmospheric air sur-rounding the wires if the applied voltage is low. However, when the applied voltage exceeds a certain value, called critical disruptive voltage, the conductors are surrounded by a faint violet glow called corona.

The phenomenon of corona is accompanied by a hissing sound, production of ozone, power loss and radio interference. The higher the voltage is raised, the larger and higher the luminous envelope becomes, and greater are the sound, the power loss and the radio noise. If the applied voltage is increased to breakdown value, a flash-over will occur between the conductors due to the breakdown of air insulation.

The phenomenon of violet glow, hissing noise and production of ozone gas in an overhead transmission line is known as corona.

If the conductors are polished and smooth, the corona glow will be uniform throughout the length of the conductors, otherwise the rough points will appear brighter. With d.c. voltage, there is difference in the appearance of the two wires. The positive wire has uniform glow about it, while the negative conductor has spotty glow.



Theory of corona formation:

Some ionization is always present in air due to cosmic rays, ultra-violet radiations and radioactivity. Therefore, under normal conditions, the air around the conductors contains some ionized particles (i.e., free electrons and +ve ions) and neutral molecules.

When p.d. is applied between the conductors, potential gradient is set up in the air which will have maximum value at the conductor surfaces. Under the influence of potential gradient, the existing free electrons acquire greater velocities. The greater the applied voltage, the greater the potential gradient and more is the velocity of free electrons.

When the potential gradient at the conductor surface reaches about 30 kV per cm (max. value), the velocity acquired by the free electrons is sufficient to strike a neutral molecule with enough force to dislodge one or more electrons from it.

This produces another ion and one or more free electrons, which is turn are accelerated until they collide with other neutral molecules, thus producing other ions. Thus, the process of ionization is cumulative. The result of this ionization is that either corona is formed or spark takes place between the conductors.

*Factors affecting Corona

The phenomenon of corona is affected by the physical state of the atmosphere as well as by the conditions of the line. The following are the factors upon which corona depends :-

1)Atmosphere

As corona is formed due to ionization of air surround ding the conductors, therefore, it is affected by the physical state of atmosphere. In the stormy weather, the number of ions is more than normal and such corona occurs at much less voltage as compared with fair weather.

2-Conductor Size :-

The corona effect depends upon the ship and conditions of the conductors. The rough and irregular surface will give rise to more corona because unevenness of the surface decreases the value of break down voltage. Thus a stranded conductor has irregular surface and hence gives rise to more corona that a solid conductor.

3-Spacing between Conductors :-

If the spacing between the conductor is made very layer as compared to their diameters , there may not be any corona effect. It is because layer distance between the conductors reduces the electro- static stresses at the conductor surface, thus avoiding corona formation.

4-Line voltage :-

The line voltage greatly affects corona. If it is low, there is no charge in the condition of air surrounding the conductors and hence no corona is formed. However if the line voltage has such a volue that electro static stress developed at the conductor surface make air around the conductor conducting then corona is formed

Advantages and disadvantage of corona :-

Corona has many advantages and disadvantages. In the correct design of high voltage overhead line, a balance should be struck between the advantages and disadvantage.

*Advantages :-

1- Due to corona formation, the air surrounding the conductor becomes conducting and hence virtual diameter of the conductor is increased. The increased diameter reduces the electro static stress between the conductors.
2- Corona reduces the effect of transient produced by surges.

*Disadvantages :-

1- Corona is a accompanied by a loss of energy. This affects the transmission efficiency of the line.
2- Ozona is produced by corona and may cause corrosion of the conductor due to chemical action.
3- The current drawn by the line due to corona is non- sinusoidal and hence non- sinusoidal voltage drop occurs in the line. This may cause inductive interference with neighboring communication lines.

*Method of Reduction Corona Effect :-

It has been seen that intense corona effects, are observed at working voltage of 33 kv or about. Therefore, careful design should be made to avoid corona on the sub- station or bus-bars rated for 33 kv and higher voltage otherwise highly ionized air may cause flash-over in the insulators or between the phases, causing considerable damage to the equipment. The corona effects can be reduce by :-

1-By increasing conductor size :-

By increasing conductor size, the voltage at which occur of corona is raised and hence corona effects are considerably reduced. This is one of the reasons that ACSR conductors which have a larger cross- sectional area are used in transmission lines.

2-By increasing conductor spacing :-

By increasing the spacing between conductors, the voltage at which corona occurs is raised and hence corona effects can be eliminated. However spacing cannot be increasing too much otherwise the cost of supporting structure (i-e bigger cross- and supports) may increase to a considerable extent.

*Important Terms :-

The phenomenon of corona plays an important role in the design of an overhead transmission line.
Therefore, it is profitable to consider the following terms much used in the analysis of corona effects :-

1-Critical disruptive voltage :-

It is the minimum phase – neutral voltage at which corona occurs. Consider two conductors of radius (r)cm and spaced (d)cm apart. If V is the phase- neutral potential, then potential gradient at the conductor
Surface is given by :

$$E = \frac{V}{r 1n \frac{d}{r}}$$

In order that Corona is formed, The value of (E)Must be made equal To break down strength of Air.
The corona begins when the peak value of of critical field intensity equals 30 kv/cm
The break down strength of air at 76 cm mercury pressure and temperature of 25 °C is 30 kv/cm (max) or $\frac{30}{\sqrt{2}} = 21.2\ kv/cm$ (r.m.s) and is denoted by E_O .
IF V_O is the phase- neutral potential required under these condition, then

$$E_O = \frac{V_O}{r 1n \frac{d}{r}} \quad kv/cm$$

E_O = break down strength of air at 76 cm of mercury
And 25 °C $= 30\,\frac{kv}{cm}\,(\text{max})\text{or}21.2\ \text{kv/cm}\ (\text{r.m.s})$

$\therefore$ *critical disruptive voltage* V_O : −

$$V_O = 21.1\, r\, 1n \frac{d}{r}\ volt$$

The above expression for disruptive voltage is under stander conditions i.e., at 76 cm of Hg (mercury) and 25℃ . however , if these conditions vary, the air density also changes, thus altering the value of E_O . The value of E_o is directly proportional air density. Thus the break down strength of air at a barometric pressure of b cm of mercury and temperature of t ℃ become

$\delta\ E_O$ *where*

$$\delta = \frac{3.92\, b}{273 + t}\quad (air\ density\ factor)$$

Under slandered conditions, the value of $\delta = 1$

Critical disruptive voltage $V_O = 21.2\ \delta\ r 1n \frac{d}{r}$

Correction must also be made for the surface of the conductor. This Is accounted for by multiplying the above expression by irregularity factor m_o.

$$\therefore V_O = 21.2\, m_o \delta\, r\, 1n \frac{d}{r} \quad kv/phase$$

$m_o = 1$ for polished conductor

$= 0.98 \rightarrow 0.92$ for dirty conductor

$= 0.87 \rightarrow 0.8$ for stranded conductor

$$\boxed{V_o = 21.2\ m_o \delta\ r 1n \frac{d}{r}} \quad kv/\ phase$$

Critical disruptive voltage

2-Visual critical Voltage :-

It is the minimum phase- neutral voltage at which corona glow appears all along the line conductors. It has been seen that in case of parallel conductors, the corona glow does not begin at the disruptive voltage V_O but at a higher voltage V_O, called visual critical voltage. The phase- neutral voltage of visual critical is :-

$$V_V = m_v \delta\, r \left(1 + \frac{0.3}{\sqrt{\delta r}}\right) 1n \frac{d}{r} \qquad kv/phase$$

Where m_V is another irregularity factor having avolue of 1 for polished conductors

0.72 → 0.82 for rough conductor

*Power loss due to corona:-

Formation of corona is always accompanied by energy loss which dissipated in the form of light, heat, sound, and chemical action. When disruptive voltage is exceeded, the power loss due to corona is given by :-

$$P = 242.2 \left(\frac{F + 25}{\delta}\right) \sqrt{\frac{r}{d}} (V - V_V)^2 \times 10^{-5} \qquad kw/km/phase$$

F = Supply frequency

V= Phase- neutral voltage

V_V = disruptive voltage (r. m .s) per phase

Ex1) A 132 kv 3φ line with 1.956 cm diameter conuctor is built so that corona takes place if the line voltage exceeds $210kv$ $(r.m.s)$. If the value of potential gradient at which ionization occurs can be taken as $30\ kv/cm$. Find spacing between the conductors.

So1) $r = \frac{1.956}{2} = 0.978\ cm$

$$E_O = \frac{30}{\sqrt{3}} = 21.2\ (r.m.s)$$

$$m_o = 1\ (\textit{smooth conductor})$$

$$\delta = 1\ (\textit{stander pressure and tempertue})$$

$$V_O = 21.1\ m_o\ \delta\ r\ 1n\frac{d}{r}$$

Disruptive voltage / phase = $\frac{210}{\sqrt{3}} = 121.25\ kv$

$$\therefore 121.25 = 21.1 \times 1 \times 1 \times D.978 \times 1n\frac{d}{r}$$

$$1n\frac{d}{r} = 5.84 \Rightarrow d = 34/cm$$

Ex2) $3-\varphi\ 220\ kv, 50\ Hz,$ transmission line consists of 1.5 cm radius conductor spaced 2m a part in equilateral triangular formation. If the temperature is 40 ℃ and atmospheric pressure is 76 cm find the corona loss per km of the line. Take $m_o = 0.85$

So1)

$$P = \frac{242.2}{\delta}(F+25)\sqrt{\frac{r}{d}}(V-V_C)^2 \times 10^{-5}\ kw/km/\varphi$$

$$\delta = \frac{3.92\ b}{273+t} = \frac{3.92\times 76}{273+40} = 0.952$$

$$V_O = 21.1\ m_o\delta\ r\ 1n\frac{d}{r}$$

$$= 21.1 \times 0.85 \times 0.952 \times 1.5 \times 1n\frac{200}{1.5} = 125.9\ kv$$

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

$$P = \frac{242.^2}{0.95^2}(50+25)\sqrt{\frac{1.5}{200}}(127-125.9)^2 \times 10^{-5}$$

$$= 0.01999 \quad kw/km/\varphi$$

$$\therefore Total\ \ corona\ loss\ per\ km\ for\ 3-\varphi$$

$$= 3 \times 0.01999 = 0.05998\ kw$$