③ Sparking Voltage - pashen's law :-

According to Townsend's theory the breakdown critirian for gasses is given as

$$\gamma\left[\exp(\alpha d)-1\right]=1$$

Where: the coffieient α and γ are functions of p & E/P

important realtionship between breakDown Voltage of the gas and p and d. where d is the gap length

While dreiving the relationship said above the made Some approeximations, i.e

$$\frac{\alpha}{P}=f_1(E/P)$$

and $\gamma=f_2(E/P)$

We know that electric field in the gap between electrodes Supplied with V volts is

$$E=V/d$$

Substituing E in α/P & γ expressions and then rewriting Townsend's critirion for Breakdown in gases we get,

$$\frac{\alpha}{P}=f_1(E/P)=f_2(V/Pd)\Rightarrow\alpha=P.f_1(V/Pd)$$

and $\gamma=f_2(E/P)=f_2(V/Pd)$.

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lec. ④

$$\gamma\left[\exp(\alpha d)-1\right]=1$$

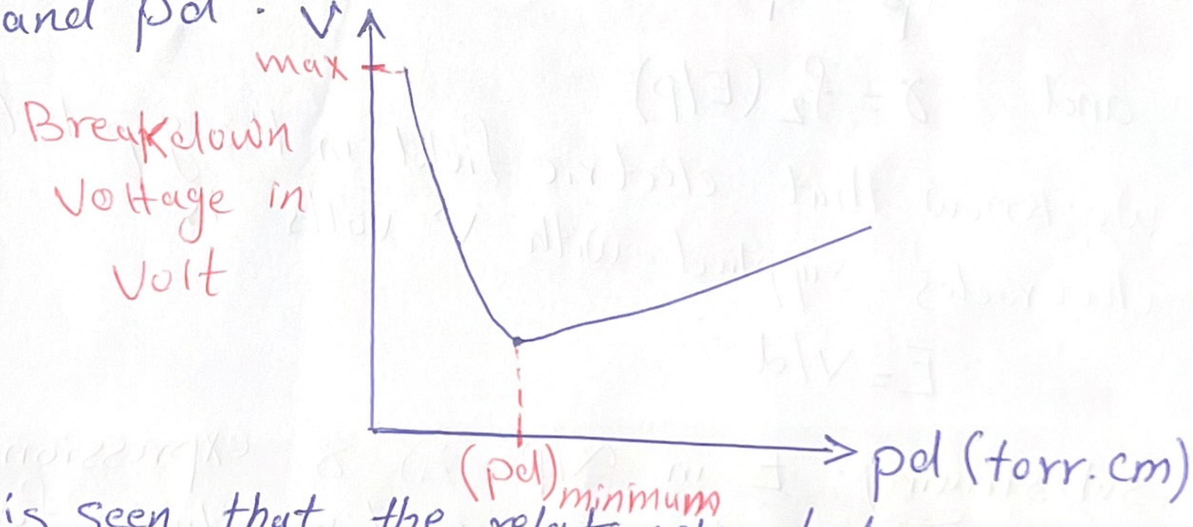
$$\Rightarrow f_2(V/pd)\left\{\left[\exp\left(pd\cdot f_1(V/pd)\right)\right]-1\right\}=1$$

This equation shows a relationship between V & pd and implies that the Breakdown Voltage various as the product p and d i.e pd varios.

$$V=f(pd)$$

This equation is known as Pashen's Law

The graph below shows the relationship between V and pd.



It is seen that the relationship between V and pd is not linear and has a minmum value for any gas.

This means that a breakdown Voltage of a uniform field gap is unique function of p and pd

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For aparticular gas and particular material used in making electrodes.

The minmum point in the graeph is due to transition from Townsend's mechanism to streamer mechanism.

In order to account for the effect of temperture the pashen's law is generally stated as

$$V = f(Nd),$$

Where: N is the density of gas molecules.

This is necessary the pressure because the gas changes with tempreature according to the gas-law

$PV = NRT$, Where V is the Volume of the gas, T is the temprature of the gas and R is a constant

Based on exprementaI results, the breakdown potentional of air is expressed as a power function in pd as

$$V = 24.22\left[\frac{293pd}{760T}\right] + 6.08\left[\frac{293pd}{760T}\right]^{1/2}$$

In avoide expression if we put $p = 760$ torr and $T = 293$ K we get,

$$E = \frac{V}{d} = 24.22 + \left[\frac{6.08}{\sqrt{d}}\right] \text{ kV/cm}$$

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and this equation gives limiting values for E for long gap as,

$$E = V/d = 24 \text{ kV/cm}$$

and $E = 30 \text{ kV/cm}$ For $\left(\frac{293\, pd}{760\, T}\right) = 1$,

Which means apressure of 760 torr at 20°C with 1 cm gap. This is usually get breakdown strenght of air at room temprature and at 1 atmosphric pressure.

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Partial Breakdown and Corona:-

ظاهرة تحدث في خطوط النقل العالي تسمى ظاهرة كورونا
(ظاهرة الهالة التي تحيط بخطوط النقل الكهربائي) فوق 30KV
تعتبر ظاهرة تفريغ للشحنات

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 atmosphric air
Surrounding the wires if the applied Voltage is low.
However, when the applied Voltage ecxeeds acertain
Value, Called Critical disruptive Voltage, the Conductors
are surround by a faint Violet glow called Corona.

تصاحب هذه الظاهرة عدة اشكال من الحالات :-

The phenomenon of Corona is accompained by:
1. Hissing Sound, 2. production of OZONE,
3. power loss and 4. Ratio interference. (noise)

عند تسليط تيار متناوب على موصلين عندما يكون البعد بينهم اكبر من القطر
المركزي فيا هذه الحالة لا تظهر اي شحنة في الهواء الجوي حول الاسلاك

← تعتبر ظاهرة Corona عملية تأين الاسلاك سببها الفولتية العالية
الموجودة في خطوط النقل باللون البنفسجي
ولكن عندما ترتفع قيمة الفولتية للاسلاك الحاملة بواسطة خطوط النقل
تظهر هذه الظاهرة حولها وتكون باللون البنفسجي .

The higher Voltage is raised, the larger and higher
of luminous envelope becomes, and greater are the
Sound, power loss and ratio noise. If the applied
Voltage is increased to breakdown are value with-
flash-over will occur between the conductors due to
the breakdown of air insulation.

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Lec. (5)

The phenomenon of Violet glow, hissing noise and production of OZone gas in an Over head transmission line is known as Corona.

If the conductors are polished and smooth, the Corona glow will be uniform thoughout the lenght of the Conductors, otherwise the rough points will appear brigther. 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. حبيبات متوهجة

Factors Effecting on CORONA :- العوامل المؤثرة

The phenomenon of Corona is affected by the physical state of the atmospheric as well as by the Conditions of the line. The following are the factors upon which Corona depends:

1. Atomsphric , 2. Conductor Size , 3. Spacing between Conductors , 4. line voltage

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MATHEMATICAL-TERMS:-

The phenomenon of Corona an important 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 radii r cm and spaced d cm apart. If V is the phase-neutral potential, then potential gradient at the conductor surface is given by:-

V: critical disruptive voltage

مهمة جداً * $g = \dfrac{V}{r \log_e \frac{d}{r}}$ Volts/cm

In order to that Corona is formed, the value of g must be made equal to the breakdown strength of air. The breakdown strength of air at 76 cm pressure and temperature of 25C° is 30 kV/cm (max) or 21.2 kV/cm (r.m.s) and is denoted by g_o. If V_c is the phase-neutral potential required under these conditions, then

$$g_o = \frac{V_c}{r \log_e \frac{d}{r}}$$

Where: g_o = breakdown strength of air at 76 cm of mercury at 25C°
= 30 kV/cm (max) or 21.2 kV/cm (r.m.s)

∴ [Critical disruptive Voltage, $V_c = g_o \, r \log_e \frac{d}{r}$]

مهمة جداً *

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The above expression for disruptive Voltage is under stander Conditions i.e, at 76 cm of Hg and 25C°. However, if these conditions vary, the air density also changes, thus altering the value of g_o.

The value of g_o is directly proportional to air density. Thus the breakdown strength of air at a barometric pressure of b cm of mercury and temperature of tC° becomes δ = Sigma

where δ = air density factor = $\frac{3.92b}{273+t}$

Under stander conditions, the value of $\delta = 1$.

Critical disruptive Voltage, ; At standard condition

$$\left[V_c = g_o \delta r \log_e \frac{d}{r} \right]$$

Correction must also be made for the surface condition of the conductor. This is accounted for by multiplying the above expression by irregularity factor m_o. (m_o: يتحكم هذا العامل في انتظام السطح او عدم انتظامه)

∴ Critical disruptive Voltage,

$$V_c = m_o g_o \delta r \log_e \frac{d}{r} \text{ kV/phase}$$

where $m_o = 1$ for polished conductors.
$= 0.98$ to 0.92 for dirty conductors.
$= 0.87$ to 0.8 for standrad conductors.

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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, It has the corona glow does not begin at disruptive Voltage V_c but at a higher Voltage V_r, Called Visual Critical Voltage. The phase -neutral effective Value of visual Voltage is given by the following empirical formula:

$$V_r = m_v g_o \delta r \left[1 + \frac{0.3}{\sqrt{\delta r}}\right] \log_e \frac{d}{r} \ \text{kV/phase}$$

Where : m_v is another irregularity factor having a value of 0.1 for polished conductors and 0.72 to 0.82 for rough Conductors.

3- Power loss due Corona :-

Formation of Corona is always accompanied by energy loss whichis dissipated in the form of light, heat, Sound and chemical action. Whe disruptive voltage is exceeded the power loss due to Corona is given by

$$P = 242.2 \left[\frac{f+25}{\delta}\right] \sqrt{\frac{r}{d}} \ (V-V_c)^2 \times 10^{-5} \ \text{kW/km/phase}$$

Where: f = Supply frequency in HZ

فولتية العابر V = phase- Voltage neutral (r.m.s)

فولتية الحرج V_c = disruptive Voltage (r.m.s) per phase

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تسبب ظاهرة Corona خسائر في الفولتية المتولدة في الاسلاك النقل الحالية ولكي نعمل على تقليل هذه الظاهرة تطلبت عدة نظريات منها :-

METHODS OF REDUCING CORONA EFFECT:-

It has been seen that intense corona effects are observed at working voltage of 33 kV or above. Therefore, careful design should be made to avoid corona on the sub-stations or busbars rated for 33 kV and higher voltages otherwise highly ionized air may cause flash-over in the insulators or between the phases, causing considerable damage to the equipment. The corona effect can be reduced by the following methods:-

يسبب اضرار قوية في المعدات

1. **By increasing conductor size:** By increasing conductor size, the voltage at which corona occurs 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 line.

ACSR = نوعية الكيبل المستخدم يكون الالمنيوم ودعم داخلياً بالستيل

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

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Example:- 8.13

A 3-phase line has conductors 2cm in diameter spaced equilartally 1 m apart. If the dielectric strength of air is 30 kV (max) per cm, find the disruptive critical voltage for the line. Take air density factor $\delta = 0.952$ and irregulartiy factor $m_o = 0.9$?

Solution.

Conductor radius, $r = 2/2 = 1$ cm

Conductor Spacing, $d = 1m = 100$ cm

Dielectric strength of air, $g_o = 30$ kV/cm (max.)
$= 21.2$ kV (r.m.s) per cm

Disruptive critical voltage, $V_c = m_o g_o \delta r \log_e (d/r)$ kV/phase [(r.m.s) . Value]

$\therefore V_c = 0.9 \times 21.2 \times 0.952 \times 1 \times \log_e 100/1 = 83.64$ kV/phase

$\therefore$ line voltage (r.m.s) $= \sqrt{3} \times 83.64 = 144.8$ kV.

Example: 8.14

A 132 kV line with 1.956 cm dia. conductors is built so that corona takes place if the line voltage axceeds 210 kV (r.m.s) - If the value of potential gradient at which ionization occurs can be taken as 30 kV per. cm find the spacing between the conductors.

Solution. Assume the line is 3-phase

Conductor radius, $r = 1.956/2 = 0.978$ cm

Dielectric strength of air, $g_o = 30/\sqrt{2} = 21.2$ kV (r.m.s) per cm

Disruptive critical voltage, $V_c = 210/\sqrt{3} = 121.25$ V

Assume smooth conductors (i.e irregularty factor $m_o = 1$) and standard pressure and temprature for which air density factor $\delta = 1$. let d cm be the spacing between the conductors.

$\therefore$ Disruptive voltage (r.m.s) per phase is

$$V_c = m_o g_o \delta r \log_e (d/r) \text{ kV}$$

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$= 1 \times 21.2 \times 1 \times 0.978 \times \log_e (d/r)$

$121.25 = 20.733 \log_e (d/r)$

or $\log_e \frac{d}{r} = \frac{121.25}{20.733} = 5.848$

or $2.3 \log_{10} d/r = 5.848$

$\log_{10} d/r = 5.848/2.3 = 2.5426$

$d/r = \text{Antilog } 2.5426$

$d/r = 348.8$

$\therefore$ Conductor spacing

$d = 348.8 \times r = 348.8 \times 0.978 = 341 \text{ cm}$

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Example: 8.15. A 3-phase, 220kV, 50 HZ transmission line consists of 1.5 cm radius conductor spaced 2 meters apart in equilateral triangular formation. If the temprature is 40C° and atmosphric pressure is 76cm. Calculate the Corona loss per km of the line. Take $m_o = 0.85$?

Solution.

As seen from art. 8.12, the corona loss is given by:

$$P = \frac{242.2}{\delta}(f+25)\sqrt{\frac{r}{d}}(V-V_c)^2 \times 10^{-5} \text{ kw/km/phase}$$

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

Assuming, $g_o = 21.2$ kV/cm(r.m.s)

∴ Critical disruptive voltage per phase is

$$V_c = m_o\, g_o\, \delta\, r \log_e \frac{d}{r} \text{ kV}$$

$$= 0.85 \times 21.2 \times 0.952 \times 1.5 \times \log_e \frac{200}{1.5} = 125.9 \text{ kV}$$

Supply voltage per phase,

$$V = 220/\sqrt{3} = 127 \text{ kV}$$

Substituting the above values, we have Corona loss as:

$$P = \frac{242}{0.952}(50+25) * \sqrt{\frac{1.5}{200}} \times (127-125.9)^2 \times 10^{-5} \text{ kw/ph/km}$$

$= 0.01999$ kw/km/phase.

∴ Total Corona loss per km for threephases.

$= 3 \times 0.01999\text{kV} = 0.05998$ kw

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Home Works

(1) Estimate the corona loss for three-phase, 110 kV, 50 HZ 150 km long transmisson line consisting of three conductors each of 10 mm diameter and spaced 2.5 m apart in an equilateral traingle formation. The temprature of air is 30C° and the atmosphric pressure is 750mm of mercury. Take irregularity factor as 0.85. Ionization of air may be assumed to take place at a maximum Voltage gradient of 30kV cm.

(2) Taking the dielectric strength of air to be 30kV/cm, calculate the disruptive critical voltage for a 3-phase line with conductors of 1 cm radius and spaced symmetrically 4m apart.

(3) A 3-phase, 220 kV, 50 HZ transmission line consists of 1.2 cm radius conductors spaced 2m at the corners of an equilateral triangle. Calculate the corona loss per km of the line. The condition of the wire is smoothly weathered and the weather is fair with temprature of 20C° and barometric pressure of 72.2 cm of Hg.

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