14/02/2020

Introduction to power System :

V.imp Schematic representation of a Typical transmission & distribution.

It consists of 3 components.

1) Generating station

2) Transmission network.

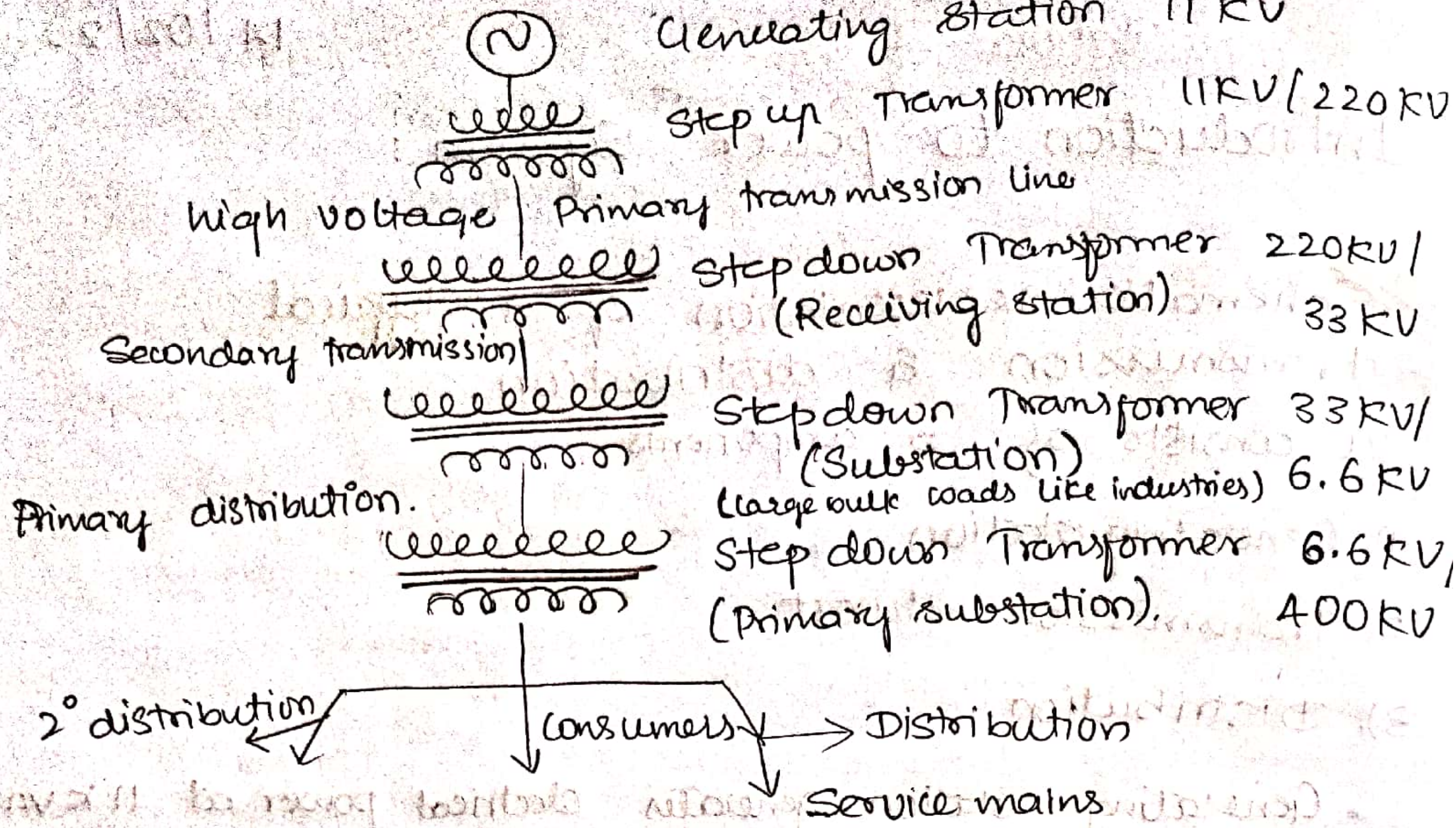
3). Distribution

* Generating station generates electrical power at 11 KVA. The level of this voltage has to be increased for transmission purpose to a voltage level of 220KVA This level may be 132 KVA, 230 KV, 440 KV (or) more as per the requirement.

* with the help of transmission lines & tower the power has to be transmitted to a very long distance

* The power is then transmitted to the receiving station through step down transformer 220KV/33KV (or) 220/11KV. The power is then transmitted to the substation.

* Substation consists of step-down transformer of rating 33 KV, 6.6 KV (or) 3.3 KV. Power transfered from receiving station to the substation with the help of conductors called feeders.



Line diagram of a Typical Transmission distribution scheme.

At the generation station power is generated with the help of 3-ø alternators running in parallel the voltage level is 11KV.

Transmission and distribution of the power can be divided into 4 types:

1) Primary transmission
2) Secondary transmission
3) Primary distribution
4) Secondary distribution.

Single line diagram of substation

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1) Primary transmission:

It is with the help of overhead transmission line for economic aspects the voltage level is increase to 132 KV, 220 KV (or) more with the help of step-up transformer

Hence this transmission is called as high voltage transmission.
It uses 3-ϕ, 3 wire system.

2) Secondary transmission:
Primary transmission line is terminated at receiving station which usually lies at the outside of the city.
At the receiving station the vtg is decreased 33 KV by step-down transformer
From this station electrical power is transmitted at 33 KV by 3-ϕ, 3 wire system to various substation.
This forms the secondary transmission. This is generally known as low vtg transmission line.

3) Primary distribution.
The sec transmission line terminates at the substation. where the voltage is reduced from 33 KV to 11 KV with the help of step down transformer.
Primary distribution is also called as high vtg distribution for large consumers like factory & industries, the power is directly transmitted from such load ------

4) Secondary distribution:
Electrical power from primary distribution line delivers to distribution substation.
These substations are located near the consumers locality & step-down vtg to 400 V

3-ϕ, 4wire for secondary distribution.
This is known as low vtg distribution.

Components of Distribution :

1) Substation :

Transmission lines bring the power upto the substat-ion at the vtg level of 33 KV.

At the substation vtg level is reduced to 3.3 KV (or) 6.6 KV.

Using feeders the power is given to, distrib local distribution centres.

2) Local distribution station :

It consists of a distribution transformer which step-down the vtg from 3.3 KV, 6.6 KV to 400 V. Then it is distributed further using distributers.

3) Feeders :

These are the large ct carrying conductors. This feeders connects the substation too the area where power is to be finally distributed to the consumers. Feeder current always remains constant.

4) Distributers :

These are the conductors used to transfer power from distribution ce centre to the consumers fro The tappings are taken for the supply to the consumer.

5) Service mains:

These are the small cables b/w the distributor -s & the actual consumer premises.

⊛ Voltage regulation w.r. to transmission line.

- VR = +ve $V_s > V_R$

  V_S – Sending voltage (Generating station)

  V_R – Receiving vtg (load)

  - lagging power factor
  - ~~Good~~ Bad factor.

- VR = –ve $V_R > V_S$ ⇒ Ferranti effect.
  - leading power factor
  - ~~Bad~~ Good factor

$$VR = \frac{V_S - V_R}{V_R} \times 100.$$

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Advantages of high transmission voltage:

1) Reduces volume of the conductor material

* Let us consider transmission of electrical power by a 3-ø line.

Let P = power transmitted in watts

V = Line voltage in volt.

cos ø = power factor of the load.

l = length of the line.

R = Resistance in ohms.

ρ = Resistivity of the conductor material.

A = Area of the cross-section of the conductor.

Total power in Electrical 3-ϕ circuit is,

$$P = \sqrt{3} V I \cos\phi$$

Power loss for 3-ϕ (w): $= 3I^2R$

$$R = \frac{\rho l}{A} \qquad I = \frac{P}{\sqrt{3}\, V \cos\phi}$$

$$w = 3I^2R$$

$$w = \frac{3P^2}{3V^2\cos^2\phi} \times \frac{\rho l}{a}$$

$$w = \frac{P^2 \rho l}{V^2 \cos^2\phi\, a}$$

$$\boxed{a = \frac{P^2 \rho l}{V^2 \cos^2\phi \cdot w}}$$

Volume of the conductor material,

Volume = area × length

Volume = $3al$ (∵ for 3-ϕ)

$$\text{Volume} = \frac{3P^2\rho l^2}{V^2\cos^2\phi\, w}$$

* From this equation it is clear that for given values of P, l, ρ & w (constant values)
* The volume of the conductor material is inversly proportional to square of the transmission voltage.

$$\text{Volume} \propto \frac{1}{V^2}$$

* Greater the transmission voltage lesser will be the conductor required.

2) Reduction in loss :

Power loss in 3-ϕ circuit, $w = 3I^2R$

$$I = \frac{P}{\sqrt{3}\, V \cos\phi}$$

$$w = \frac{3P^2 \rho l}{3V^2 \cos^2\phi . a}$$

$$w = \frac{P^2 \rho l}{V^2 \cos^2\phi . a}$$

$$\boxed{w = \frac{P^2 \rho l}{V^2 \cos^2\phi\, a}}$$

Power loss in a line is inversly proportional to square of transmission voltage.

$$w \propto \frac{1}{V^2}$$

3) Reduction in current :

Power transmitted by 3-ϕ circuit is,

$$P = \sqrt{3}\, V I \cos\phi$$

where, V = transmission voltage

I = load current

$\cos\phi$ = power factor

Hence the load current is given by,

$$I = \frac{P}{\sqrt{3} V \cos\phi}$$

'I_L' is inversly proportional to transmission voltage with the increased in transmission voltage V. I_L gets reduced.

As I_L reduces size of conductor also reduces for transmitting same amount of power.

4) Increases transmission efficiency:

The relationship b/w input power & a output power is given by,

Input power = Output power + losses

$$\text{Efficiency } \eta = \frac{\text{Output power}}{\text{Input power}}$$

$$\eta = \frac{\text{O/p power}}{\text{O/p power + losses}}$$

Total 3ϕ current losses given by,

$$w = 3I^2R$$

$$R = \frac{\rho l}{a} \qquad I = \frac{P}{\sqrt{3} V \cos\phi}$$

$$w = \frac{P^2 \rho l}{V^2 \cos^2\phi \, a} \qquad a = \frac{P^2 \rho l}{V^2 \cos^2\phi}$$

current density (J) is given by,

$$J = \frac{I}{a} \Rightarrow a = \frac{I}{J}$$

Input power = O/P power + losses

$$= P + W$$

$$= P + \frac{P^2 \rho l}{V^2 \cos^2\phi \cdot a}$$

$$= P + \frac{P^2 \rho l \cdot J}{V^2 \cos^2\phi \cdot I}$$

$$= P + \frac{P^2 \rho l \cdot J}{V^2 \cos^2\phi \cdot P} \times \sqrt{3} V \cos\phi$$

$$I/P \text{ power} = P + \frac{P\sqrt{3} \rho l J}{V \cos\phi}$$

$$I/P \text{ power} = P\left[1 + \frac{\sqrt{3}\rho l J}{V \cos\phi}\right]$$

$$\text{Efficiency } \eta = \frac{O/P}{I/P}$$

$$\eta = \frac{P}{P\left(1 + \frac{\sqrt{3}\rho l J}{V\cos\phi}\right)}$$

$$\eta = \frac{1}{1 + \frac{\sqrt{3}\rho l J}{V\cos\phi}}$$

$$\boxed{\eta = \frac{V\cos\phi}{V\cos\phi + \sqrt{3}\rho l J}}$$

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ρ, l, J all are constants. Efficiency is directly proportional to transmission voltage.

Transmission efficiency increases when line voltage increases.

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5) Regulation: Decreases in voltage drop (or) line drop.

The voltage drop in transmission line is given by $3I^2R$

$$R = \frac{\rho l}{a}$$

Voltage drop $= 3IR$

$= 3I \frac{\rho l}{a}$ $\quad A = \frac{I}{J}$

$= 3I \frac{\rho l \cdot J}{I}$

Voltage drop $= 3\rho l J$

% line drop $= \frac{3\rho l J}{V} \times 100$

Same as,

$$\text{Voltage regulation} = \frac{\text{Voltage drop}}{\text{Source voltage}} \times 100.$$

6) Increased power handling capacity

7) The no. of circuits & the load required reduces as transmission voltage increases.

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SHORT NOTE ON :

i) HVAC (High voltage AC)
ii) EHVAC (Extra high voltage AC)
iii) UHVAC (Ultra high voltage AC)
iv) HVDC (High voltage DC)

i) HVAC :

* The power can be generated at high voltages.
* AC voltage can be steped up (or) steped down.

Disadvantages of HVAC transmission.

* AC lines requires more conductive material than DC.
* AC transmission line construction is more complicated than DC.
* Effective resistance.
  ~~RAC~~ R_{AC} is greater than R_{DC} due to skin effect
* Continuous power losses due to line changing current because of line capacitance.

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Neccesities of Extra high voltage transmission:

* It is economical with the EHV transmission to interconnect the power system on a large scale.
* No. of circuit & land requirements of a transmission decreases with the use of higher transmission voltages.

• Major Advantages of EHV transmission.

• UHVAC:

• Advantages of HVDC systems:

* Cost of transmission is less. Since only two conductors are used for transmission.
* There is no reactive power so transmission losses is reduced.
* Due to high voltage transmission current is less.
* I^2R losses less.

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Overhead Transmission Lines:

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* Basic requirements of tower:
* Must be mechanically very strong
* Capable of carrying load of conductors & insulators with exteam load condition
* Maintance cost must be low
* Must be long lasting having longer life
* Must be light in weight.
* Easily accessible for election of conductor
* Must be economical
* Should not effect the appearance of the locality.

Various types of towers:

* Wooden poles
* Reinforced concrete poles
* Steel tubular poles
* Latis steel towers

Types of Line conductors:

Conductors used for bulk power transmission in power system it has to fulfill the following requirements.

* They should have low weight
* They should have high tensile strength.
* High conductivity.
* Low co-efficient of expansion
* Low corona loss
* Low resistance & low cost.
* ACSR (Aluminium conductor steel reinforced)
* All aluminium alloy conductor (AAC)
* All aluminium conductor (ASC)
* Thermal resistant aluminium alloy (ATI)
* Super thermal resistant aluminium alloy
* Gap type thermal resistant aluminium alloy (GTACSR)
* Gap type super thermal resistant aluminium alloy (GZTACSR)
* Bundled conductors.

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ACSR: (Aluminium conductor steel reinforced).

Aluminium:

* Low cost
* Conductivity
* Low tensile strength
* Low mechanical strength.

* Maximum lifespan.

Steel :
* Low conductivity.
* Increase (High) tensile strength.
* High mechanical strength

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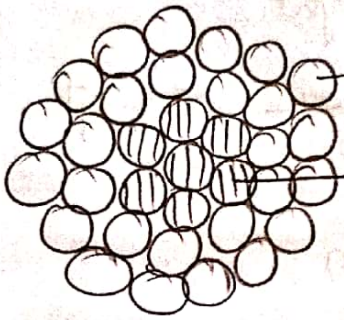

* There are 7 steel strands which forms a core.
* It is surrounded by 2 layers along 30 Aluminiu strands.
* Steel core doesn't contribute to the conduction of current practically.
* The current carrying capacity & resistance of this conductor depends upon conductivity of aluminium

Advantages of ACSR :
* Low corona loss and low skin effect.
* These conductors are inexpensive & having useful life span, durability.
* Due to high mechanical & tensile strength, life span is more & sag is less.

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All aluminium alloy conductor (AAC) :
* The conductors made from aluminium alloys are suitable in urban areas as they provide tensile strength & conductivity.

* Some of these alloys are costly.
* One of the alloys of aluminium are known as similac which contains 0.5% of silicon, as 0.5% of magnesium & rest of the aluminium.
* Due to this there is a improvement in conductivity and mechanical strength.

AEC (All aluminium conductors):

* Aluminium is used in transmission system, electrolytically refined aluminium is rolled & drawn hard for the used as a conductors.
* For a specific resistance cross-sectional area of aluminium conductor is greater than copper while its weight 50% of the copper conductor.
* This makes the transpotation & erection is economical
* Corona effect is reduced due to increased diameter of the conductor.
* These conductors are used in distribution where transmission lines are short & voltages are lower
* Chances of interface faults due to swing, if these conductors are employed in a area where there are high winds. This is because aluminium conductors are lighter with large conductor area and more sag.

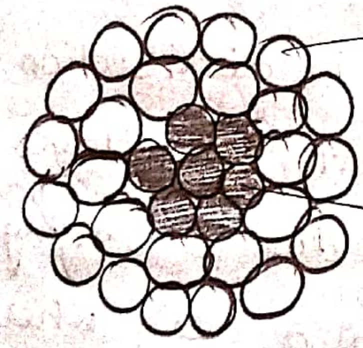
Thermal Resistant Aluminium Alloy conductor:

* This conductor is similar in construction to ACSR conductor.
* The change is that aluminium wires are replaced by hard aluminium wires of heat resistant aluminium alloy known as "TAL"
* These wires are doped with zirconium which makes these conductors well suited for high temperature.

Features of the conductors:

* Very high current carrying capacity.
* Good mechanical & electrical properties at high temperatures.
* Very stable at high temperature.
* Cost effective design.

Super thermal resistant Aluminium alloy conductor.

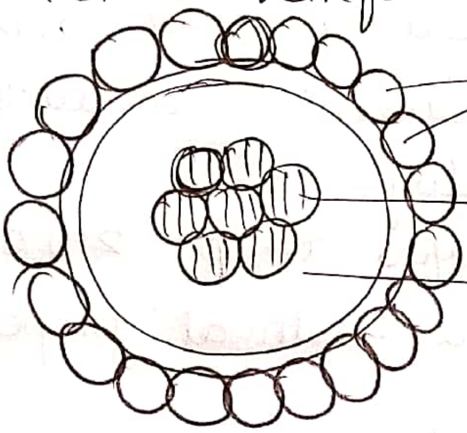


* Super thermal alloy is manufactured from aluminium zirconium rods
* Outer layers are made from super thermal resistant aluminium alloy wires.
* These are concentrically arranged over inner core of Aluminium clad.

* The current capacity of this conductor is more, the load capacity of the system can be increased simply by replacing existing conductors by super thermal resistant aluminium alloy conductors without changing the steel towers.

Thus it is very cost effective and stable at high temperature.

Gap type thermal resistant Aluminium alloy Conductors steel reinforced.



* There is a small gap between steel core and super thermal resistant alloy layers.
* This gap is filled with grease to avoid friction
* The central core is made up of extra high strength steel core.
* The conductor part arranged around the core is made up of thermal resistant aluminium alloy

Features of gap Thermal resistant.

* It offers excellent sag & current carrying capacity.
* Construction period is short.

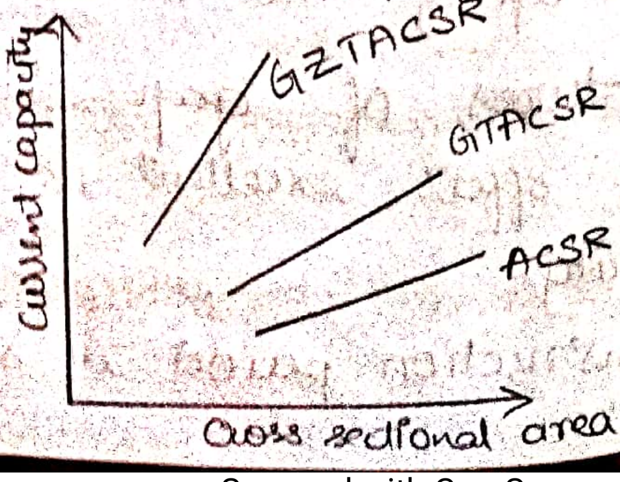
* It can carry 1.6 times higher current than the ACSR conductor also high mechanical strength, low corona loss, low skin effect.
* Grease is filled to avoid friction loss & high current carrying capacity.

Gap type super thermal resistant aluminium alloy conductor reinforced:

* Construction is similar to gap type resistant aluminium alloy conductor steel reinforced
* But the outer aluminium conductors are made up of zirconium alloy
* It can withstand upto temp 210°C without effecting mechanical & electrical properties.

Features:

* It can carry 2 times higher current than ACSR conductor
* Constructional operation
* Continuous operation at higher temperature.
* Low sag at higher temperature.
* Very good mechanical & electrical properties.
* Low thermal point.



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Bundled Conductors :

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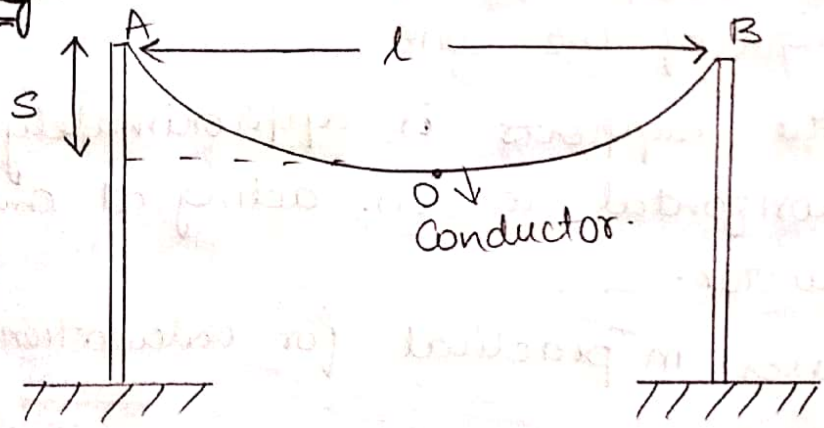
* **Sag :**



Consider an overhead transmission line suspended b/w 2 supports A & B as shown in fig.

The transmission lines is fully streched but it is allowed to sag down.

'O' is the lowest point on the conductor.

*The difference in the levels b/w the point of support & the lowest point on the conductor is called "Sag".

And denoted by 'S'.

$$\text{Sag } (S) = \frac{WL^2}{8T}$$

L - length
W - weight
T - Tension.

Important points related to Sag.

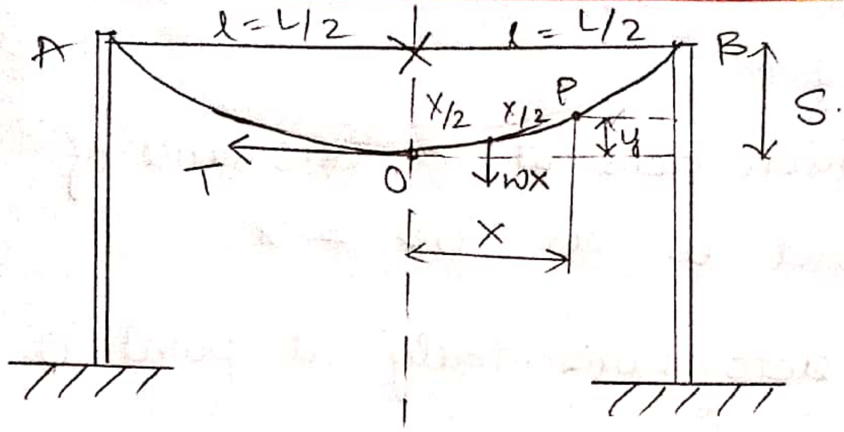
* When the supports are at the same level, then the shape of the conductor is catenary. The shape of the conductor is called sag span curve.

* Tension at any point on the conductor acts tangentially. This tension 'T' has 2 components: One acting horizontally while other vertically.
  The horizontal component of tension is constant through-out the length of the wire.

* The tension at the supports is approximately equal to the horizontal tension. acting at any point on the conductor.

* There are 2 cases in practical for calculation of sag.
  1) The supports supporting the conductor located at equal area.
  2) The supports supporting the conductor are located at unequal level.

1) The supports supporting the conductor located at equal area:



* A & B are the supports which are located at equal level.
* Point 'O' is at the mid-span. and at the lowest point on the conductor.
* 'L' Length of the span in meters.
* 'W' weight per unit length of the conductor in kg/m.
* 'T' is tension in conductor. in kg.
* Consider point 'P' on the conductor, co-ordinates of the point 'P' is (x, y).
* ~~Length of the span 'L' is~~
* Let ~~'L'~~, $l = L/2$.

As the curve is very small due to small sag it can be assumed that, length 'OP' of the conductor is same as the x-co-ordinate of the point 'P'. $l(OP) = x$.

* Now, there are 2 external forces acting on the portion 'OP' of the conductor.

i) Tension (T)

ii) weight (wx) which acts at a distance of $x/2$ from the point 'O' as 'OP' $= x$.

* The tension (T) acts horizontally at point O

* Taking the moments of these 2 forces about point 'P' and equating them we get,

$$Ty = wx \cdot \frac{x}{2}$$

$$y = \frac{wx^2}{2T}$$

* The equation shows that, at the support A & B the vertical distance 'y' from the origin 'O' indicates the sag 'S'.

At A (or) B $y = S$

$$x = l = \frac{L}{2}$$

$$S = \frac{wl^2}{2T} = \frac{w}{2T}\left(\frac{L}{2}\right)^2 = \frac{wL^2}{8T}.$$

$$\boxed{S = \frac{wL^2}{8T}}$$

Problem:

1) An overhead line has a span of 250m. The tension of the line is 1500 kg while

the conductor weight 750 Kg / 1000 mts. Calculate maximum sag

⇒ $T = 1500 Kg$

$L = 250 m.$

$w = ~~187.5 Kg~~ \; 750 Kg$

~~$S = \frac{wL^2}{8T}$~~

~~$= \frac{187.5 (250)^2}{8 \times 1500}$~~

~~$S = 976.56$~~

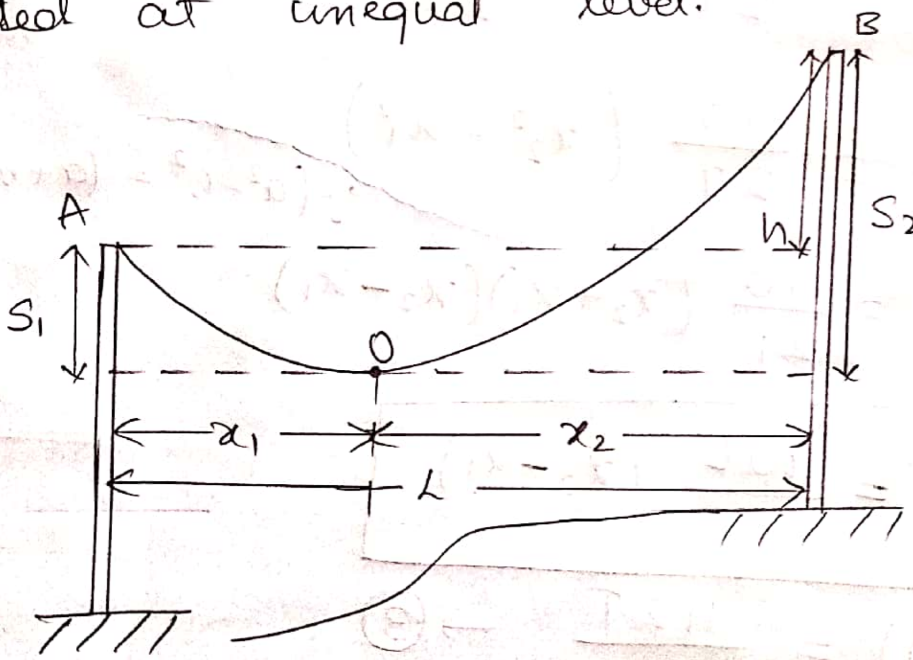
$S = \frac{wL^2}{8T}$

$= \frac{750 \times (250)^2}{8 \times 1500}$

$= 3906.25 \; m^2$

$= 3.906 \; cm^2$ 26/02/2020

2) The supports supporting the conductor are located at unequal level.



L - Total span length.

h - Difference in the level

T - Tension in the conductor

x_1 = Distance of a pt 'O' from the support A

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x_2 - Distance of point 'O' from the support B.

W - Weight per unit length of the conductor.

Sag at support A,

$$S_1 = \frac{w x_1^2}{2T} \rightarrow (1)$$

Sag at support B,

$$S_2 = \frac{w x_2^2}{2T} \rightarrow (2)$$

$L = x_1 + x_2$ = Total span length

$$\boxed{h = S_2 - S_1} = \frac{w x_2^2}{2T} - \frac{w x_1^2}{2T}$$

$$= \frac{w}{2T}\left(x_2^2 - x_1^2\right)$$

$\because (a^2 - b^2 = (a+b)(a-b))$

$$= \frac{w}{2T}(x_2 + x_1)(x_2 - x_1)$$

$$\boxed{h = \frac{wL}{2T}(x_2 - x_1)}$$

$$(x_2 - x_1) = \frac{h\,2T}{wL} \rightarrow (3)$$

$$x_2 + x_1 = L \rightarrow (4)$$

By solving (3) & (4):

$$x_2 - x_1 = \frac{h2T}{wL}.$$

Add $$x_2 + x_1 = L.$$

$$2x_2 = \frac{h2T}{wL} + L.$$

$$\boxed{x_2 = \frac{hT}{wL} + \frac{L}{2}.}$$

$$x_1 = L - x_2$$
$$= L - \frac{hT}{wL} + \frac{L}{2}.$$

$$\boxed{x_1 = \frac{L}{2} - \frac{hT}{wL}.}$$

Once the values of x_1 & x_2 are known the sags of x_1 & x_2 can be calculated.

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Problems:

1) The 2 towers of height 95 m & form support the line conductor at a river crossing. The horizontal distance b/w towers is 400m. If the tension in the conductor is 1100 kg/m. Its weight is 0.8 kg

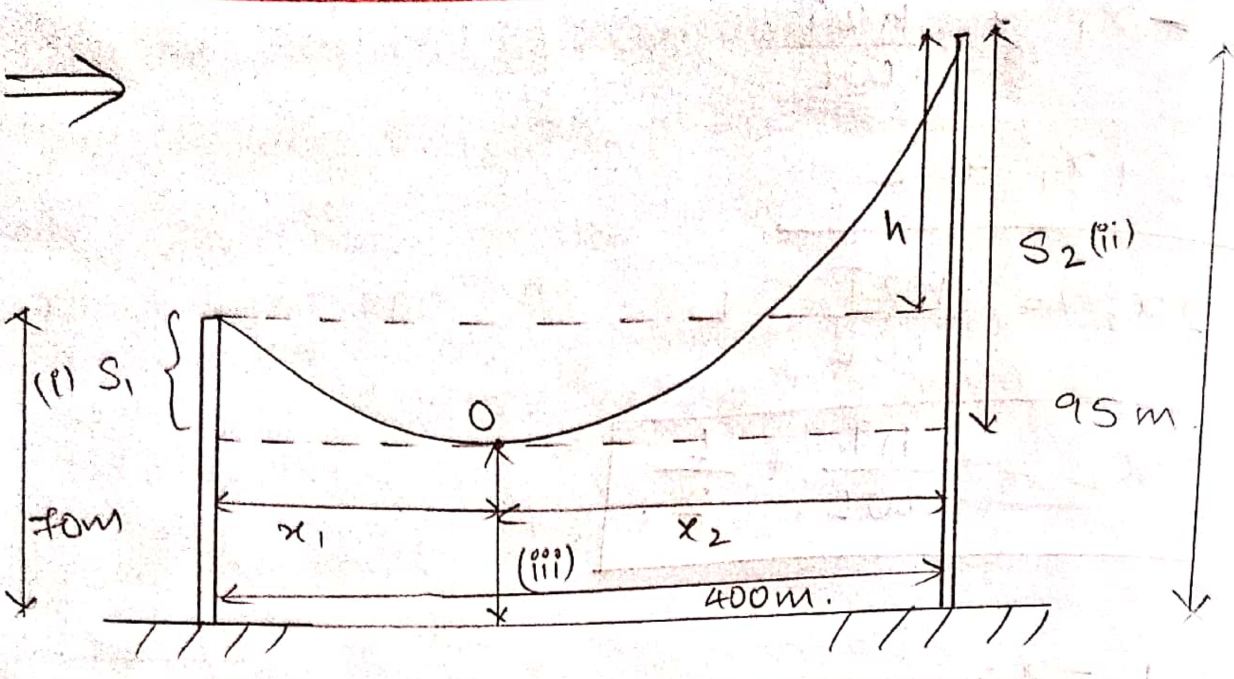
Calculate, (i) Sag at the lower support

(ii) Sag at upper support

(iii) Clearance of lowest point on the tragector from the water level.

Assume, bases of the supports are at water level.

⇒



$L = 400m$

$w = 0.8 \text{ Kg}$

$T = 1100 \text{ Kg/m.}$

(i) Sag at lower support

$$S_1 = \frac{w x_1^2}{2T}$$

$$\therefore x_1 = \frac{L}{2} - \frac{Th}{wL}$$

$h = 95 - 70 = \underline{\underline{25 m}}$

$$= \frac{400}{2} - \frac{1100 \times 25}{0.8 \times 400}$$

$$= 200 - 85.9375$$

$$x_1 = \underline{114.06 m}$$

$$S_1 = \frac{0.8 \times (114.08)^2}{2(1100)} = \underline{\underline{4.73}}$$

(ii) Sag at higher support

$$S_2 = \frac{w x_2^2}{2T}$$

$$x_2' = \frac{L}{2} + \frac{Th}{wL}$$

$$= \frac{400}{2} + \frac{1100 \times 25}{0.8 \times 400}$$

$$x_2 = 285.93 m$$

$$S_2 = \frac{0.8 \times (285.93)^2}{2(1100)}$$

$$S_2 = 29.73$$

(iii) distance from lowest point to water level,

$$D = 70 - S_1$$

$$= 70 - 4.73.$$

$$D = 65.27 m$$

2) A overhead line conductor is supported by 2 towers which are at 70m height above the water level. The towers are seperated by each other by horizontal distance of 300m, The tension in the conductor is 1500 kg/m. Find the clearance at a point mid way b/w the towers.

If the size of a conductor is $0.92\ cm^2$ and density of conductor material is $8.87\ g/cm^3$

$\Rightarrow$ weight = density × Area

weight/meter = Area of cross section in m^2 × density in kg/m^3.

Given;

height of towers = 70 m.

$L = 300m$.

$T = 1500\ kg/m$.

Density = $8.87\ g/cm^3$

Area of cross section = $0.92\ cm^2$.

$$A = (0.92) \times (10^{-2})^2\ m^2$$

$$A = 0.92 \times 10^{-4}\ m^2$$

$$\text{Density} = \frac{8.87 \times 10^{-3}}{10^{-6}} = 8870.$$

weight/meter = $0.94 \times 10^{-4} \times 8870 = 0.83378$

$W = 0.816\ kg/m$.

Sag = 6.12

Clearance = 70 − 6.12

= 63.88 m.

3) A transmission line conductor at a river crossing is supported from 2 towers at a heights of 50 m & 80 m above the water, the horizontal distance b/w the towers is 300 m. If the tension in the conductor is 2000 kg. Find the clearance b/w conductor & water at a point mid way b/w the towers. weight of conductor /m is 0.844 Kg

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$\Rightarrow x_1 = \frac{L}{2} - \frac{Th}{wL}$ $x_2 = \frac{L}{2} + \frac{Th}{wL}$

$h = 80 - 50$

$h = 30$ mts.

$= \frac{300}{2} - \frac{2000(30)}{0.844 \times 300}$

$= 150 - 236.96$

$x_1 = -86.96$ m

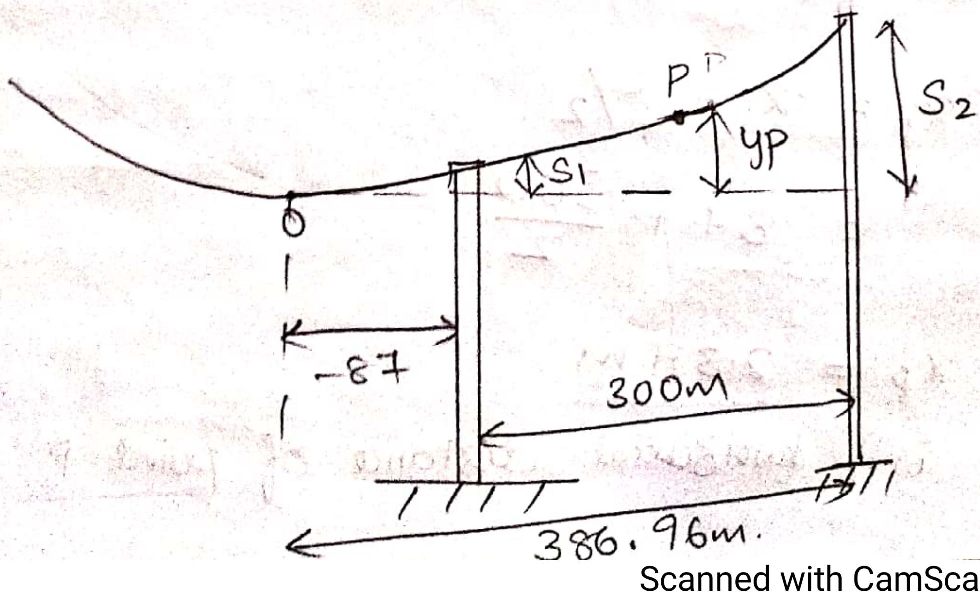
$x_2 = \frac{300}{2} + \frac{2000(30)}{0.844 \times 30}$

$= 386.96$ m

Verification:

$L = x_1 + x_2$

$L = 300$ m



It can be seen that x_1 is -ve which indicates that lowest point of trajectory i.e; point 'O' occurs to the left of support 'A'.

So, support 'A' is to the right point of 'O'

Now, the origin is 'O' & point 387m 'P' is located mid way b/w the towers.

$$S_1 = \frac{w x_1^2}{2T}$$

$$= \frac{0.844 \times (-87)^2}{2 \times 2000}$$

$$S_1 = 1.59 \simeq 1.6\,m$$

$$S_2 = \frac{w x_2^2}{2T}$$

$$= \frac{0.844 (387)^2}{2 \times 2000}$$

$$S_2 = 31.6\,m.$$

It can be calculated as,

$$x_p = x_1 + L/2.$$

$$= 87 + \frac{300}{2}$$

$$x_p = 237\,m$$

This is horizontal distance of point 'P' from origin 'O'

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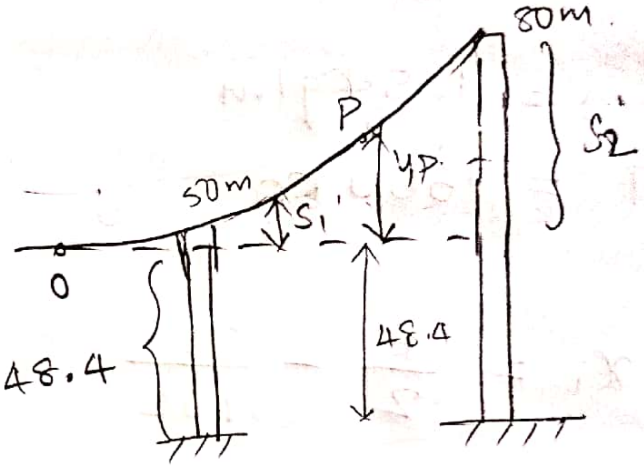
The corresponding vertical distance of point 'P',

$$y_P = \frac{w(X_P)^2}{2T}$$

$$= \frac{0.844 \times (237)^2}{2 \times 2000} = \underline{11.85 m}$$

To find the distance from point 'P' to the ground gives,



$D = 50 - S_1$

$= 50 - 1.6$

$= 48.4 m$

$D = 48.4 + y_P$

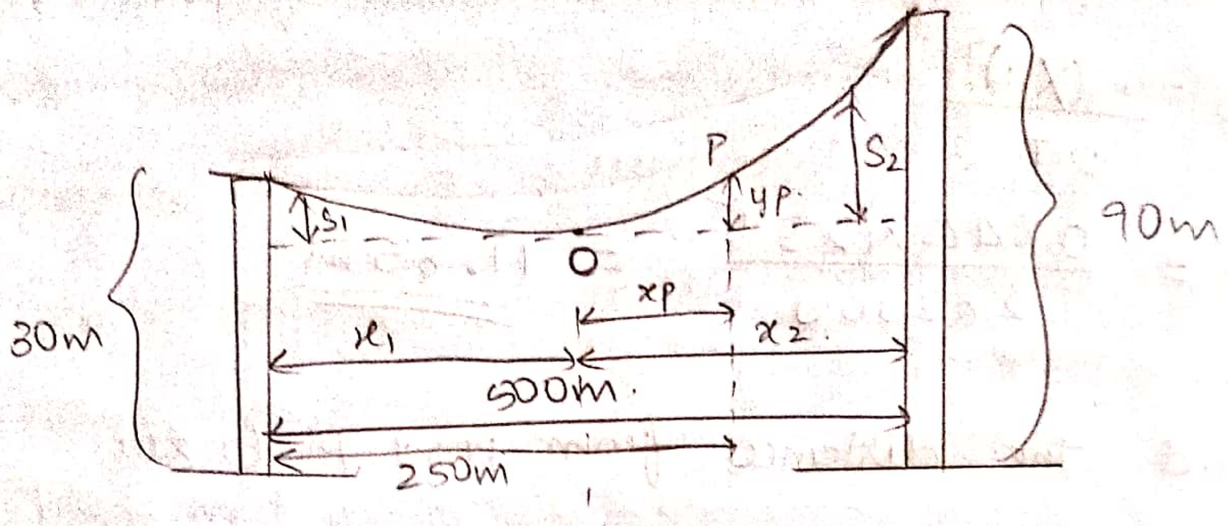
$= 48.4 + 11.84$

$= \underline{60.24 m}$

Assignment:

1) The towers of height 30m & 90m respectively. The horizontal distance b/w towers is 500m. The tension in the conductor is 1600kg. Find (i) the minimum clearance of the conductor & water. (ii) Clearance mid way between the supports. weight of the conductor is 1.5kg/m. Bases of the towers considered to be at the water level.

⇒



$w = 1.5$ kg/m

$T = 1600$ kg

$h = 90 - 30$

$h = 60$

$$x_1 = \frac{L}{2} - \frac{Th}{wL}$$

$$= \frac{500}{2} - \frac{1600 \times 60}{(1.5)(500)}$$

$$= 250 - 128$$

$$x_1 = 122\,m$$

$$x_2 = \frac{L}{2} + \frac{Th}{wL}$$

$$= 250 + 128$$

$$x_1 = 378\,m$$

(ii) $$S_1 = \frac{w x_1^2}{2T}$$

$$= \frac{1.5 \times (122)^2}{2 \times 1600}$$

$$S_1 = 6.976\,m$$

$$S_2 = \frac{w x_2^2}{2T}$$

$$= \frac{1.5 \times (378)^2}{2 \times 1600} = 66.97\ m.$$

(ii) Minimum clearance of the conductor & water :

$D = 30 - S_1$

$= 30 - 6.976.$

$D = 23.024 \, m$

30.71

(iii) $x_p = 250 - x_1$

$= 250 - 122.$

$x_p = 128 m$

* $y_p = \frac{w(x_p)^2}{2T}$

$= \frac{1.5 \times (128)^2}{2 \times 1600}$

$y_p = 7.68 \, m$

* $\Rightarrow 30 - S_1$

$\Rightarrow 30 - 6.976$

$= 23.024$

$\Rightarrow y_p + 23.024$

$= 7.68 + 23.024$

$= 30.704 m$

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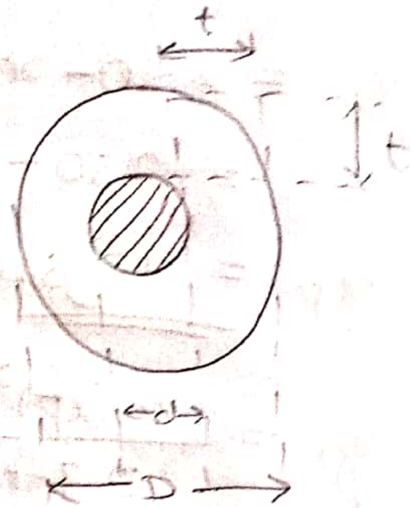
~~Effect~~ Effect of Atmospheric condition on transmission line.

29/02/202

1) Effect of ice coating.

2) wind pressure.

1) Effect of ice coating:



when transmission line is coated with ice, transmission line thickness & weight of the conductor increases & hence increases vertical sag also.

d → diameter of the conductor

~~D~~ t → diame thickness of ice coating

D – Overall diameter of the conductor.

$$\boxed{D = d + 2t}$$

Area of the conductor is, $(\pi/4) D^2$

Area of the ice-coated covering is, $\frac{\pi}{4}(D^2 - d^2)$

weight of the conductor ⇒ Density × weight of ice per unit length.

Density of ice = 915 kg/m³

$(a+b)^2 = a^2 + b^2 + 2ab$

$$\Rightarrow 915 \times \frac{\pi}{4}\left[(d+2t)^2 - d^2\right]$$

$d^2 + 4t^2 + 4dt - d^2 \Rightarrow 4t(t+d)$

$$= 915 \times \frac{\pi}{4} \left[(d + 2t) + d \right] \left[(d + 2t) - d \right]$$

$$= 915 \pi t \, (d + t) \text{ kg/m.}$$

2) Effect of wind pressure :

The wind flows horizontally & hence the wind pressure is ~~considered~~ considered to be acting $\perp^{lr.}$ to the conductor.

- Thus force due to wind acts at right angles to the projected surface of the conductor as shown.

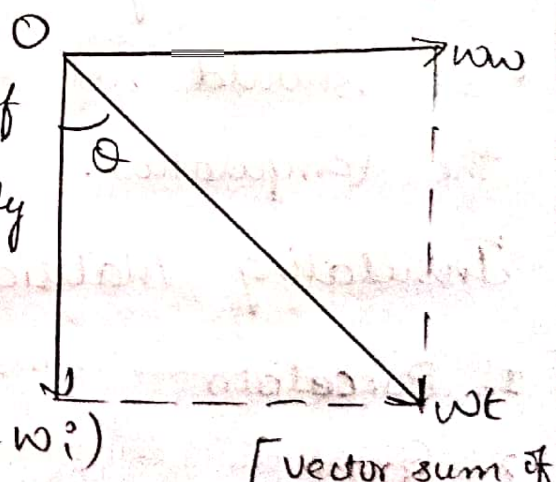
$$W_w = P(d + 2t).$$

- Hence the conductor gets acted upon by 2 additional forces.

One vertically downword → w_i

and other in horizontal → w_w.

Effect of ice and wind.



[vector sum of horizontal & vertical forces]

w = weight of the conductor itself

w_i = weight of ice acting vertically down

w_w = wind force acting horizontally

$$W_t = \sqrt{(w + w_i)^2 + w_w^2}$$

Line vibration and Vibration dampers:

1. Aeoline
2. Galloping

• Factor affecting conductor vibration:

Overhead line Insulators:

05/03/2020

Properties of insulators:

* Insulator gives insulation to the conductor and also withstand capability to the conductor load, along with wind pressure extras. etc.
* Resist any leakage current.
* Insulators must be free from impurities such as, holes, cracks, laminations etc.
* Dielectric strength of insulator must be high
* The insulating material should be non-porous
* It should not be affected by the changes with the temperature.

Insulating Materials:

1. Porcelain
2. Glass
3. Synthetic resin.

1. Porcelain:

* It is a ceramic material manufactured from china clay.
* The plastic clay is mixed with silicon and feldsbar
* The fine powdered mixture of clay, silicon & feldspar is processed in the mills.
* It is heated at the controled temp., it has been given a particular shape & it is covered with glaze
* The cast iron with galvonising is used for metal parts inside the insulators.
* The porcelain is free from ~~cta~~ cracks, holes & laminations.
* Its insulation resistance is very high. (around MΩ)
* Porcelain is heated at the temp. such that insulators become mechanically strong.
* Also become non porous.
* Its rough surface catches the dust & moisture very quickly hence it is important to provide glazed surface to the insulators so, that it remains clean from dust & moisture
* The dielectric strength of porcalain material is 60 KV / cm.

2) Glass :

* As glass is transparent cracks, bubbles & defects, in the insulator can be easily detected by inspection.

* The dielectric strength is very high.
* Low co-efficient of thermal expansion hence, less affected by the temp. changes.
* Cheaper than ~~porcelain~~ porcelain
* Resistivity is very high
* Simple design is possible.
* Higher compressive strength than porcelain.

Disadvantages: 11/03/2020

Types of insulators:

1. Pin type insulators → low tension
2. Suspension type insulators → high tension
3. Strain insulators. → at high load (crossing)
4. Stay insulators

v.imp: 8-10M

String efficiency:

Non-uniformity in the voltage distribution over a string of suspension insulators is expressed in terms of parameters called string efficiency.

~~String~~ String efficiency is defined as the ratio of total voltage across the string to the product of number of units and the voltage across the unit adjacent to the line conductor.

$$\text{String efficiency} = \frac{\text{Voltage across the string}}{n \times \text{Voltage across the adjacent to line conductor}} \times 100$$

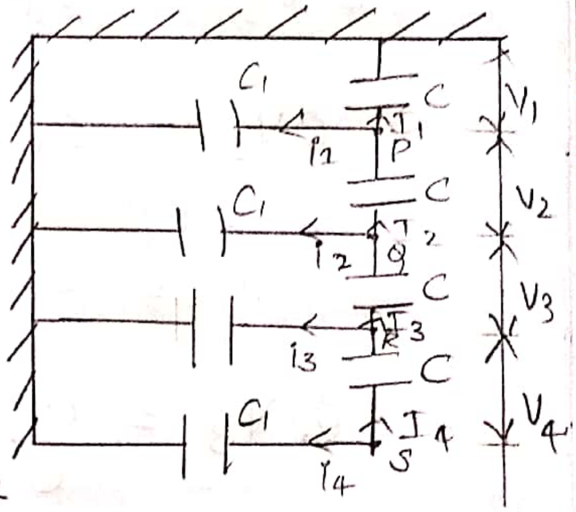
where: n - no. of units (or) disc in the string

More the value of string efficiency, more uniform is the voltage distribution across the string.

The ratio of shunt capacitance to the mutual capacitance is 'K'.

Method of Calculating String efficiency:

Consider a string of suspension insulator consisting of 4 disc.



The voltage distribution is shown in the figure.

$C_1 = KC$

where: C_1 = Shunt capacitance

C = Mutual Capacitance.

$$I_c = \frac{V_c}{X_c} \qquad X_c = \frac{1}{2\pi f c}.$$

$$\therefore \boxed{I_c = 2\pi f C V_c.}$$

At node P:

$$I_2 = I_1 + i_1 \longrightarrow ①$$

$$2\pi f C V_2 = 2\pi f C \cdot V_1 + 2\pi f C_1 V_1$$

$$CV_2 = V_1 (C + C_1)$$

$$V_2 = V_1 (1 + C_1/C).$$

$$\boxed{V_2 = V_1 (1 + K)} \rightarrow (2)$$

At node Q:

$I_3 = i_2 + I_2.$ $\quad I_2 = i_1 + I_1$

$$2\pi f C V_3 = 2\pi f C_1 (V_1 + V_2) + 2\pi f C V_2.$$

$$C V_3 = C_1 \left(V_1 + V_1(1+K)\right) + C\left(V_1 (1+K)\right)$$

$$CV_3 = C_1 (V_1 + V_1 + V_1 K) + C (V_1 + V_1 K)$$

$$= C_1 (2V_1 + V_1 K) + C (V_1 + V_1 K)$$

$$V_3 = \frac{C_1}{C} \cdot V_1 (2 + K) + V_1 (1 + K)$$

$$V_3 = K V_1 (2 + K) + V_1 (1 + K)$$

$$V_3 = V_1 \left[2K + K^2 + 1 + K\right]$$

$$\boxed{V_3 = V_1 \left[K^2 + 3K + 1\right]} \rightarrow (3)$$

At node R:

$$I_4 = i_3 + I_3$$

$$2\pi f C V_4 = 2\pi f C_2 (V_1 + V_2 + V_3) + 2\pi f C V_3$$

$CV_4 = C_2 (V_1 + V_1 + V_1 K + V_1 K^2 + V_1 3K + V_1)$
$+ CV_3.$

$V_4 = \frac{C_1}{C} [3V_1 + 4KV_1 + V_1 K^2] + V_3$

$= K [3V_1 + 4KV_1 + V_1 K^2] + V_1 (K^2 + 3K + 1)$

$\Rightarrow V_1 [K^3 + 4K^2 + 3K + K^2 + 3K + 1]$

$$V_4 = V_1 [K^3 + 5K^2 + 6K + 1] \rightarrow (4)$$

Put $K = 0.25)$

$V_2 = V_1 (1 + 0.25)$

$V_2 = 1.25 V_1$

$V_3 = V_1 [0.25^2 + 3(0.25) + 1]$

$V_3 = 1.81 V_1$

$V_4 = V_1 [0.25^3 + 5(0.25)^2 + 6(0.25) + 1]$

$V_4 = 2.82 V_1$

$V = V_2 + V_3 + V_4 + V_1.$

$= V_1 + 1.25 V_1 + 1.81 V_1 + 2.82 V_1.$

$V = 6.8906 V_1$

$\eta = \frac{V}{n V_4} \Rightarrow \frac{6.8906 V_1}{4 \times 2.82 V_1} \times 100 = 61.08 \%.$

8-10M

12/03/2020

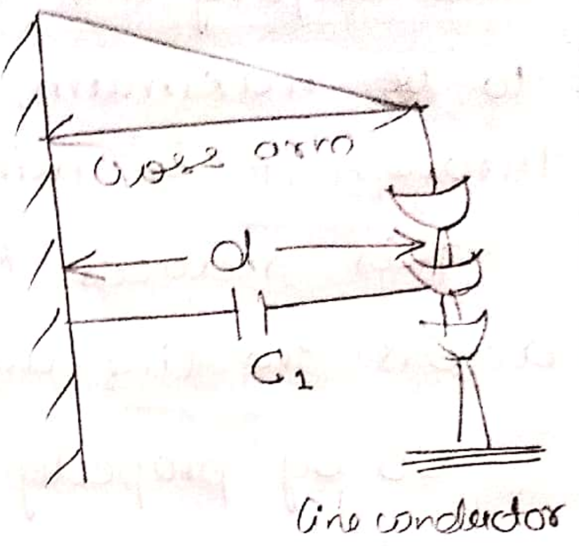
Methods of Increasing String efficiency:

1. Reduceing the ratio of shunt capacitance to the self capacitance
2. By grading the insulator.
3. Use of guard-ring to provide static schelding.

1. Reducing the ratio of shunt capacitance to the self capacitance:

* The voltage across line unit depeds on the value of 'K' which is ratio of shunt capacitonce to self capacitance.
* String efficiency is dependent of on the voltage across the line unit.
* Lesser the value of 'K' higher the string efficiency and more uniform is the voltage distribution
* Now, $K = \frac{C_1}{C}$ ie; Ratio of shunt capacitance to self capacitance
* To reduce the value of 'K', 'C_1' must be reduced.
* This is possible by increasing the distance b/w insulator and tower. $C = \frac{\varepsilon_0 A}{d}$ $\downarrow C \propto 1/d\uparrow$
* This can be achieved by increasing the length of the cross arm as shown in fig.

* More the length of the cross arm, less is the value of 'K'.



* But this method has practical limitations such as,

i) Use of long cross arm increases the cost.

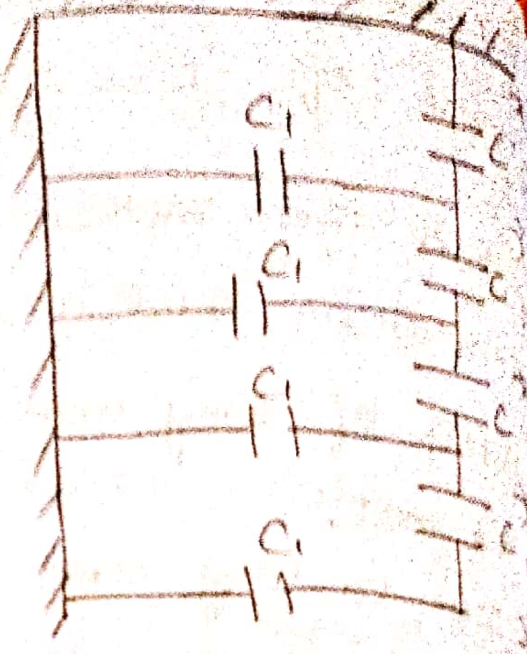
ii) Due to long cross arm overall strength of the tower reduces.

2) <u>By grading the insulator:</u>

* By grading the insulator more uniform voltage distribution across the string is achieved.
* In this method of grading the insulators are so selected that self capacitance (or) mutual capacitance of various units are different & the values of shunt capacitance decrease from line unit towards top-unit.
* So, top unit has minimum mutual capacitance while the line unit has maximum mutual capacitance.
* The voltage for the given current across the capacitor is inversely proportional to the capacitance.
* So, more the capacitance lesser is the voltage across capacitance.

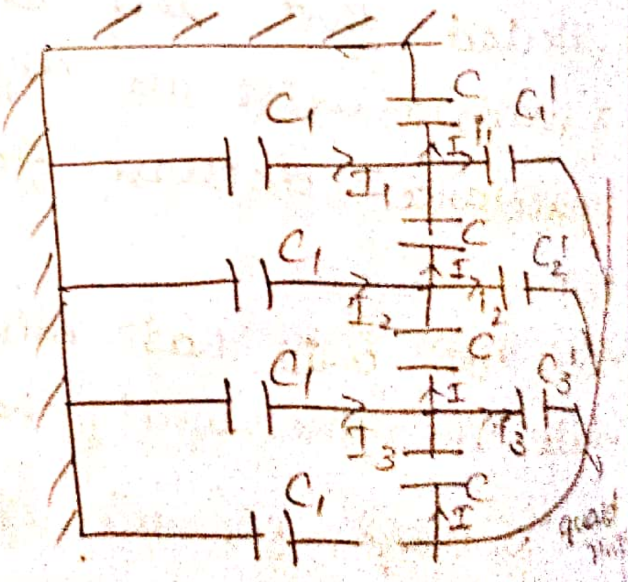
Thus keeping line capacitance to be maximum current through it is minimum.

This reduces the voltage across the line unit.



So by properly grading the insulators ie; by using different sized insulators in a string uniformed voltage distribution can be achieved and string efficiency can be increased.

3) <u>Use of guard ring to provide static scheilding</u> :-



* In this method a large metal ring surrounded the line unit & connected to the metal part of the bottom of the line unit

* Such a ring is called Guard ring.

* Guard ring can be designed in such a way that shunt capacitance ~~aero~~ currents I_1, I_2, I_3 are equal to the currents through newly introduced

capacitors C_1, C_2, C_3.

* Due to this charging current through self capacitors remains same, giving uniform voltage distribution.
* But such design is not practically possible.
* The primary aim of the guard ring is to reduce the electrical stress of the lower unit.

Arching arms: (from text book):

2nd MODULE 18/04/2020.

Inductance Calculation:

⇒ Limits for internal flux ⇒ 0 to r

— " — External flux ⇒ r to ∞

v.imp

Inductance of single phase overhead wire line.

Inductance of conductor A $L_A = \frac{\psi_A}{I_A}$

$$= \frac{\mu_0}{2\pi}\left[\frac{1}{4} + \log_e \frac{d}{r}\right] H/m$$

$$L_A = 10^{-7}\left[1/2 + 2\log_e \frac{d}{r}\right]$$

loop inductance = $2L_A$ H/m.

$$\text{loop inductance} = 10^{-7}\left[1 + 4\log_e \frac{d}{r}\right] H/m$$

Expression in Alternate form.

$$L_A = 2\times 10^{-7} \log \frac{d}{r'} \ H/m$$

$$r' = r e^{-1/4} = 0.7788r.$$