Date 17/09/19

CHAPTER - VI

SAG AND TENSION CALCULATIONS AND OVERHEAD LINE INSULATORS

SAG :-

→ The difference in levels b/w the points of Support and the lowest point of the Conductor (catenary curve) is known as Sag.

→ The following factors will Effect the Sag in over head System.

(i) Weight of Conductor

(ii) length of the Span.

(iii) Working tensile Stress (or) Strength

(iv) Temperature

→ Calculation of the Sag at Equal tower heights (or) Supports.

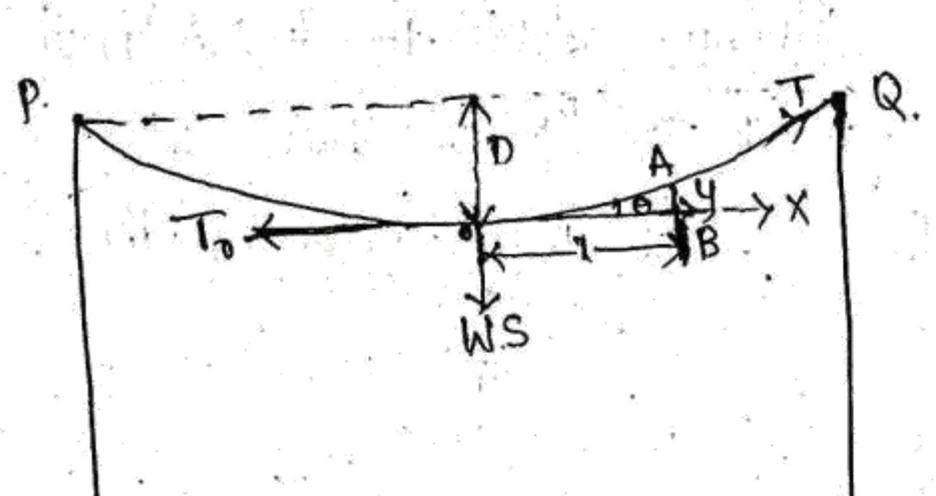

fig (a)

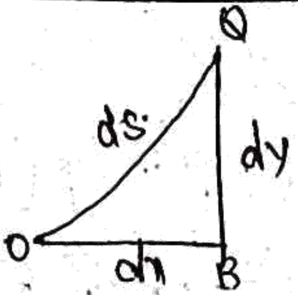

fig (B)

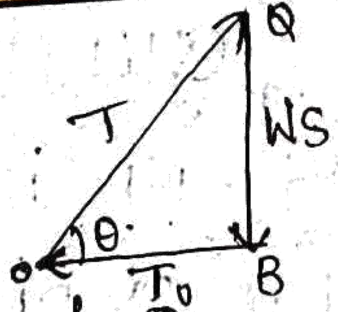

fig (C)

→ When a Conductor is Suspended b/w "P & Q" Tower as Shown in fig "a". It forms a Catenary Curve

→ Let "2L = length of the Conductor (BOQ)
W = Weight of the Conductor /m
D = Maximum Sag in meters.
T = Tension at point "A" of the Conductor Acting towards Support.
T_0 = Tension at point "O" of the Conductor Acting horizontal
S = length of the Conductor of Small Section "OA"

→ Let us Consider a Small Section "OA" of Conductor of length "S".

→ At Equilibrium State the tension (T) at point "A", The tension (T_0) at point "O" and Weight of the Conductor is Shown in the fig 'c'.

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from fig (B) & (C)

$$\tan\theta = \frac{dy}{dx} \quad ; \quad \tan\theta = \frac{W_s}{T_0}$$

$$dy/dx = \frac{Ws}{T_0} = \frac{Ws}{H}.$$

$$ds^2 = dx^2 + dy^2$$

$$ds = \sqrt{dx^2 + dy^2}$$

$$ds = dx\sqrt{1 + (dy/dx)^2} \Rightarrow dx = \frac{ds}{\sqrt{(1) + \left(\frac{Ws}{H}\right)^2}}$$

Integrating the above Equation,

$$x = H/W \cdot \sinh\left(\frac{Ws}{H}\right).$$

$$s = H/W \sinh\left(\frac{Wx}{H}\right).$$

Now, $dy/dx = \frac{Ws}{H}$.

$$dy = \frac{W}{H} \cdot H/W \sinh\left(\frac{Wx}{H}\right) dx.$$

$$dy = \sinh\left(\frac{Wx}{H}\right) dx.$$

⇒ Integrating the above Equation.

$$y = H/W \cosh\left(\frac{Wx}{H}\right) + B \longrightarrow (1)$$

At $x = 0$, then $y = 0$.

$$\therefore 0 = H/W + B \Rightarrow \boxed{B = -H/W} \longrightarrow (2)$$

Substitute Eqn (2) in Eqn (1) We get

$$y = H/W \cosh\left(\frac{Wx}{H} - H/W\right).$$

$$y = H/W \left(\cosh\left(\frac{Wx}{H}\right) - 1\right).$$

$$y = H/W \left(1 + \left[\frac{W^2x^2}{2H^2} + \frac{W^4x^4}{24H^4} + \cdots\right] - 1\right)$$

Neglect higher order terms.

$$y = H/W \left[\frac{W^2x^2}{2H^2}\right]$$

$$y = \frac{Wx^2}{2H} \quad (x = \ldots)$$

then $y = \frac{Wx^2}{2H}$ $H = T$

$$\boxed{y = \frac{WL^2}{2T}}$$

The Sag at the bottom of the Conductor then $x = l/2$.

$$y = \frac{W(l/2)^2}{2T} = \frac{Wl^2}{8T}$$

∴ The Sag at Equal tower heights,

$$y = \frac{Wl^2}{8T}.$$

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Problems:-

1. Calculate the minimum sag permissible for a 160m Span, 1cm diameter, Copper Conductor allowing a maximum tensile stress of 2000 kg/cm². Assume a horizontal Wind pressure of 4 kg/cm² of projected area. Take the Specific Gravity of Copper as 8.9 g/cm³

Sol:- Given data,

Span = length = l = 160 m.

diameter = d = 1.0 cm

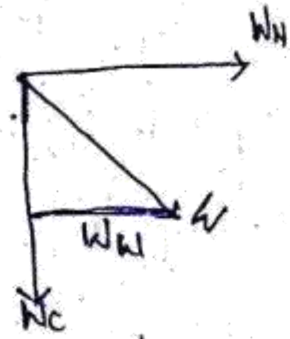
Max tensile stress (T) = 2000 kg/cm³.

horizontal Wind pressure (P) = 4 kg/cm²

Specific gravity of Copper = 8.9 gm/cm³

→ length of the Conductor.

$$W = \sqrt{(W_w)^2 + (W_c)^2}$$



⇒ Weight of Wind = Air pressure x projected area

Projected Area = Area of the Conductor

$$\pi d^2/4 = \frac{\pi \times 1^2}{4} = 0.785 cm^2$$

Wind Weight = 4 x 0.785 = 3.12 kg.

→ Weight of Conductor = Specific gravity into the volume of Conductor.

$= 8.9 \times 0.78 \times 1 = 6.94$ kg

$= 6.9 \times 10^{-3}$ kg.

Resultant Weight $W = \sqrt{(W_{m})^2 + (W_c)^2}$

$W = \sqrt{(3.12)^2 + (6.94 \times 10^{-3})^2}$

$= 3.12$ Kg.

Tension (T) = Max tensile Stress x Area

$= 2000 \times 0.785$

$= 1570$ kg.

$\therefore$ Sag $= \frac{Wl^2}{8T} = \frac{3.12 \times (160)^2}{8 \times 1570}$

$= 6.35$ m

2. An over head line Was a Span of 160 m of a Copper Conductor b/w level Supports. the Conductor diameter is 1.2 cm and has a breaking Stress of 35 kg/mm² ; Calculate.

(i) The deflecting Sag

(ii) Horizontal Sag

(iii) vertical Sag. The light is Subjected to a Wind pressure of 40 kg/m². of projected area and Radial ice floating of 9.53 mm thickness. The density of the Ice is 913.5 kg/m3. Allow a Safety factor of "2" and take the density of Copper has 8.9 gm/cm³.

Sol:- Given data,

Span = 160 m

diameter (d) = 1.2 cm

breaking Stress = 35 kg/mm²

Wind pressure (p) = 40 kg/m²

ice Coating (t) = 9.53 mm.

density of ice (d) = 913.5 kg/m³

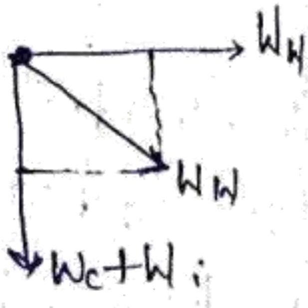
Safety factor = 2

density of Copper = 8.9 gm/cm³

⟹ Deflecting Sag = $\frac{Wl^2}{8T}$

Resultant Weight of Conductor

$$W = \sqrt{(W_c+W_i)^2 + (W_w)^2}$$



⟹ Tension (T) = $\frac{\text{breaking Stress} \times \text{Area}}{\text{Safety factor}}$

Area of the Conductor = $\frac{\pi d^2}{4} = \frac{\pi \times (1.2 \times 10^{-2})^2}{4}$

$= 1.13 \times 10^{-4}$

Tension (T) = $\frac{35 \times 10^6 \times 1.13 \times 10^{-4}}{2}$

$T = 1977.5$ kg

⇒ Weigh to Conductor = Specific gravity × Volume for 1m

= density of copper × Area × 1m

$= 8.9 \times 10^{-3} \times 10^{6} \times \pi/4 \, (0.012)^2 \times 1m$

$W_c = 1.006$ kg

⇒ Weight of the ice $(W_i) = 913.5 \times \pi t\,(d+t)$.

$= 913.5 \times \pi \times 9.53 \times 10^{-3}(0.012 + 9.53 \times 10^{-3})$

$W_i = 0.588$ kg

⇒ Weight of Wind $(W_W) = p \times (d + 2t)$

$= 40 \times (1.2 \times 10^{-2} + 2 \times 9.53 \times 10^{-3})$

$= 1.242$ kg.

⇒ Resultant Weight $(W) = \sqrt{(1.006 + 0.588)^2 + (1.242)^2}$

$W = 2.02$ kg.

⇒ $\cos\theta = \frac{W_c + W_i}{W} = \frac{1.006 + 0.588}{2.02}$

$\cos\theta = 0.789$

⇒ $\sin\theta = \frac{W_W}{W} = \frac{1.242}{2.02}$

$\sin\theta = 0.615$

(i) Deflecting torque $= \frac{W l^2}{8T}$

$Y = \frac{2.02 \times (160)^2}{8 \times 1977.5}$ ⇒ $Y = 3.26m$

(ii) Vertical Sag = $Y \times \cos\theta$

$= 3.26 \times 0.78 \Rightarrow 2.54m$ //

(iii) Horizontal Sag = $Y \times \sin\theta$

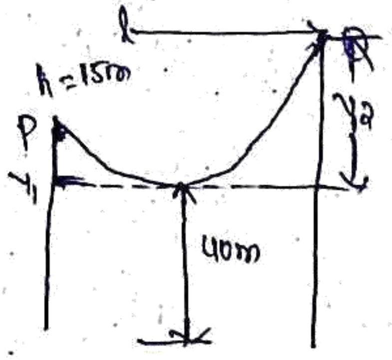
$= 3.26 \times 0.61$

$= 1.98m.$ //

26/09/19

1. An over head Conductor having an ultimate Strength of 8000kg/cm² and an area of 2 cm². is Erected b/w Supports placed 600 m apart and having level difference of 15 m. If the minimum ground clearance is to be 40m. find the tower heights the Conductor is Subjected to a horizontal wind pressure of 1.5 kg/m. the Self weight of the Conductor 1.75 kg/m. Assume a Safety factor of "4".

Sol:-



Given data,

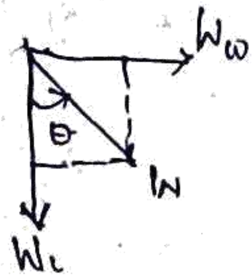
ultimate Strength = 8000 kg/cm³

Area = 2cm².

Span (l) = 600 m

difference in height (h) = 15 m.
ground clearance = 40 m.
Tower height = ?
Wind pressure = 1.5 kg/m^2
Weight of Conductor = 1.75 kg/m
Safety factor = 4.

⇒ Weight of Conductor (W) = $\sqrt{W_c^2 + W_w^2}$



Weight of Conductor = 1.7 kg/m

Weight of Wind = Air pressure x projected area

$= 1.5 \times 2 \times 10^{-4}$

$= 3 \times 10^{-4}$ kg.

$\therefore W = \sqrt{(W_c)^2 + (W_w)^2} = \sqrt{(1.7)^2 + (3 \times 10^{-4})^2}$

$\boxed{W = 1.7 \text{ kg}}$

Tension =

⇒ Sag w.r.t to lowest tower weight-

$$y_1 = \frac{W x_1^2}{2T}$$

difference in height (h) = $y_2 - y_1$.

$$x_1 = \frac{l}{2} - \frac{Th}{WL} \; ; \; x_2 = \frac{l}{2} + \frac{Th}{WL}$$

Now, Tension (T) = $\frac{\text{Ultimate Strength} \times \text{Area}}{\text{Safety factor}}$

$$= \frac{8000 \times 2}{4} = 4000 \text{ kg.}$$

$$\therefore x_1 = \frac{600}{2} - \frac{4000 \times 15}{1.7 \times 600} = 241.17 \text{ m}$$

$$x_2 = \frac{600}{2} + \frac{4000 \times 15}{1.7 \times 600} = 358.82 \text{ m.}$$

$$\therefore y_1 = \frac{Wx_1^2}{2T} = \frac{1.7 \times (241.17)^2}{2 \times 400} = 12.35 \text{ m}$$

$$y_2 = \frac{Wx_2^2}{2T} = \frac{1.7 \times (358.82)^2}{2 \times 4000} = 27.34 \text{ m}$$

⇒ lowest tower hight = y_1 + ground Clearance

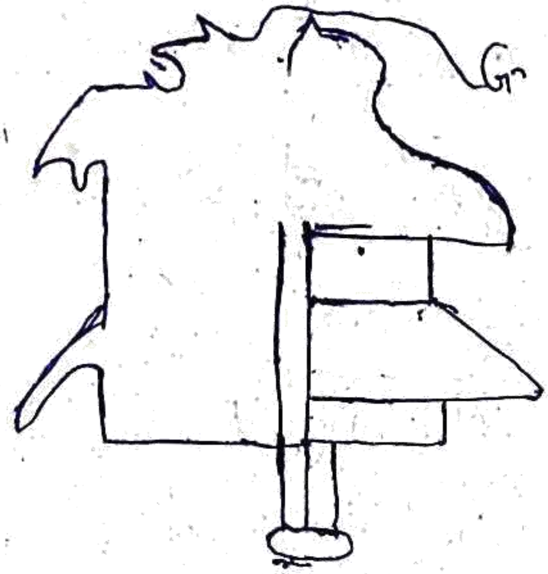
= 12.35 m + 40 m

= 52.35 m.

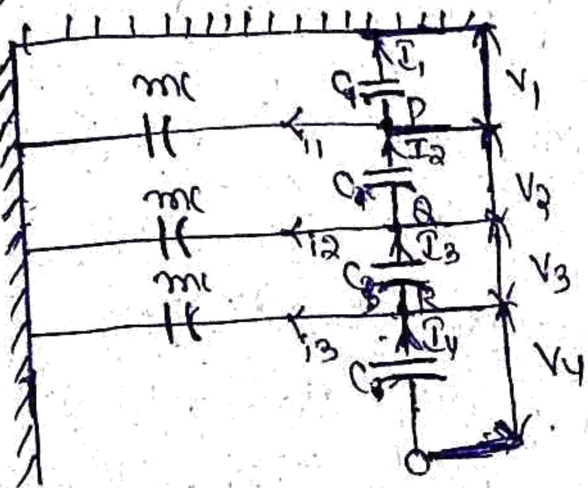
→ highest tower hight = y_2 + ground Clearance

= 27.34 + 40

= 67.34 m.



String Efficiency:-



⟹

⟹ The String Efficiency is used to calculate the potential distribution along the String with 'n' no. of disks (or) units.

⟹ The greater the String Efficiency the voltage distribution among all the units are nearly Equal.

⟹ let 'C' = The mutual Capacitance b/w the links

mc = Shunt Capacitance b/w the links and Earth

m = Capacitance to ground / mutual Capacitance

V_1 = voltage across the 1st unit i.e., near the cross arm

V_2, V_3, V_4 = voltage across 2nd, 3rd & 4th units respectively

Derivation:-

⟹ Apply KCL at node 'P'

$$I_2 = i_1 + I_1$$

$$V_2 WC = V_1 Wmc + V_1 WC$$

$$V_2 WC = WC V_1 (1+m)$$

$$V_2 = V_1 (1+m) \longrightarrow (1)$$

⟶ Apply KCL at node 'Q'

$$I_3 = i_2 + I_2.$$

$$V_3 Wc = (V_1+V_2) Wmc + V_2 WC.$$

$$V_3 WC. = V_1 Wmc + V_2 Wmc + V_2 WC.$$

$$V_3 WC = Wc (V_1 m) + WC.V_2 (1+m)$$

$$V_3 WC = WC [V_1 m + V_1 (1+m)(1+m)]$$

[∵ from Eqn (1)]

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

$$V_3 = V_1 [m + m^2 + 1 + 2m]$$

$$\boxed{V_3 = V_1 [m^2 + 3m + 1]} \longrightarrow (2)$$

⟹ Apply KCL at node 'R'

$$I_4 = i_3 + I_3$$

$$V_4 WC = (V_1+V_2+V_3) Wmc + V_3 WC.$$

$$V_4 WC = [V_1 + V_1(1+m) + V_1(m^2+3m+1)] W mc + V_1(m^2+3m+1) WC$$

$$V_4 WC = WC [V_1 + V_1(1+m) + V_1(m^2+3m+1)] m + V_1(m^2+3m+1)$$

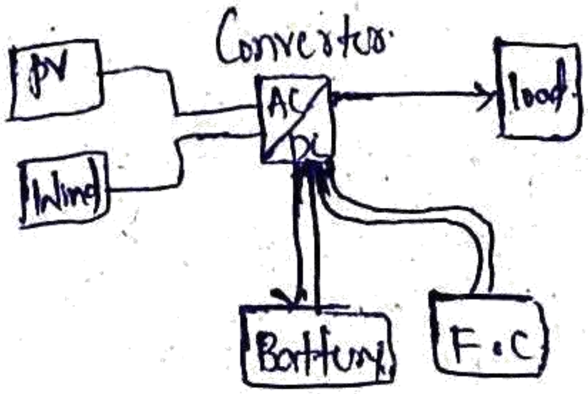
$$V_4 = V_1 [1 + (1+m) + (m^2+3m+1)m + (m^2+3m+1)]$$

$$= V_1 [m + m + m^2 + m^3 + 3m^2 + m + m^2 + 3m + 1]$$

$$\boxed{V_4 = V_1 (m^3 + 5m^2 + 6m + 1)}$$

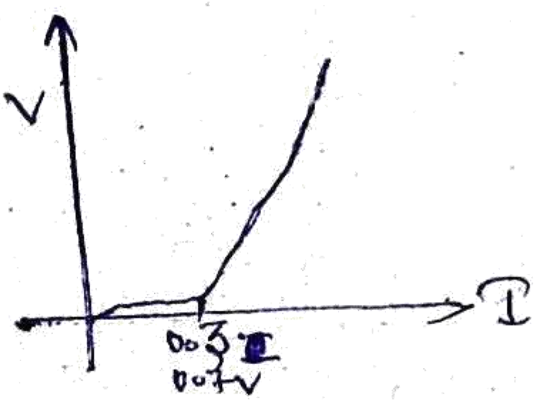
RES 26/08/19

PV- Battery - fuel cell wind :-



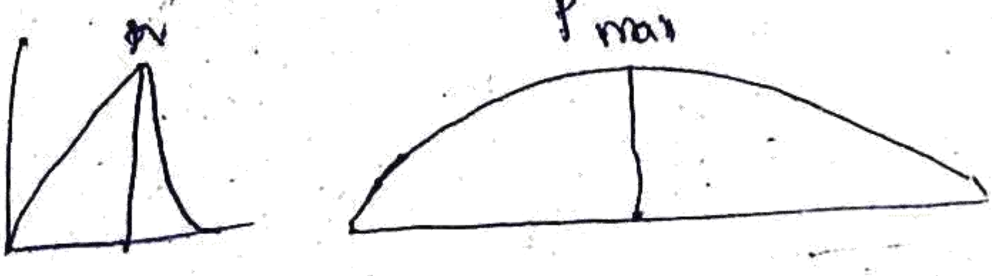
* fuel cell is a static device which converts Hydrogen energy into electrical energy and it stores the electrical energy in form of hydrogen

P-V Characteristics :-



MPPT :-

(Maximum power point tracking)



→ Sun flower Technique :-