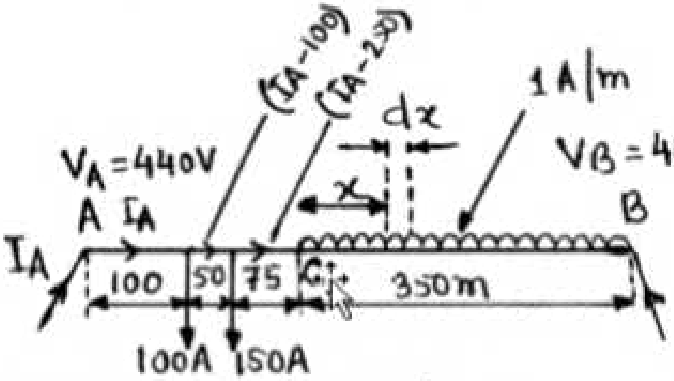
Prob: A direct current 2-wire distributor 575m long is fed at both points A & B at 440V. The load consists of 100A at 100m from A, 150A at 150m from A & a uniform loading of 1A/m for the last 350m. Resistance of each cond. is 0.05Ω/km. At what point is the load voltage a minimum & what is its value?



r = go & return resistance

$= 2 \cdot 0.05\,\Omega/km = 0.1\,\Omega/km$

$= 0.1 \cdot 10^{-3}\,\Omega/m = 10^{-4}\,\Omega/m$

Soln:

Let, I_A be the current supplied from end A.

Then, voltage drop from A to B

$$= V_A - V_B = I_A \cdot 100r + (I_A - 100) \cdot 50r + (I_A - 250) \cdot 75r$$

$$+ \int_0^{350} (I_A - 250 - x \cdot 1) \cdot r\,dx = 0$$

Simplifying, $I_A = 300A$

Since $I_A = 300A$, The point of minimum potential occurs in between C and B.

Now, the voltage drop in the elemental distance dx at a distance x from C = dv

$$= (I_A - 250 . x . 1) . r . dx$$

For point of minimum potential $\frac{dv}{dx} = 0$

or, $\frac{dv}{dx} = (I_A - 250 - x) . r = 0$

or, $x = I_A - 250 = 50 m$ (from C)

$\therefore$ Distance of point of min. potential from end A $= (100 + 50 + 75) + 50 = 275 m$

Similarly, distance of point of min. potential from end B = 350 − 50 = 300 m

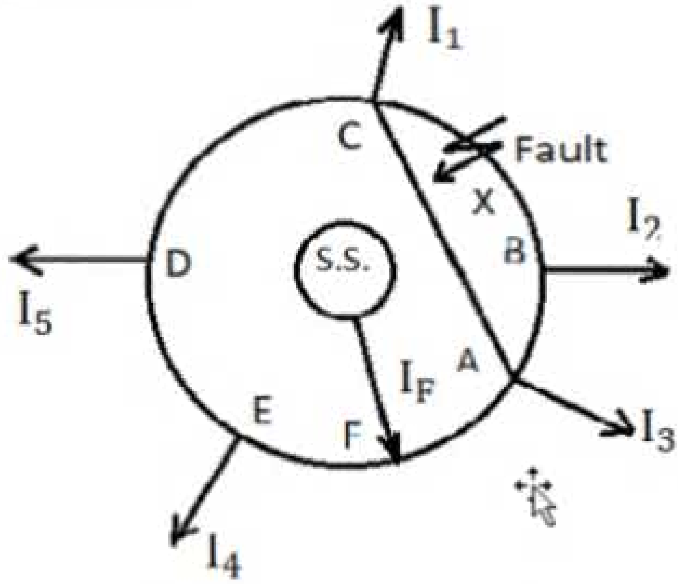
Load voltage at point of min. potential

= Voltage at B − Voltage drop in distributed load for 300m

$$= 440 - \frac{1}{2}(300)^2 \cdot 1 \cdot 10^{-4} = 435.5\,V$$

Ring Distributor

- It employs a distributor which after covering the whole area of supply returns back to starting point.
- It is closed on itself.
- ABCDEFA forms a complete ring.
- Loads are connected at A, B, C, D & E; F is feeding point.
- For any load, there are two parallel paths→ greater reliability of supply.



- For fault at 'X', 'BC' is isolated for continuity of supply.
- More saving in conductor compared to a radial distributor.
- Often, two points are joined to reduce voltage drop further.

- Two examples of ring distributors are shown in the figs.
- In second fig. current directions are are chosen arbitrarily.
- Let, r Ω/m be go & return of distributor.
- Applying Kirchhoff's law in closed path FABCF,

$$I.(l_1.r) + (I - I_1).(l_2.r) + (I - I_1 - I_2).(l_3.r) - I_A.(l_7.r) = 0 \ldots\ldots\ldots(1)$$

- Applying Kirchhoff's law in closed path FEDCF,

$$(I_F - I - I_A).(l_6.r) + (I_F - I - I_A - I_5).(l_5.r) + +(I_F - I - I_A - I_5 - I_4).(l_4.r) - I_A.(l_7.r) = 0 \ldots(2)$$

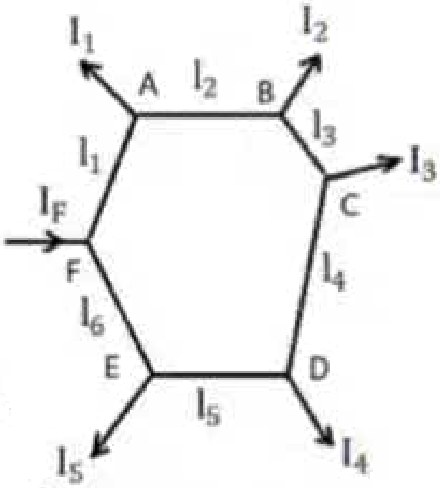


fig. Simple ring distributor.

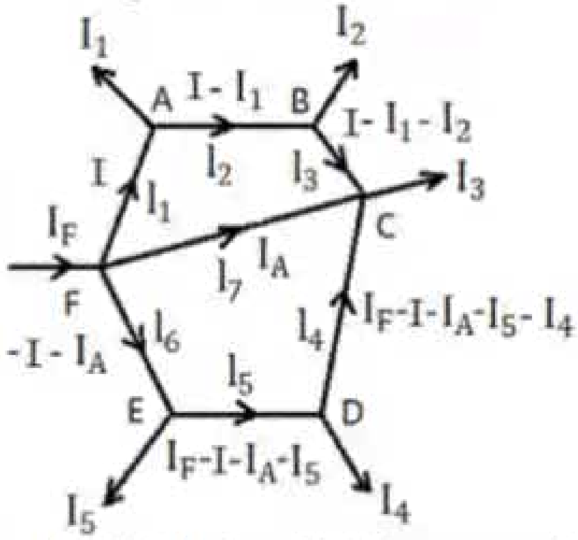


Fig. Ring distributor with inter-connection.

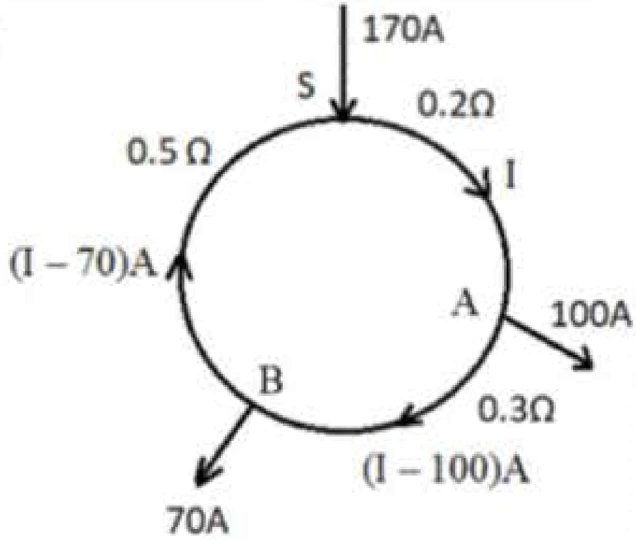
- In eqns. (1) & (2),

(i)loads I_1, I_2, I_3, I_4 & I_5 &

(ii)distances l_1, l_2, l_3, l_4, l_5, l_6 & l_7 are known.

- Hence, eqns. (1) & (2) may be solved for I & I_A.
- So, voltage drop up to any load point may be calculated.

Prob: A ring main is supplied at point S and loaded at point A with 100A & at point B with 70A. The sectional resistances are: SA, 0.2Ω; AB, 0.3 Ω; BS, 0.5 Ω. (a) Find the current in AB. (b) Find the voltage drop between S & each Load point. (c) Find the voltage drop between S & A when load at B is removed.



Soln: Considering the current directions, Voltage drop in the closed path,

$$I. 0.2 + (I - 100). 0.3 + (I - 170). 0.5 = 0$$

Solving, $I = 115A$.

(a) Current in AB = (115 – 100)A = 15A (from A to B).

(b) Voltage drop between S & A= I. 0.2 = 23V (from S to A).

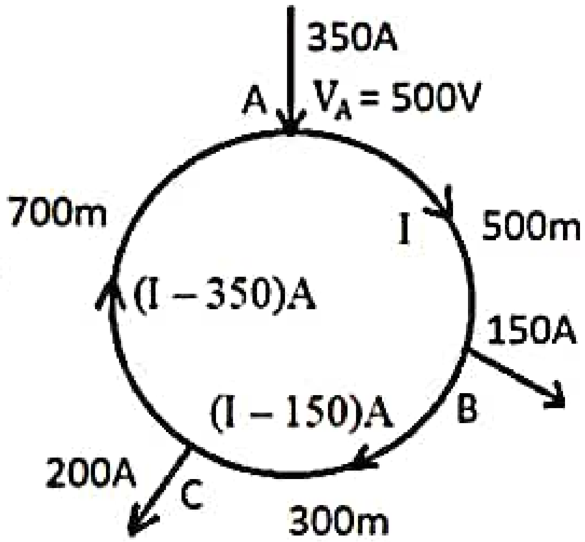
Voltage drop between S & B= -(I – 170). 0.5 =27.5V (from S to B).

(c) When load at B is removed, then current at A is received through two parallel paths: S – A & S – B - A.

So, equivalent resistance = $\frac{0.2.\ (0.5 + 0.3)}{0.2 + (0.5 + 0.3)} = 0.16\Omega$

Therefore, voltage drop between S & A = 0.16. 100 = 16V.

Prob: In the direct-current ring main shown, a voltage of 500V is maintained at A. At B, a load of 150A is taken & at C, a load of 200A is taken. Find voltages at B & C. Resistance of each conductor of the main is 0.03Ω/km.



Resistance of each conductor =0.03Ω/km = 0.03 .10⁻³ Ω/m

Soln: Applying Kirchhoff's Voltage law,

$I.(0.03.10^{-3}.2.500) +$

$(I-150).(0.03.10^{-3}.2.300) +$

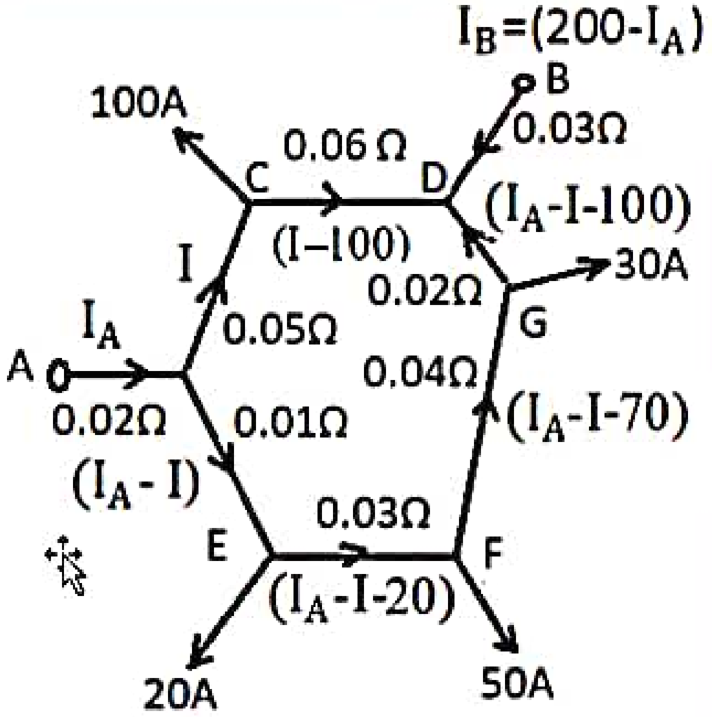
$(I-350).(0.03.10^{-3}.2.700) = 0$

Solving, I = 193.3333A

Voltage at B=V_A - {$I.(0.03.10^{-3}.2.500)$}= 494.2V (A - B).

Voltage at C=V_A -{$-(I-350).(0.03.10^{-3}.2.700)$}= 493.42V (A - C)

Prob: Find the current supplied to the ring main from A & B (a) for equal voltages at A & B, (b) for the voltage at B higher than that at A by 5V.



Soln: $I_A + I_B = 100+20+50+30$

$= 200A$

Or, $I_B = 200 - I_A$ .....(1)

(a) Voltage drop from A to B, via C & D,

$I_A . 0.02 + I . 0.05 + (I - 100) . 0.06 - (200 - I_A) . 0.03 = 0$

Simplifying,

$5 . I_A + 11 . I = 1200$ .....(2)

Similarly, Voltage drop from A to B, via E, F & G,

$$I_A . 0.02 + (I_A - I) . 0.01 + (I_A - I - 20) . 0.03 + (I_A - I - 70) . 0.04$$
$$+ (I_A - I - 100) . 0.02 - (200 - I_A) . 0.03 = 0$$

Simplifying,

$15 . I_A - 10 . I = 1140$ .....(3)

Solving eqns. (2) & (3),

$I = 57.2093A$ & $I_A = 114.1395A$

Therefore, $I_B = 200 - I_A = 85.8605A$.

(b) $V_B = V_A + 5$ .....(4)

So, from eqn. (2),

$5 . I_A + 11 . I - 1200 = -500$

Or, $5 . I_A + 11 . I = 700$ .....(5)

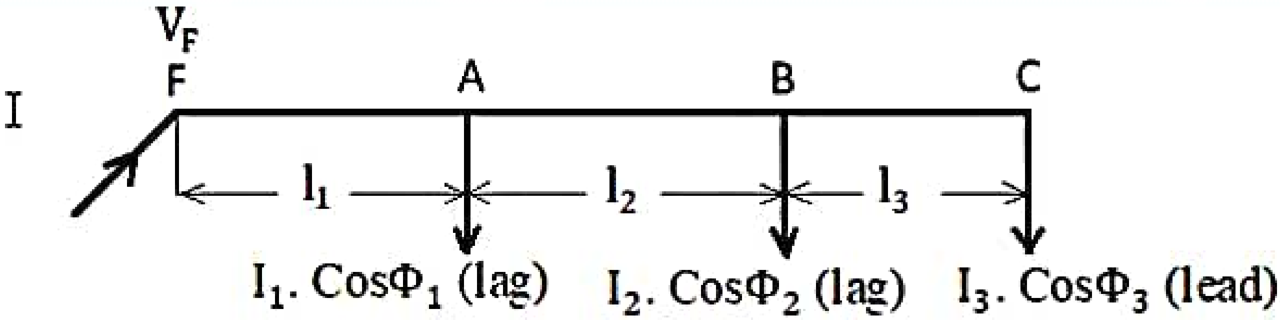
From eqn. (3),

$15.I_A - 10.I = 1140 - 500 = 640$ .....(6)

Solving eqns. (5) & (6),

$I = 33.9535A$ & $I_A = 65.3023A$

$I_B = 200 - I_A = 134.6977A$



Distributor impedance = Z = (R + j X) Ω/unit length

Example: Consider the a.c. two wire distributor fed at one end.

Then, the total voltage drop from F to C = V_{FC} =

$l_1 . (R + jX) . (I_1 . Cos\Phi_1 - j . I_1 . Sin\Phi_1) + (l_1 + l_2) . (R + jX) . (I_2 . Cos\Phi_2 - j . I_2 . Sin\Phi_2) + (l_1 + l_2 + l_3) . (R + jX) . (I_3 . Cos\Phi_3 + j . I_3 . Sin\Phi_3)$

So, consumer voltage at C = $V_C = V_F - V_{FC}$

Similarly, consumer voltages at A & B may also be calculated.

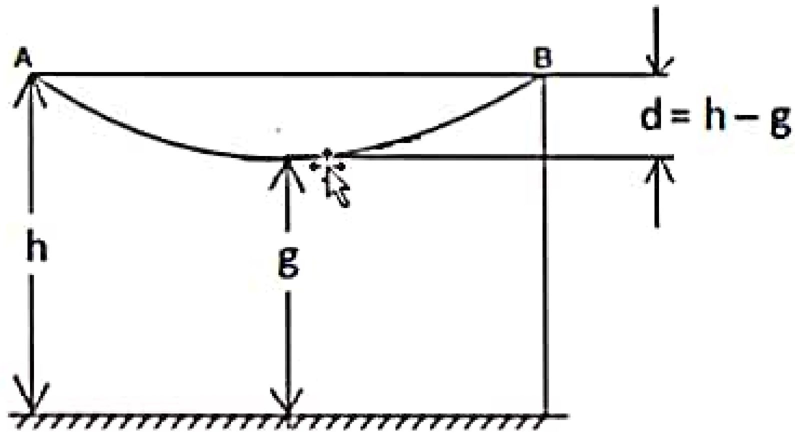
•Horizontal distance between two adjacent supports is span.

•Under normal condition of erection height of the conductor at centre of span is less than that at the support.

•Difference between the two is known sag.

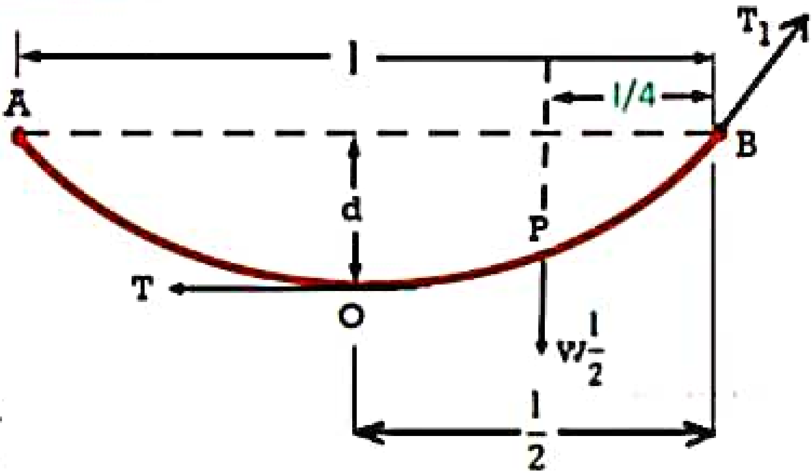
•Sag calculation is easy for conductors of homogeneous material→ all Cu or all Al.

•More involved for conductors of composite materials →ACSR (Aluminium Conductor Steel Reinforced) conductors.



•Knowledge of sag is important as it determines min. ground clearance.

Parabolic Method of Sag Calculation



- If weight of cond. is uniformly distributed horizontally, a freely suspended cond. hangs in shape of a parabola. Let,

w=weight of cond./unit length

T = tension in cond. at point O,

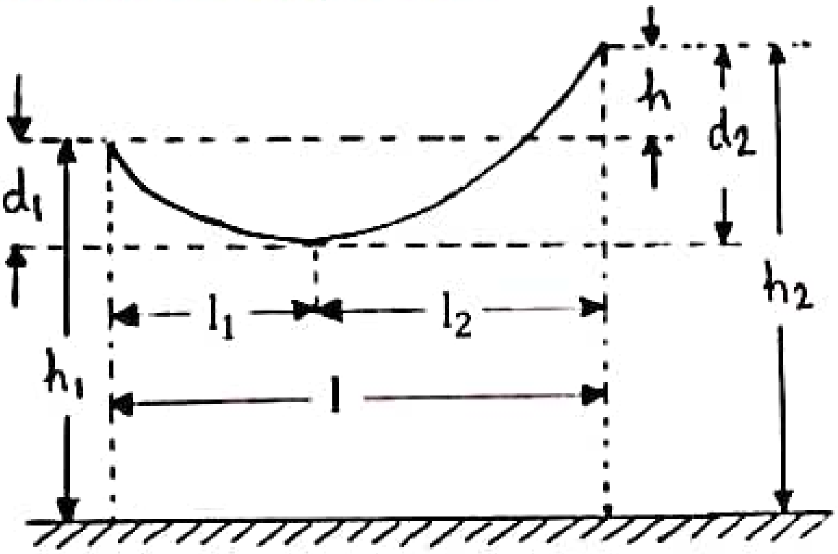
T_1= tension in cond. at B & d= sag.

Consider equilibrium of OPB. At P, at a distance $\frac{l}{4}$, a force $w.\frac{l}{2}$ due to weight of cond. for portion OPB is acting downwards. Taking moment of all forces about point B,

$$T.d + \{ -(w.\frac{l}{2}).\frac{l}{4} \} + T_1.0 = 0 \Rightarrow \text{Sag} = d = \frac{wl^2}{8T} = \frac{w.(\frac{l}{2})^2}{2T}$$

Expression of Sag for Supports at Different Levels

- This case inevitably arises in hilly areas, uneven lands or in sloping grounds.
- Where maxm. benefit is taken by erecting supports at most elevated spots.



Here, $d_1 = \frac{\omega . l_1^2}{2T}$ ---(1)

$d_2 = \frac{\omega l_2^2}{2T}$ ---(2)

So, $d_2 - d_1 = h_2 - h_1 = h$ ---(3)

$$\text{Or, } h = \frac{\omega l_2^2}{2T} - \frac{\omega l_1^2}{2T}$$

$$= \frac{\omega}{2T}\left(l_2^2 - l_1^2\right)$$

$$= \frac{\omega}{2T}(l_2 + l_1)(l_2 - l_1)$$

$$= \frac{\omega}{2T} \cdot l \cdot \{l_2 - (l - l_2)\}$$

$$= \frac{\omega}{2T} \cdot l \cdot (2l_2 - l)$$

$$\text{Or, } (2l_2 - l) = \frac{2Th}{\omega l}$$

$$\text{Or, } l_2 = \frac{1}{2}\left(l + \frac{2Th}{\omega l}\right) \quad \text{---} (4)$$

$$\text{Similarly, } l_1 = \frac{1}{2}\left(l - \frac{2Th}{\omega l}\right) \quad \text{---} (5)$$

First, l_1 and l_2 are calculated from eqns.(5) and (4), then d_1 and d_2 are calculated from eqns. (1) and (2).

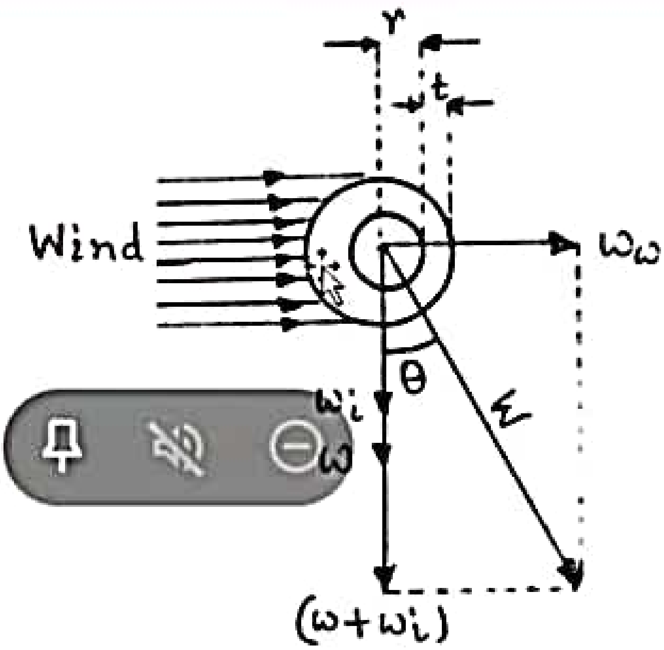
Effects of Wind & Ice Covering

During service conductor is subjected to forces due to:

(i) Its own weight (w), acting vertically downwards,

(ii) Wind pressure of various strength (w_w) and

(iii) Weight of ice covering (w_i), acting vertically downwards.



Let,

r = radius of conductor in m.m.

t = thickness of ice covering in m.m.

w = weight of conductor/m in kg.

P = wind pressure in kg/m^2

w_{ice} = weight/unit volume of ice in Kg/m^3

Then, volume of ice per metre length of conductor

$$= \frac{\{\pi(r+t)^2 - \pi r^2\}}{10^6} . 1 \cdot 0 \, m^3 = \frac{\pi(r+t+r)(r+t-r)}{10^6} . 1 \cdot 0 \, m^3$$

$$= \frac{\pi . (2r+t) . t}{10^6} m^3$$

So, weight of ice covering $= \omega_i$

$$= \omega_{ice} \cdot \frac{\pi . (2r+t) . t}{10^6} \text{ kg.}$$

Without ice covering wind load ω_ω

$$= P . \frac{2r}{10^3} . 1 \cdot 0 \text{ kg.}$$

With ice covering wind load ω_ω

$$= P . 2 . \frac{(r+t)}{10^3} . 1 \cdot 0 \text{ kg.}$$

So, resultant load W

$$= \sqrt{(\omega + \omega_i)^2 + \omega_\omega^2} \text{ Kg}$$

$$\text{and } \tan\theta = \frac{\omega_\omega}{(\omega + \omega_i)}$$

$$\text{Hence, sag } d = \frac{W l^2}{8T}$$

Vertical sag $= d \cdot \cos\theta$

If wind velocity is given, then wind pressure is found from the formula,

$$P = 0{\cdot}006\, V^2 \text{ Kg/m}^2$$

Loading factor is defined as $q = \frac{W}{\omega}$

Prob: A single span of a transmission line is 150m long, the supporting structures being level. The conductors have a cross section of 2.5 cm^2 hard drawn copper. Find the sag which must be allowed if tension is not to exceed one-fifth of the ultimate strength (40,000N per cm^2), (a) in still air & (b) with a wind pressure of 13N per metre & a 1.25cm ice-coating. In the later case also find the vertical sag. Take specific gravity of copper as 8.9gm/cc & density of ice as 920kg/m^3.

Soln: Given data: Span $l = 150$ m

Cross section $\pi r^2 = 2.5$ cm^2 (r = radius)

Or, $r = 0.892$ cm $= 8.92$ m.m.

Ice-coating $t = 1.25$ cm. $= 12.5$ m.m.

Working tension $T = \frac{1}{5} \times 40{,}000 \ N/cm^2$

$= \frac{1}{5} \times 40{,}000 \times \frac{1}{9.81} \ Kg/cm^2$

$= 815.494 \times 2.5 \ kg$

$= 2038.735 \ kg.$

Weight of conductor/cm $= 2.5 \times 1 \times 8.9 \ gm$

So, weight of conductor/m $= \frac{2.5 \times 8.9}{1000} \times 100$

$= 2.225 \ kg \ (= \omega \text{ say})$

(a) Sag in still air $d = \frac{\omega l^2}{8T} = \frac{2.225 \times (150)^2}{8 \times 2038.735}$

$= 3.0695 \ m$

(b) Weight of ice/m $= \dfrac{w_{ice} \times \pi.(2r+t).t}{10^6}$ kg ($= w_i$ say)

$= \dfrac{920 \times \pi \times (2 \times 8.92 + 12.5) 12.5}{10^6}$ kg $= 1.0961$ kg

Wind load $w_w = 13$ N $= \dfrac{13}{9.81}$ kg $= 1.3252$ kg

So, resultant load $W = \sqrt{(w+w_i)^2 + w_w^2}$

$= \sqrt{(2.225+1.0961)^2 + (1.3252)^2}$

$= 3.5756$ kg

Hence, sag $d = \dfrac{Wl^2}{8T} = \dfrac{3.5756 \times (150)^2}{8 \times 2038.735}$

$= 4.9727$ m

Click to Vertical sag $= d \cos\theta$

$$= d.\cos\left[\tan^{-1}\left(\frac{w_w}{w+w_i}\right)\right]$$

$$= 4.9327 \times \cos\left[\tan^{-1}\left(\frac{1.3252}{2.225+1.0961}\right)\right]$$

$$= 4.58145\ m$$

- **Prob:** An overhead line conductor consists of seven strands silicon-bronze, having an ultimate strength of 78500N per cm^2 & an area of 2.2 cm^2. When erected between supports 600m apart & having a 15m difference in level, find the vertical sag which must be allowed so that factor of safety shall be 5 with conductor loaded with 1kg of ice per metre & a wind pressure of 17.15N per metre. The conductor weighs 2.03kg per metre.

Soln:

Given data :

Span l = 600m; difference of height of supports = h = 15m;

weight of conductor/m = ω = 2.03 kg; ice loading/m = ω_i = 1 kg;

wind load = ω_ω = 17.15N = $\frac{17.15}{9.81}$ kg = 1.7482 kg.

Working tension $T = \frac{78500}{5}$ N/cm^2

$$= \frac{78500}{5 \times 9.81} \times 2.2 \text{ kg} = 3520.8970 \text{ kg}.$$

Cross sectional area = 2.2 cm^2

$\therefore$ Resultant load $W = \sqrt{(w+w_i)^2 + w_w^2} = \sqrt{(2.03+1)^2+(1.7482)^2}$

$= 3.4981$ kg.

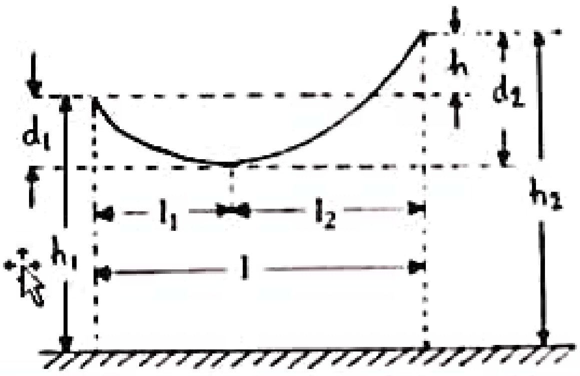
Here, $l_1 = \frac{1}{2}\left[l - \frac{2Th}{Wl}\right] = \frac{1}{2}\left[600 - \frac{2 \times 3520.8970 \times 15}{3.4981 \times 600}\right] = 274.8375\,m$

So, sag w.r.t. the lower support $d_1 = \frac{Wl_1^2}{2T} = \frac{3.4981 \times (600)^2}{2 \times 3520.8970}$

$= 37.5259\,m$

Now, $\cos\theta = \cos\left[\tan^{-1}\left(\frac{w_w}{w+w_i}\right)\right] = 0.8662$

Hence, vertical sag $= d_1 \cos\theta = 37.5259 \times 0.8662 = 32.5021\,m$



Prob: A transmission line conductors have an effective diameter of 19.5m.m. & weight of 0.85kg/m. If the maximum permissible sag is 6.3m, with a horizontal wind pressure of 39kg/m^2 of projected area & 12.7m.m. radial ice coating, calculate the permissible span between two supports when they are at same level, allowing a factor of safety of 2. Ultimate strength of the conductor is 8000kg & weight of ice is 910kg/m^3.

Soln:

Given data :

Conductor diameter = 19.5 m.m.

$\therefore$ Radius $= r = \frac{19.5}{2} = 9.75$ m.m ; weight of conductor/m $= w = 0.85$ kg ;

maxm. permissible sag $= d = 6.3$ m ; wind pressure $P = 39$ kg/m^2 ;

ice coating $= t = 12.7$ m.m ; ultimate strength $= 8000$ kg ;

factor of safety = 2 ; weight of ice/unit volume $= w_{ice} = 910$ kg/m^3

Here, weight of ice covering $= w_i = \dfrac{w_{ice} \cdot \pi (2r+t) \cdot t}{10^6}$ kg

$$= \frac{910 \times \pi \times (2 \times 9.75 + 12.7) \times 12.7}{10^6} \text{ kg} = 1.169 \text{ kg}$$

$$\text{Wind load} = \frac{P \cdot 2 \cdot (r+t)}{10^3} \text{ kg} = \frac{39 \times 2 \times (9.75 + 12.7)}{10^3} = 1.7511 \text{ kg} = w_w$$

So, resultant load $= W = \sqrt{(w+w_i)^2 + w_w^2} = \sqrt{(0.85+1.169)^2 + (1.7511)^2}$

$= 2.6727$ kg

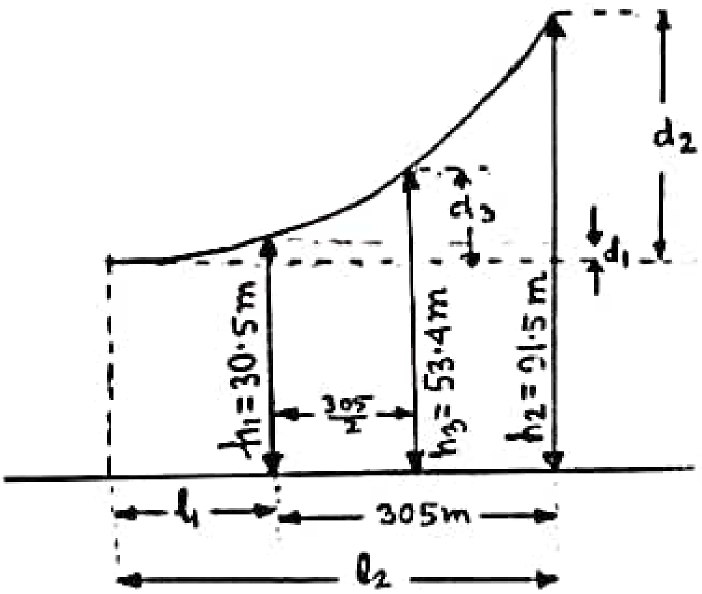
Now, working tension $= T = \dfrac{8000}{2} = 4000$ kg

As, sag $d = \dfrac{Wl^2}{8T}$, span $= l = \sqrt{\dfrac{8Td}{W}} = \sqrt{\dfrac{8 \times 4000 \times 6.3}{2.6727}}$ m

$= 274.646$ m

Prob: An overhead line at a river crossing is supported from two towers of heights 30.5m & 91.5m above the water level with a span of 305m. If the required clearance between the conductor & water level midway between the towers is 53.4m and if both the towers are on the same side of maximum sag point of the parabolic configuration, calculate the stringing tension on the conductor. Weight of conductor is 0.88kg/m. Also calculate the distances of the two towers from the point of maximum sag.

Soln:



Given data:

Height of towers $h_1 = 30.5m$ and $h_2 = 91.5m$; Span $= l = 305m$;
Clearance of conductor at middle of span $= h_3 = 53.4m$;
weight of conductor/m $= \omega = 0.88$ kg.

Here, $d_2 - d_1 = h_2 - h_1 = \frac{\omega}{2T}(l_2^2 - l_1^2)$

Or, $91.5 - 30.5 = \frac{0.88}{2T}(l_2 + l_1)(l_2 - l_1) = \frac{0.88}{2T}(305 + 2l_1) \times 305$

or, $T = 2.2(305 + 2l_1)$ ---(1)

Here, $d_2 - d_1 = h_2 - h_1 = \frac{\omega}{2T}(l_2^2 - l_1^2)$

Or, $91.5 - 30.5 = \frac{0.88}{2T}(l_2 + l_1)(l_2 - l_1) = \frac{0.88}{2T}(305 + 2l_1) \times 305$

or, $T = 2.2(305 + 2l_1)$ ---(1)

Equating (1) and (2),

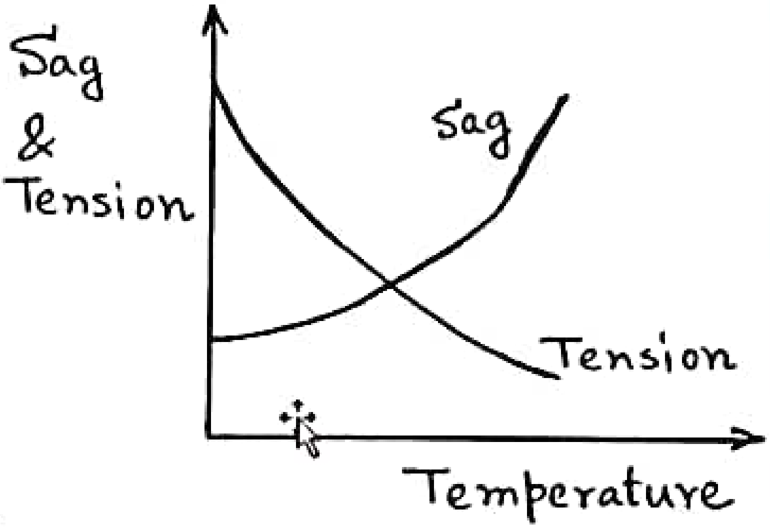
$$2.930\left(2l_1+\frac{305}{2}\right)=2.2(305+2l_1)$$

Solving, $l_1 = 153.5032\,m$

$l_2 = l_1 + 305 = 458.5032\,m$

$\therefore$ Tension $T = 2.2(305+2l_1) = 1346.4145\,m$

Stringing Chart



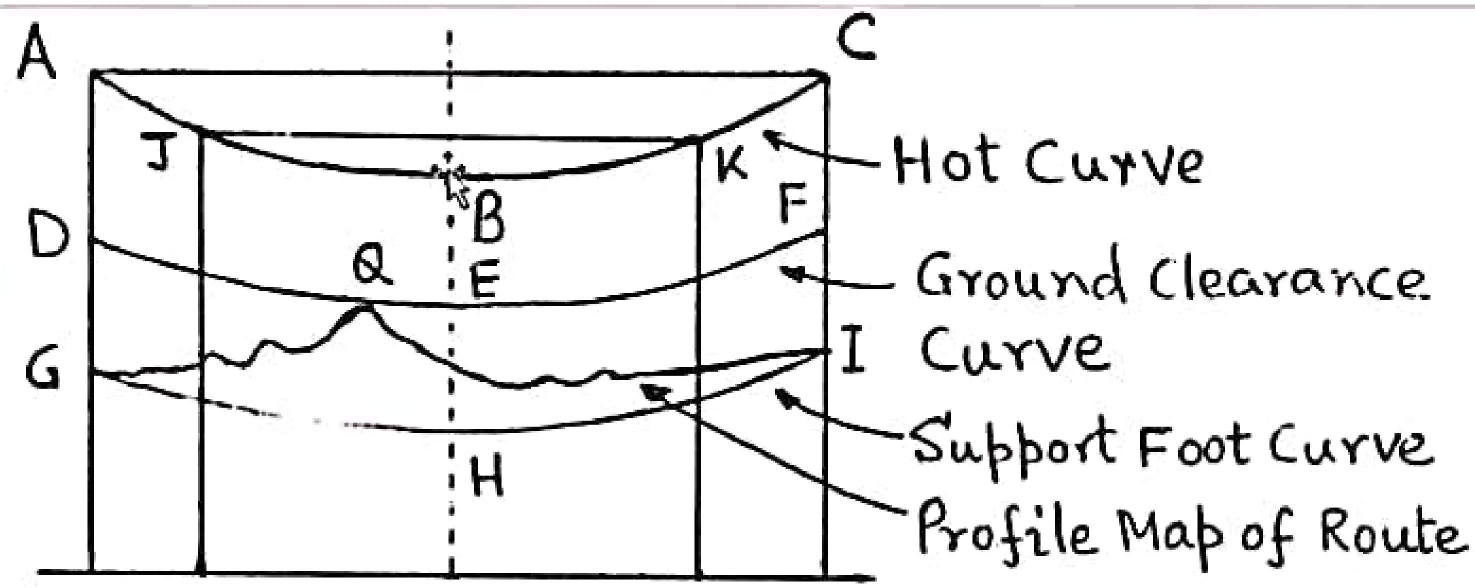
•Both sag & tension depends on temperature.

- Maxm. & min. temp. of the proposed route are known From previous years records.
- Sag & tension are calculated in this range of temp.
- Curves of sag vs. temp. & tension vs. temp. are known as stringing charts/erection sag curves.
- These are useful to adjust sag & tension properly at the time of erection.

Sag Template

- Use of sag template is essential to allocate the position & height of the supports correctly on the profile.
- It is usually made of transparent celluloid, perspex or sometimes cardboard.
- The following curves are marked on it.

1. Hot temperature curve: Obtained by plotting sag at maxm. temp. vs. span length (AJBKC).
2. Ground clearance curve: It is situated below the hot curve & is at a distance from it, equal to the ground clearance as prescribed by the regulations for the given line (DQEF).
3. Support foot curve: This curve gives the location of the footing of the towers. It is situated below the hot curve at a distance – height of a standard tower from the lowest point of attachment to the ground level (GHI).


A
C
J
K
B
F
D
Q
E
G
I
H
Hot Curve
Ground Clearance Curve
Support Foot Curve
Profile Map of Route