Department of Electrical Engineering
Assignment
Date: 14/04/2020

Course Details

Course Title: Electric Power Transmission **Module:** 4rth
Instructor: Aamir aman **Total Marks:** 30

Student Details

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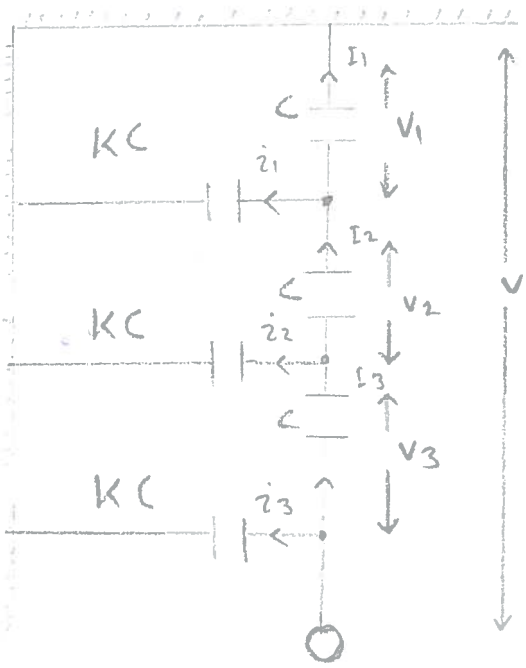
Q1	(a)	In a 66 kV overhead line, there are three units in the string of insulators. If the capacitance between each insulator pin and earth is 22% of self-capacitance of each insulator, Find i) The distribution of voltage over 3 insulators and ii) String efficiency.	Marks 05 CLO 1
	(b)	A 3-phase line has conductors 4 cm in diameter spaced equilaterally 2 m apart. If the dielectric strength of air is 60 kV (max) per cm. Find the disruptive critical voltage for the line. Take air density factor $\delta = 1.5$and irregularity factor mo = 0·6.	Marks 05 CLO 1
Q2	(a)	An overhead transmission line conductor having a parabolic configuration weighs 3.789 kg per meter of length. The area of X-section of the conductor is 6·2 $cm^2$and the ultimate strength is 950.665 kg/cm^2. The supports are 300 m apart having 25 m difference of levels. Calculate the sag from the taller of the two supports which must be allowed so that the factor of safety shall be 2. Assume that ice load is 2 kg per meter run and there is no wind pressure.	Marks 10 CLO 1
Q3	(a)	A transmission line has a span of 400 meters between level supports. The conductor has a cross-sectional area of 2.34 cm2, weighs 70 kg/km and has a breaking stress of 42 kg/cm^2. Calculate the sag for a safety factor of 6, allowing a wind pressure of 522 kg per square meter of projected area. What is the vertical sag?	Marks 05 CLO 2
	(b)	The towers of height 60 m and 120 m respectively support a transmission line conductor at water crossing. The horizontal distance between the towers is 800 m. If the tension in the conductor is 400 kg, Find the minimum clearance of the conductor and water and clearance mid-way between the supports. Weight of conductor is 3.5 kg/m. Bases of the towers can be considered to be at water level.	Marks 05 CLO 2

Question 1 (a)

Solution: The figure shows the equivalent circuit of string insulators.

let V_1, V_2 and V_3 be the voltage across top, middle and bottom unit respectively.

If C is the self capacitance of each unit, then KC will be the shunt capacitance.



$$K = \frac{\text{Shunt Capacitance}}{\text{Self-capacitance}}$$

$$K = 22\% = 0.22$$

$$\boxed{K = 0.22}$$

Voltage across the string $V = 66\,kV/\sqrt{3}$

$$\boxed{V = 38.10\,kV}$$

At junction A

$$I_2 = I_1 + i_1$$

$$V_2 \omega C = V_1 \omega C + V_1 K \omega C$$

$$V_2 \omega C = V_1 \omega C (1 + K)$$

$$V_2 = V_1 (1 + K) \quad - (A)$$

put value in equation (A)

$$V_2 = V_1 (1 + 0.22)$$

$$\boxed{V_2 = 1.22 V_1} \quad \text{---} \quad (1)$$

At junction B

$$I_3 = I_2 + i_2$$

$$I_3 = I_1 + i_1 + i_2$$

$$V_3 \omega C = V_1 \omega C + V_1 K \omega C + V_2 K \omega C$$

$$V_3 \omega C = K \omega C (V_2 + (V_1 + V_2))$$

$$V_3 = V_2 + (V_1 + V_2) K \quad - (B)$$

put value in (B)

$$V_3 = 1.22 V_1 + (V_1 + 1.22 V_1) 0.22$$

$$V_3 = 1.22 V_1 + (0.22 V_1 + 0.2684 V_1)$$

$$V_3 = 1.7084 V_1 \quad \text{---} \quad (II)$$

voltage across the whole string

$$V = V_1 + V_2 + V_3 \quad - (C)$$

put $V_2 = 1.22 V_1$ &

$V_3 = 1.7084 V_1$

in equation (C)

So $V = V_1 + 1.22V_1 + 1.7084V_1$

$38.10 = 3.9284\ V_1$

$$V_1 = \frac{38.10}{3.9284}$$

$$\boxed{V_1 = 9.698\ kV}$$

Now

$V_2 = 1.22\ V_1$

$V_2 = 1.22 \times 9.698$

$\boxed{V_2 = 11.83\ kV}$

$V_3 = 1.7084\ V_1$

$V_3 = 1.7084 \times 9.698$

$\boxed{V_3 = 16.54\ kV}$

(ii) String efficiency $= \dfrac{\text{voltage across string}}{\text{No. of insulator} \times V_3} \times 100$

$$= \frac{38.10}{3 \times 16.54} \times 100$$

$$= \frac{38.10}{49.62} \times 100$$

$$= 76.78\ \%$$

Question 1 (B)

Given data:

Conductor diameter = 4cm

Conductor Spacing = 2m = 0.02cm

Dielectric strength of air, g_o = 60 KV/cm = 42.4 KV/cm

Air density factor = δ = ~~0.95~~ 1.5

irregularity factor m_o = 0.6

Required data:

Disruptive critical voltage V_c = ?

Solution:

We know that

$$V_c = m_o g_o \delta r \log_e (d/r) \text{ KV/phase (r.m.s value)} \quad (1)$$

Radius of conductor is

$$r = 4cm/2 = 2cm$$

put value in equation (1)

$$V_c = 0.6 \times 42.4 \times 1.5 \times 2 \times \log_e \left(\frac{0.02}{2}\right) \text{ KV/phase}$$

$$= -152.64 \text{ KV/phase}$$

Line voltage (rms) = $\sqrt{3} \times -152.64 = -264.3$

Question 2 (a)

Given data:

length $l = 300\ m$

height $h = 25\ m$

weight $W = 3.789\ kg/m$

x-section area of conductor $= 0.2\ cm^2$

ultimate strength $= 950.665\ kg/cm^2$

$W_i = 2\ kg/m$

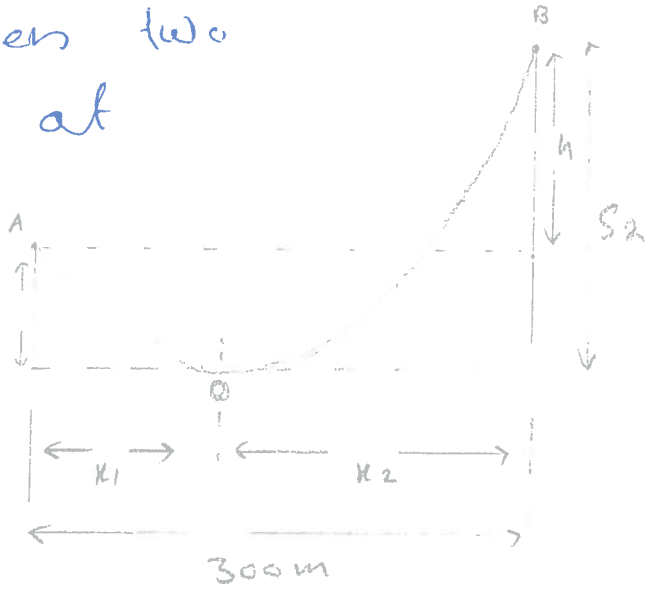
Safety factor $= 2$

Required data:

Calculate sag from the taller of two support.

Solution:

The figure show conductor suspended between two support A & B at different level with O as the lowest point on the conductor.



Here Working Tension $T = \frac{\text{Ultimate strength} \times \text{cross sectional}}{\text{Safety factor}}$

$$T = \frac{950.665 \times .6.2}{2}$$

$$T = \frac{5894.123}{2}$$

$$\boxed{T = 2947.06 \text{ kg}}$$

Now total weight of length of Conductor is

$$W_t = W + W_i$$

$$= 3.789 + 2$$

$$\boxed{W_t = 5.789 \text{ kg}}$$

let the lowest point O of the Conductor be at distance x_1 from the support at lower level, and at a distance x_2 from the support at higher level.

So $$x_1 + x_2 = 300 \text{ m} \quad \text{— (1)}$$

Now $$h = S_2 - S_1$$

$$h = \frac{W_t x_2^2}{2T} - \frac{W_t x_1^2}{2T}$$

$$h = \frac{W_t}{2T}(x_2^2 - x_1^2)$$

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

Ans: $x_2^2 - x_1^2 = (x_2 - x_1)(x_2 + x_1)$

$$\frac{2T \times h}{W_t (x_2 + x_1)} = x_2 - x_1$$

Now put value.

$$x_2 - x_1 = \frac{2 \times T \times 4}{w_t \times (x_2 + x_1)}$$

$$x_2 - x_1 = \frac{2 \times 2947.06 \times 25}{5.789 \times 300}$$

$$x_2 - x_1 = \frac{147353}{1736.7}$$

$$x_2 - x_1 = 84.84\ x_1 \quad \text{(ii)}$$

Compare equation (i) and (ii) to get the value of x_1 & x_2

So

$$x_1 + x_2 = 300\ m$$
$$-x_1 + x_2 = 84.84$$

$$\frac{2x_2}{2} = \frac{384.84}{2}$$

$$\boxed{x_2 = 192.42\ m}$$

Now put the value of x_2 in eqn (i) to get x_1

$$x_1 + x_2 = 300$$
$$x_1 + 192.42 = 300$$
$$x_1 = 300 - 192.42$$
$$\boxed{x_1 = 107.58\ m}$$

Now Sag for the taller of two tower is

$$S_2 = \frac{w_c H_2^2}{2T} \quad -(7)$$

$$S_2 = \frac{5.789 \times (192.42)^2}{2 \times 2947.06}$$

$$S_2 = \frac{5.789 \times 37025.45}{5894.12}$$

$$S_2 = \frac{214340.36}{5894.12}$$

$$\boxed{S_2 = 36.36 \text{ m}}$$

Question 3 (a)

Given data:

Length of span = 400 m

X-section of area of Conductor = 2.34 cm^2

weight = 70 kg/km = 0.07 kg

Breaking stress = 42 kg/cm^2

Safety factor = 6

wind pressure = 522 kg/m^2

Required data:

Vertical Sag = ?

Solution:

first we find T = ?

$$\text{So } T = \frac{\text{Breaking Stress} \times \text{cross-section area Conductor}}{\text{Safety factor}}$$

$$T = \frac{42\ kg/cm^2 \times 2.34\ cm^2}{6}$$

$$T = \frac{98.28}{6} =$$

$$\boxed{T = 16.38\ kg}$$

Now diameter of conductor

$$d = \sqrt{\frac{4 \times \text{area}}{\pi}}$$

$$d = \sqrt{\frac{4 \times 2.34}{3.14}}$$

$$d = \sqrt{2.98}$$

$$\boxed{d = 1.726 \text{ cm}}$$

Wind force per m length = pressure x projected area in m^2

$$W_w = 522 \text{ kg/m}^2 \times (1.726 \times 10^{-2} \times 1)$$

$$\boxed{W_w = 9 \text{ kg}}$$

total weight of Conductor per meter length

$$W_t = \sqrt{W^2 + W_w^2}$$

$$W_t = \sqrt{(0.07)^2 + (9)^2}$$

$$W_t = \sqrt{0.0049 + 81}$$

$$\boxed{W_t = 9 \text{ kg}}$$

Now

$$S = \frac{W_t \, l^2}{8T} \quad -(A)$$

$$S = \frac{9 \times (400)^2}{8 \times 16.38}$$

$$S = \frac{9 \times 160,000}{131.04}$$

$$S = \frac{1440,000}{131.04}$$

$$\boxed{S = 10989.01 \text{ m}}$$

The slant sag makes an angle with the vertical where value of θ is given by

$$\theta = \tan^{-1}\left(W_w/W\right)$$

$$\theta = \tan^{-1}\left(9/0.07\right)$$

$$\theta = \tan^{-1}(128.5)$$

$$\theta = 89.55^\circ$$

Now

$$\text{Vertical Sag} = S\cos\theta$$

$$= 10989.01\ (\cos(89.55^\circ))$$

$$= 10989.01 \times 0.00785$$

$$\boxed{\text{Vertical Sag} = 86.29\ \text{m}}$$

Question 3 (b)

Given data:

Height ; $h = 120m - 60m = 60m$

Length ; $l = 800m$

Tension ; $T = 400\ kg$

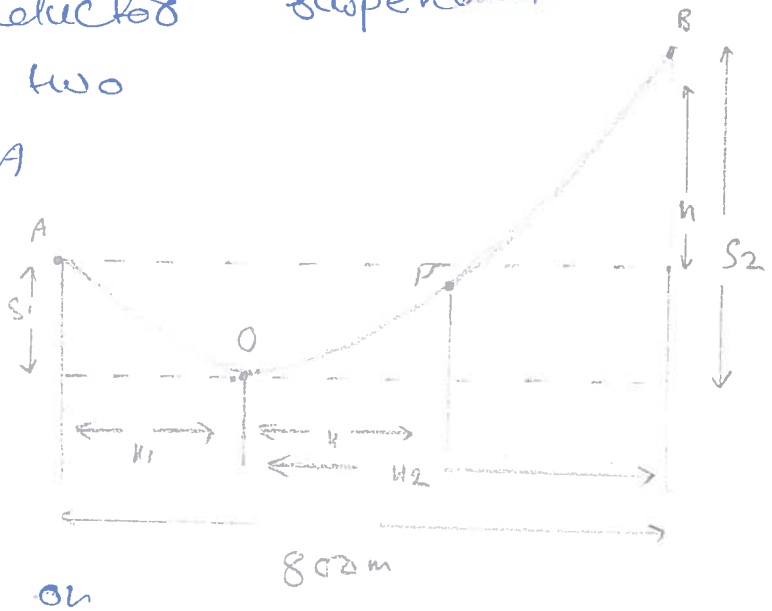
Weight of Conductor ; $w = 3.5\ kg/m$

Required data:

minimum clearance of the conductor and water and clearance mid-way b/w the support = ?

Solution:

The figure show that the conductor suspended between two support A and B at different level with O as the lowest point on the conductor



Let the lowest point "O" of the conductor be at a distance x_1 from the support at lower level and a distance x_2 from the support at higher level

So $$x_1 + x_2 = 800 \text{ m} \quad \text{— (A)}$$

Now $$h = S_2 - S_1$$

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

$$h = \frac{w}{2T}\left(x_2^2 - x_1^2\right) \quad \because a^2 - b^2 = (a+b)(a-b)$$

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

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

$$x_2 - x_1 = \frac{2 \times T \times h}{w \times (x_2 + x_1)} \quad \text{— (B)}$$

put value in (B)

$$x_2 - x_1 = \frac{2 \times 400 \times 60}{3.5 \times 800}$$

$$x_2 - x_1 = \frac{48000}{2800}$$

$$x_2 - x_1 = 17.14 \text{ m} \quad \text{— (B)}$$

Compare equation A & B to get the value of x_1 & x_2

So

$$x_1 + x_2 = 800 \quad \text{(A)}$$

$$-x_1 + x_2 = 17.14 \quad \text{(B)}$$

$$2x_2 = 817.14$$

$$\frac{2x_2}{2} = \frac{817.14}{2}$$

$$\boxed{x_2 = 408.57 \text{ m}}$$

put value of x_2 in equ (A) to get x_1

$$x_1 + x_2 = 800$$

$$x_1 + 408.57 = 800$$

$$x_1 = 800 - 408.57$$

$$\boxed{x_1 = 391.43 \text{ m}}$$

Now

$$S_1 = \frac{W x_1^2}{2T} \quad \text{(i)}$$

$$S_1 = \frac{3.5 \times (391.43)^2}{2 \times 400}$$

$$S_1 = \frac{3.5 \times 153217.44}{800}$$

$$S_1 = \frac{536261.04}{800}$$

$$\boxed{S_1 = 670.32 \text{ m}}$$

Now Clearance of the lowest point O from water level

$= 60 - 670.32$

$= -610.32$ m

Let the mid point (P) be at a distance x from the lowest point O

$x = 400 - x_1$

$x = 400 - 391.43$

$\boxed{x = 8.57 \text{ m}}$

Sag at mid point P

$$\text{Sag} = \frac{wx^2}{2T} - c$$

$$= \frac{3.5 \times (8.57)^2}{2 \times 400}$$

$$= \frac{3.5 \times 73.44}{800}$$

$$= \frac{257.04}{800}$$

$\text{Sag} = 0.3213$ m

Clearance of mid point (P) from water level

$= -610.32 + 0.3213$

$\boxed{= -609.9 \text{ m}}$