Power System Engineering
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Lecture – 28
Sag & Tension Analysis (Contd.)

So, just now we have seen that example 5 this is your example 5 right.

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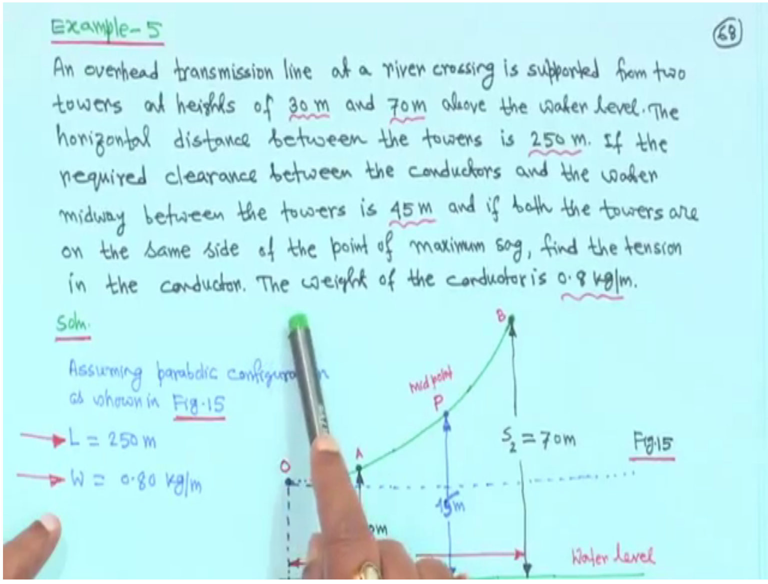

So, just reading once again the problem, an overhead transmission line at a river crossing is supported a from 2 towers at heights of 30 meter and 70 meter above the water level, the horizontal distance between the tower is 250 meters, if the required clearance between the conductors and the water midway between the tower is 45 meter, and if both the towers are on the same side of the point of maximum Sag, find the tension in the conductor, the weight of the conductor is given 0.8 kg per meter right.

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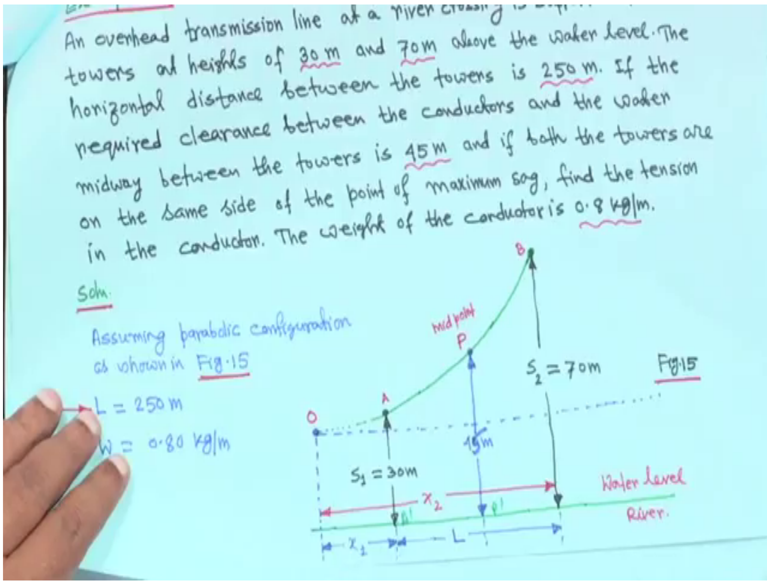

So, this is actually that your what to call the diagram. So, this is that a point A and point B and from the water level midpoint height is 45 meter and from here clarity 30 meter and from here clarity 70 meter. So, we are assuming that it is a parabolic configuration. So, length L is given here the 250 meters right, and S 1 is 30 meter say S 2 is the 70 meter, and this is the water level and W is 0.80.8 kg per meter right.

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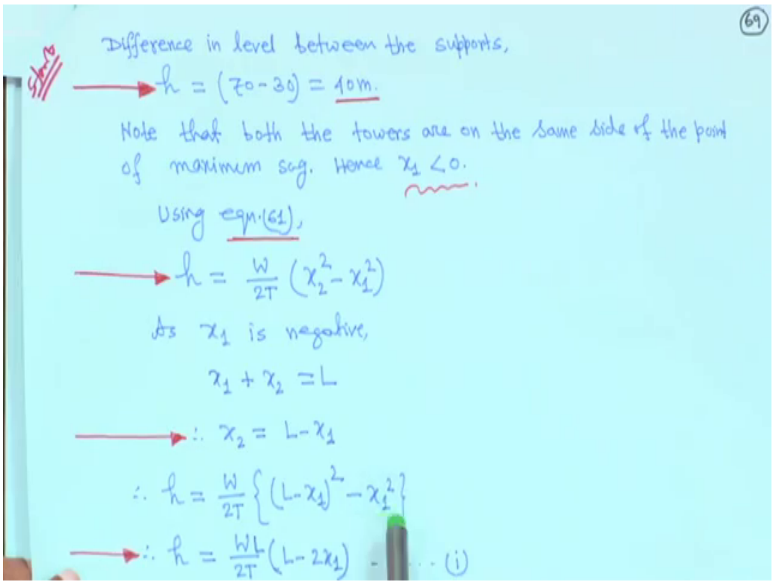

Therefore, the this this one your what you call then just hold on, then this one is the difference in level between the support, h is equal to 70 minus 30 40 meter, and note that both the towers on the same side of the point of minimum Sag if it is set so; that means, x 1 is negative right later we will see. So, using equation 61 in equation, 61 it was given h is equal to W upon 2 T x 2 square minus x 1 square, as x was in negative; that means, x 1 plus x 2 is equal to L this we have seen earlier also right so; that means, x 2 is equal to L minus x 1. So, you put here x 2 is equal to L minus x 1 and simplify, then your h will be WL W into capital L of course, divided by 2 T into L minus 2 x 1. So, this is say equation 1 right.

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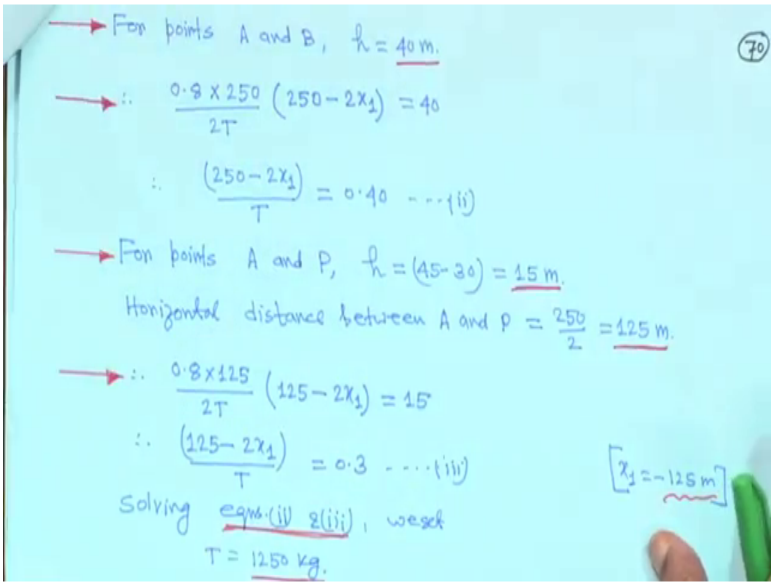

Therefore the 4 points A and B the difference is h is equal to 40 meter because one is your 70-meter height and point B and point A is a 40 meter from the your what you call 30 meters from the your water levels, your river water level. So, difference is 70 minus 30 is equal to 40 meter right, therefore, this you substitute all the values 0.8 into 250 upon 2 T 250 minus 2 x 1 is equal to 40 therefore, this equation you can write 250 minus 2 x 1 over T is equal to 0.4, I mean it simplified right in this form this is equation 2.

A for points A and P the midpoint from the water level is 45. So, difference between them that point A and point P and point h 45 minus 30. So, 15 meter this is also it is it is also given in this a diagram, it is just hold on in this diagram, it is given this is this is the diagram here it is given everything is given, right and a horizontal distance between A and P that is 250, because it is midpoint this P is midpoint and horizontal distance will be between A and P will between A and P the horizontal distance, I mean if you if you make a drags line that is between this distance I have this distance from here to A.

If I make this is your say A dash and this is your say P dash that is a horizontal distance A P dash this is the midpoint. So, naturally total is 250. So, it will be 250 by 2. So, 125 meter, and again you substitute in thous equation it will be 0.8 upon 1 into 125 upon 2 t, is equal to 125 minus 2 x 1 is equal to 15, that is again we are using the same equation right and; that means, you can write 125 minus 2 x 1 upon T is equal to point 3 solve then you will get T is equal to 1250 kg and this is x 1 is equal to it as I said it x 1 will become negative.

So, if you solve for x 1 also it is coming minus 125 meter right. So, next we will take another example that example 6, just hold on this is your example 6.

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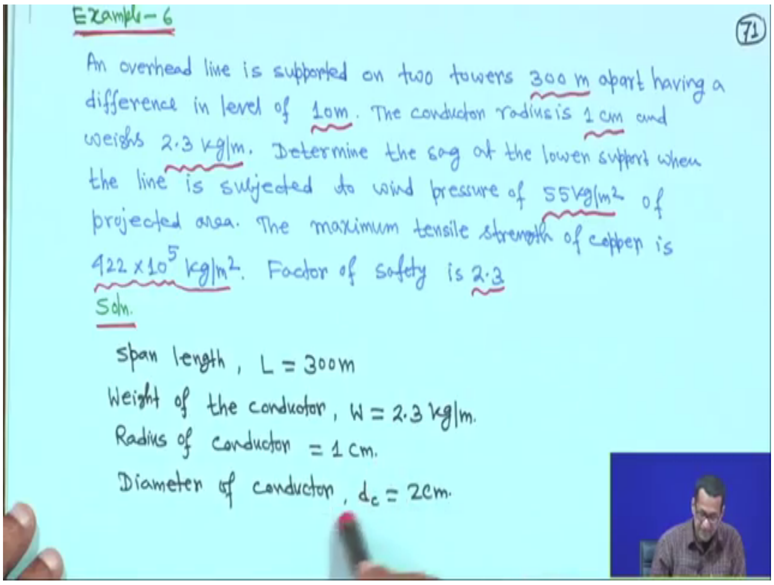

So, here it is says that an overhead line is supported on 2 towers, they are 30 meter apart right having a difference in level of 10 meter; that means, they are not at the same level, the conductor radius is 1 centimeter and weights is 2.3 kg per meter. So, you have to determine the Sag at the lower support when the line is subject to wind pressure of 55 kg per meter square, that is P of the projected area.

The maximum tensile strength of copper coil your of copper is given at 422 into 10 to the power 5 kg per meter square, and factor of safety is given 2.3 right. So, you have to find out the Sag at the lower support when the line is subject to all sort of data. So, a factor of safety is given 2 point your 3 now span length is given this is 300 meters. So, span length is given. So, L is equal to 300-meter weight of the conductor is also given, that is your

2.3 per kg per meter right, radius of the conductor is given 1 centimeter, and diameter of the conductor will be then 2 centimeters just that is the diameter of the conductor.

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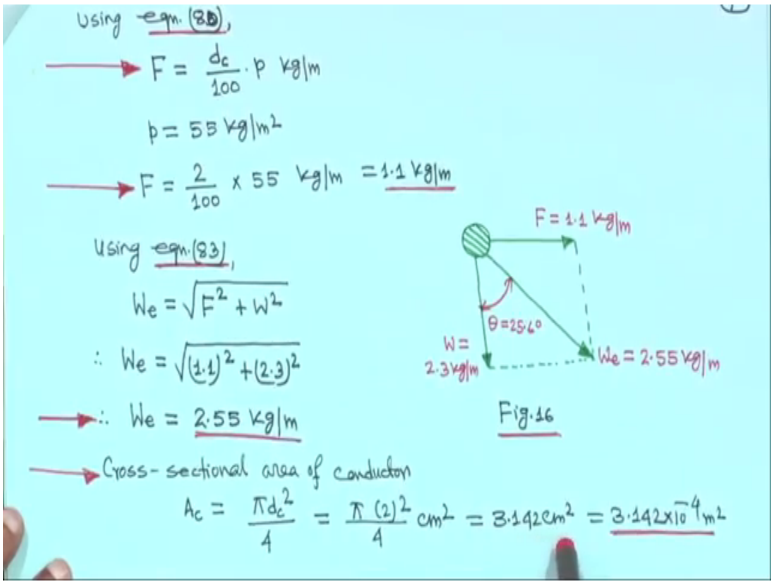

Now, now using equation 80, all things have been derived equation 80, F is equal to this formula dc upon 100 into P kg per meter, P is given 55 kg per meter square right therefore, and dc is equal to we have seen 2 centimeter. So, F is equal to 2 by 100 into 55 kg per meter. So, this will be 1.1 kg per meter right.

Now, equation 83 right, we know W is equal to F square plus W square this is We this is your W and this is your F right. So, We will be root over F square plus W square this is equation 83, these values I have put after calculating value right then, if you calculate We F is your F is your 1.1 right it is computed here and your W is 2.3 kg per meter that is also known to you. So, it will be root over 1.1 square plus 2.3 square this will become 2.55 kg per meter. So, it is 2.55 kg per meter that is all turn to 1.

Now, cross section area of the conductor Ac, it is pi dc square by 4. So, pi into 2 square upper 4-centimeter square it is 3.142-centimeter square converted 2-meter square. So, it will be 3.142 in 10 to the power minus 4-meter square right this is the cross-sectional area of the conductor.

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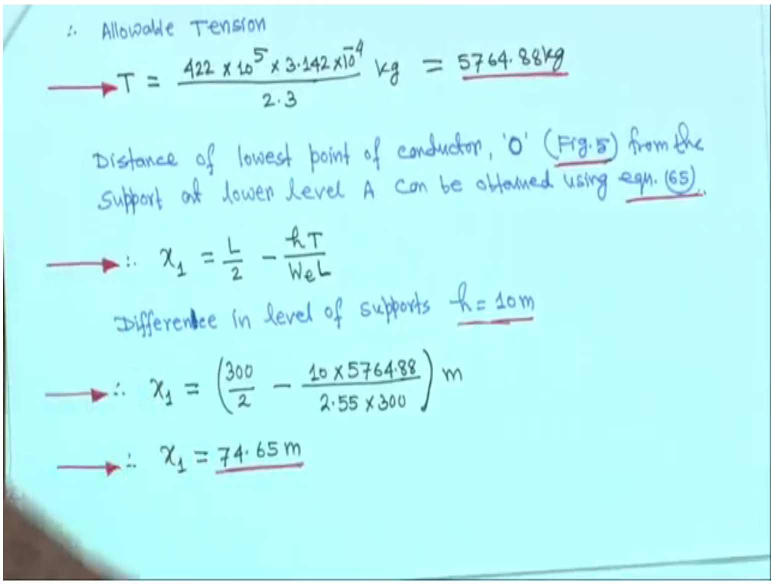

Now, allowable tension, now directly you can calculate right if it is give factor of safety is given 2.3. So, it is given 422 into 10 to the power 5 kg per meter square, this is the data given, that your maximum tensile strength 422 in 10 to the power 5 kg per meter square therefore, it will be 422 in 10 to the 5 into the cross-sectional area is 3.142 in 10 to the power minus 4-meter square cross-sectional area, divided by factor of safety 2.3 is kg is equal to 5764.88 kg.

Now, distance of the lowest part of the conductor, that is your if you go to figure 5, just hold on right this is P this is go back to your figure 5, this is figure 5 right supports at different levels. So, here the distance of lowest point of conductor O, this is the lowest point of the conductor in figure 5 O, from the support at your lower level a can be obtained using 65 equation 65. So, equation 65 we have derived x 1 is equal to L by 2 minus ht upon W e into L. So, difference in level of support h is equal to 10 meter, because in the problem it is because in the problem it is it is given that your this thing, it is that overhead support 300 meter apart having a difference level of difference in level of 10 meter this 10 meter is given in the problem.

Therefore, difference in level of support is h is equal to 10 meter therefore, x 1 is equal to 300 by 2 minus 10 into 5764 this one the tension 0.88 divided by 2.5 that is 55We into L is equal to 300 meter.

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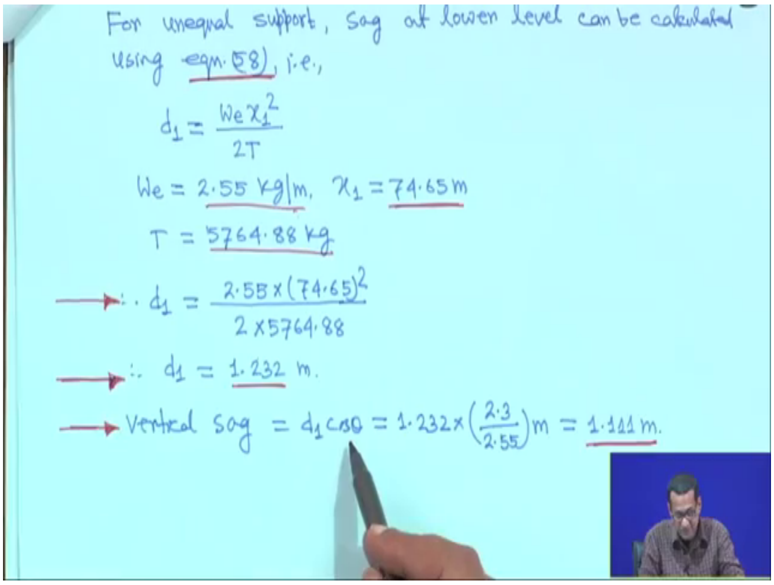

So, x 1 you will get 74.65 meter right, for unequal support Sag at lower level can be calculated using equation 58. So, 58 equation is d 1 is equal to W e into x 1 square upon 2 T, So, W is 2.55 kg per meter x 1 just we have obtained 74.65 meter and T is equal to 5764.88 kg therefore, d 1 is equal to 2.55 into 74.65 whole square divided by 2 into 5764.88 right.

So, d 1 is coming 1.32-meter and. Now, therefore, vertical Sag will be d 1 cos theta; that means, this one this this project these resultant to your force diagram.

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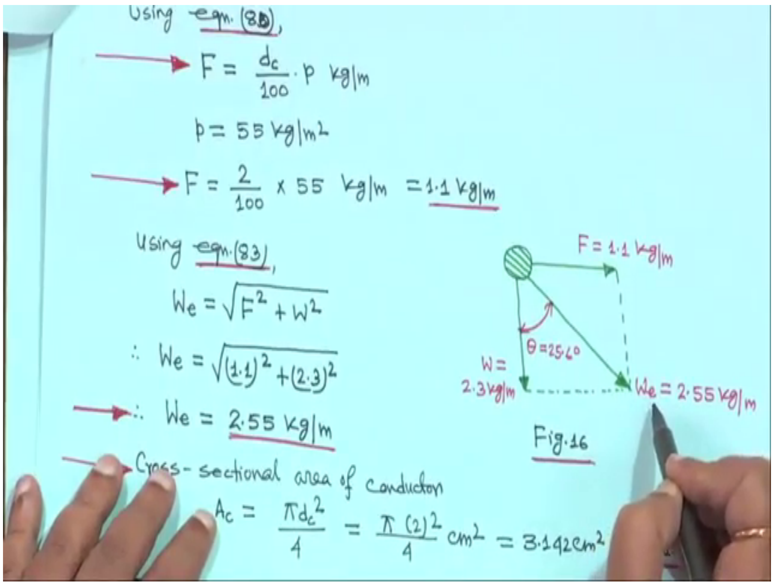

This is your theta that is basically in between result and W e and the weight of the conductor w. So, this is actually if you take find out cos theta that W upon W e, that is your theta will come 25.6 degrees.

So, vertical Sag will be d 1 cos theta that is 1.232 into your 2.3 by 2.55, that is actually your cost 25.6 degree anyway I have written like this.

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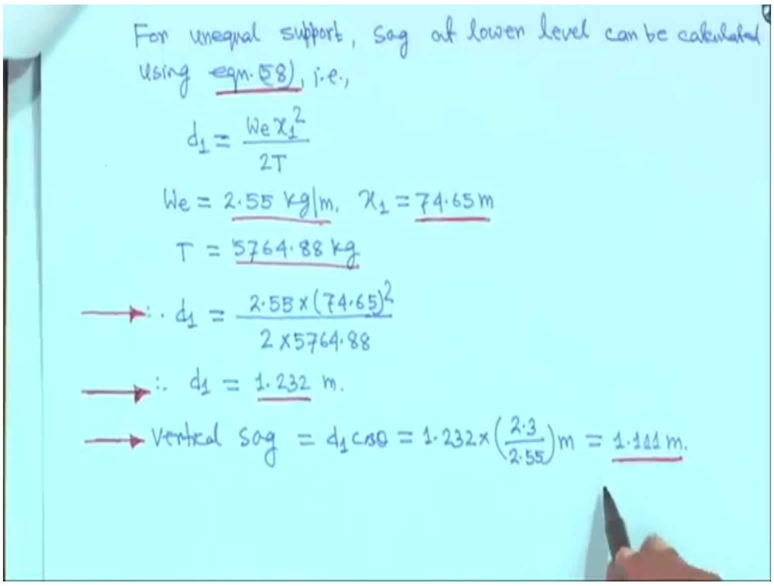

So, that is actually 1.111 meter approximately right this is the vertical Sag. So, problems are simple actually just little bit practice is necessary.

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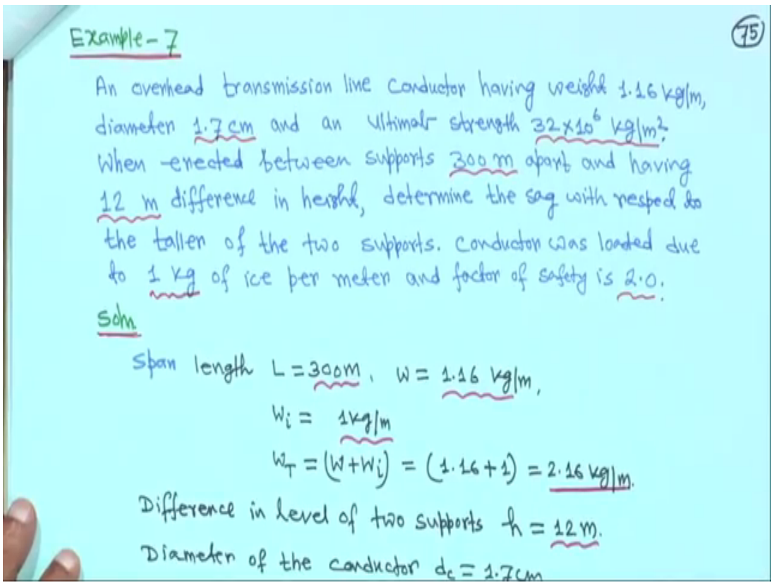

Now, take another example all the theories initially we have done. So, this way after that all supported by all the examples, now here also and over a transmission line conductor having weight 1.16 a kg per meter, diameter is 1.7 centimeter and ultimate strength is 32 into 10 to power 6 kg per meter square right, when elected between supports 300 meter apart, I mean 2 towers or poles they are 300 meter apart and having 12-meter difference in height that is h is equal to 12 meter this is given.

Determine the Sag with respect to the taller of the 2-support right, conductor was loaded due to 1 kg of ice per meter, and factor of safety is given 2 right. So, here we are conduct considering that that ice coating on the conductor, now span length is given that is L is equal to capital L is equal to 300-meter W is given 1.16 kg per meter, and Wi is equal to 1 kg per meter right this is the weight of the conductor, the total weight WT is equal to W plus wi. So, W is 1.16 and Wi the weight of the ice per 1 kg per meter. So, it is plus 1 that is 2.16 kg per meter. So, difference in level of 2 support is given h is equal to 12 meter this h is equal to 12 meter is given. So, diameter of the conductor is given dc, is equal to your 1.7 centimeter these are given these are the data right.

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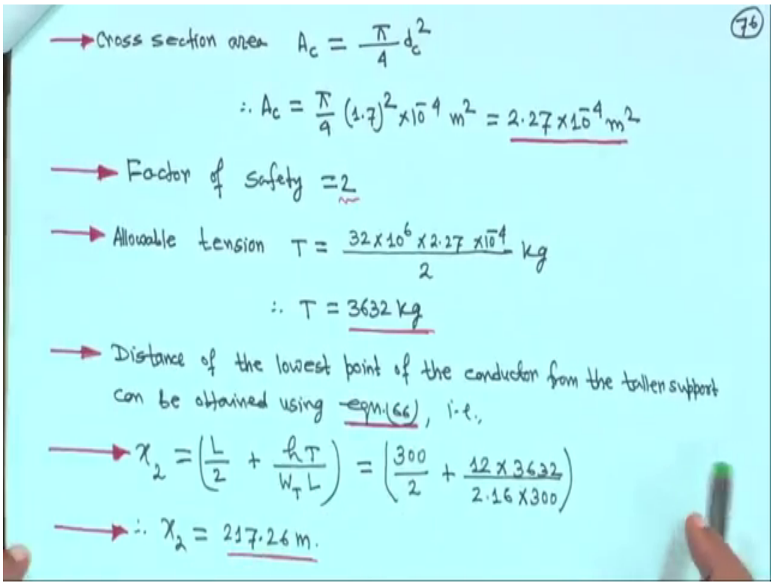

Now cross section area is equal to Ac pi by 4 dc square right, this is just without ice formation right. So, Ac is equal to pi by 4 1.7 square converted to meter square into 10 to power minus 4 meter square, this is 2.27 into 10 to the power minus 4 meter square, now factor of safety is given 2 and I ultimate tensile strength is given 32 in 10 to power 6 kg per meter square therefore, allowable tension T will be 32 into 10 to the power 6 then the cross sectional you multiply in meter per meter square that is 2.27 into 10 to power minus 4 divided by factor of 32 kg that is T is equal to 3632 kg right.

Now, distance of the lowest point of the conductor from the taller support can be obtained using equation 66 this all we have derived, x 1 x 2 all you have derived right. So, x 2 is equal to L by 2, capital L by 2 plus h into T upon WT into L, this is from equation 66 just to go through this derivation once that is all. So, it is 300 by 2 plus h is 12 difference is 12 into 3632, that is the T this one divided by 2.16, that is W into L 300 right that is coming x 2 is equal to 217.26 meter this is x 2 right.

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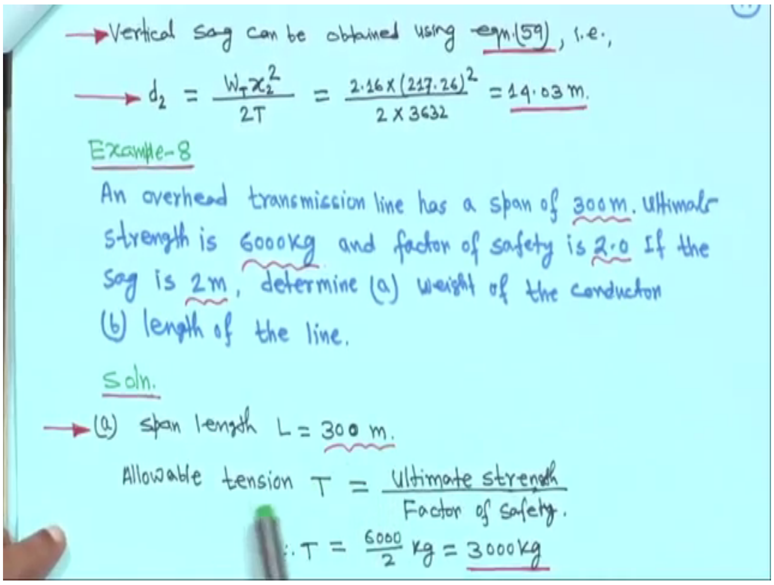

So, vertical Sag can be obtained using equation 59, we have seen that d 2 vertical Sag will be W 2 x 2 square upon 2 T, So, it is WT 2.16 x 2 is 217.26 is square divided by 2 into 3632, there is a tension t, that is 14.03 meter. So, problem is very simple right.

So now next one is that your and over a transmission line right has a spam of the 300 meter, right ultimate strength is 600 kg, and factor of safety is 2. So, if the Sag is 2-meter Sag is given. So, you have to find out a the weight of the conductor and the b, length of the line, this is simple one. So, span length is given 300 meter. So, this allowable tension T this should be always your mind, that if ultimate strength is given, there must be some factor of safety will be given. So, ultimately allowable tension will be ultimately your what you call, strength divided by factor of safety right.

So, that is ultimate strength is 600 a sorry 6000 and factor of safety is 2 it is given. So, it is 6000 by 2 is equal to your 3000 kg right that is T,

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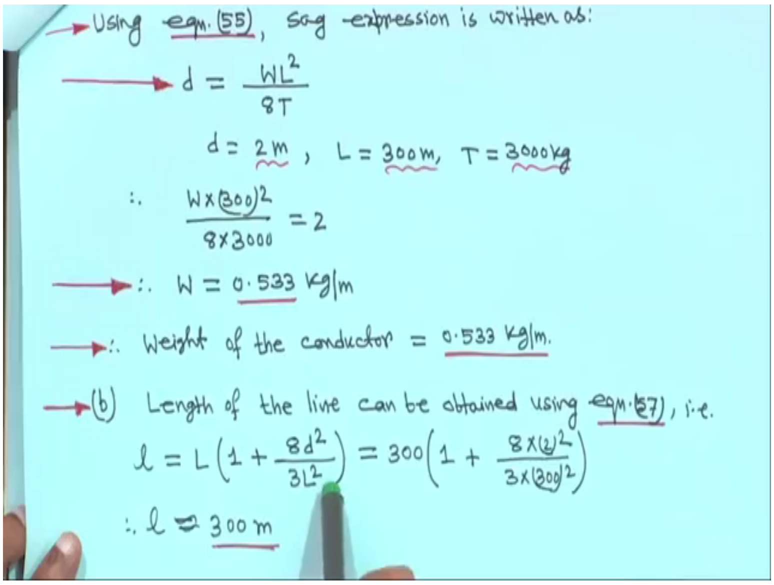

Now, from equation 55, Sag expression is written as d is equal to WL square upon 8 T this we have seen in equation 55 therefore, d is given 2-meter L is given 300-meter T is given 300 kg. So, you will get solved you substitute all W into 300 square divided by 8 into 3000 is equal to 2. So, W will get 0.533 kg per meter.

Now, weight of the conductor therefore, 0.0533 kg per meter, now b you have to find out length of the line, length of the line can be obtained using 57. So, you go to sequence 57, it is derive a small l is equal to capital L 1 plus 8 d square upon 3 L square L is the horizontal distance between the towers, and small l is the length of the conductor that you have seen right therefore, capital L is 300 and 1 plus 8 into d 2 square because d is given 2 divided by 3 into capital L square that is 300 square.

So, approximately it becomes small l becomes 300 meter, the reason is it is approximate one right approximate one it will be 300.0 something right 0 0 something why I have written; that means, your Sag is very small it is given 2 meter, and that is why that horizontal length and the length of the conductor length almost close to your 300 L 1 L right.

So, but if you make it will find 0.00 something 300.00 something what happens, that is why the horizontal distance and length of the conductor they are very close to each other right.

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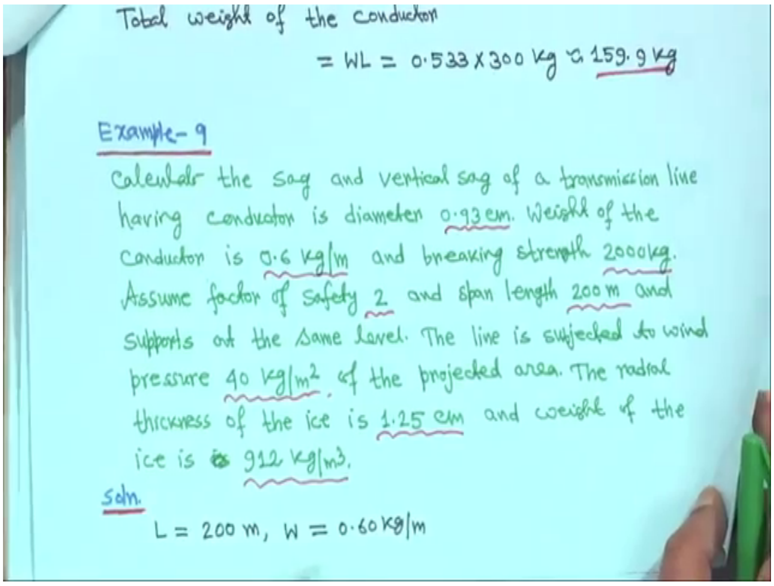

Because Sag is very small 2 meter only that is why this problem is taken, next one is and the last example for this one is that example nine.

So, here the calculate the Sag and vertical Sag of a transmission line having conductor having conductor is diameter of 0.93 centimeter right weight of the conductor is 0.6 kg per meter and breaking strength 2000 kg assuming a factor of safety 2, whenever factor of safety will be given that the breaking strain means ultimate tensile strength; that means, this one tension has to be found out to this one divided by factor of safety right, and span length is given 200 meter and right, and supports at the same level right there at the same level. So, no question of difference of your tower or height level right.

The line is subjected to wind pressure 40 kg per meter square of the projected area, the radial thickness of the ice is given 1.25 centimeter; that means, your ice radial thickness is also given wind pressure is also given and weight of the ice is 912 kg per meter cube. So, you have to find out that your Sag and the vertical Sag both, now capital L is given that is your 200 meter and W is equal to 0.6 kg per meter.

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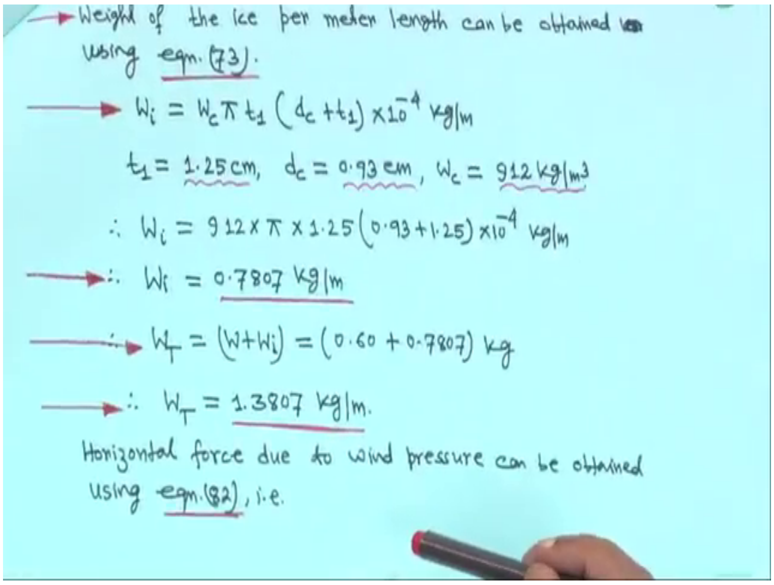

So, weight of the ice per meter length can be obtained using equation 73. So, equation 73 have seen weight of the object I is Wi is equal to Wc pi into t 1 in bracket dc plus t 1 into 10 to the power minus 4 kg per meter, this is from equations 73.

So, t 1 is given that is your 1.25 centimeter dc is given 0.93 centimeter and Wc is given that is your 912 kg per meter cube right therefore, Wi is equal to 900 your 912 into pi into 1.25, into bracket 0.93 plus 1.25 into 10 to power minus 4 kg per meter therefore, Wi will be point 7807 kg per meter, that is that weight, weight of the ice per meter length of the conductor, that is 0.7807 kg per meter therefore, WT is equal to W plus Wi is equal to 0.6 plus 0.7807 kg, hence WT the total 1.3807 kg per meter after that the problem is very simple right.

So, in there you are after this one that your horizontal force due to wind pressure, can be obtained using equation your 82 right.

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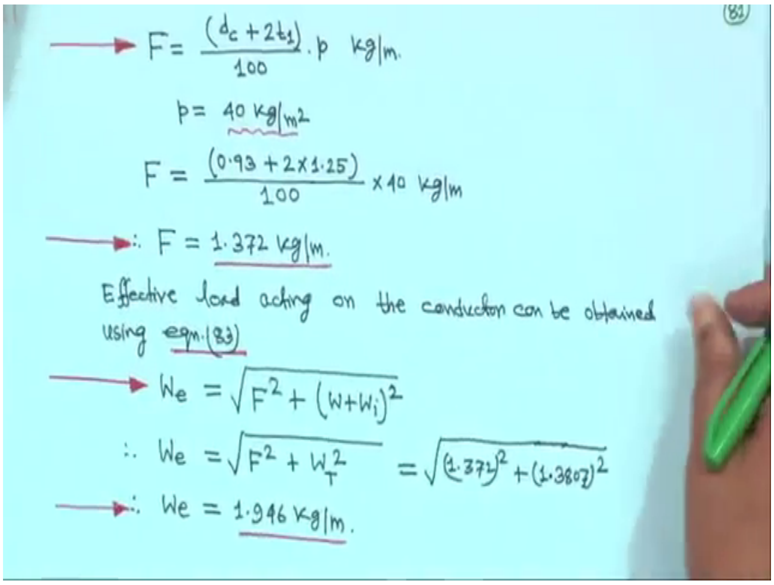

So, equation 82 your then we can write equation 82 here, that is your F is equal to dc plus 2 t 1 upon 100 into P kg per meter this is equation 82. So, P is given 40 kg per meter square, F is given 0.93 plus 2 into your F is you have to calculate. So, it is dc 0.93 plus 2 into 1.2 pi by 100 into P is 40 kg per meter.

Hence F is equal to 1.372 kg per meter now effective load acting on the conductor can be obtained as, using equation 83 this we have seen W e is equal to root over F square plus W plus Wi basically, it is a WT W plus Wi square, that is We e is equal to root over F square plus WT square, F is equal to just we have calculated 1.372. So, root over 1.372 square a plus WT is 1.3807 square. So, We is equal to 1.946 kg per meter.

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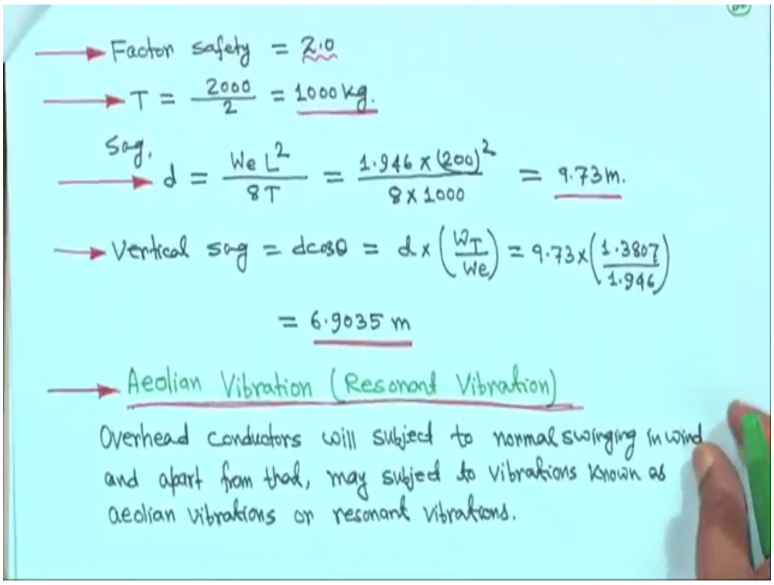

So, we effective weight of the conductor we got.

Now, this one now factor of safety is given 2; that means, T is equal to 2000 by 2, that is thousand kg therefore, Sag this this formula for this one We L square upon 8 t, this you know we have derived already. So, W is 1.946 into 200 square that is L where just horizontal span length right and divided by 8 into 1000 it will come 9.73 meter therefore, vertical Sag will be d cos theta just we have seen d into cos theta will be WT upon We. So, 9.73 into 1.3807 divided by 1.946 is equal to 6.9035 meter.

So, with this that Sag and tens and these 9 examples we have taken, and your what you call this will help you a lot right, next before closing the Sag and tense in chapter. So, little bit of little bit of thing is there that you can early on vibration or resonant vibration of the conductor right.

Generally, over it conductors will subject to normal swinging in wind, that we know right because, wind is always blowing at some speed right and apart from that may subject to vibration known as aeolian vibration, or resonant vibration right.

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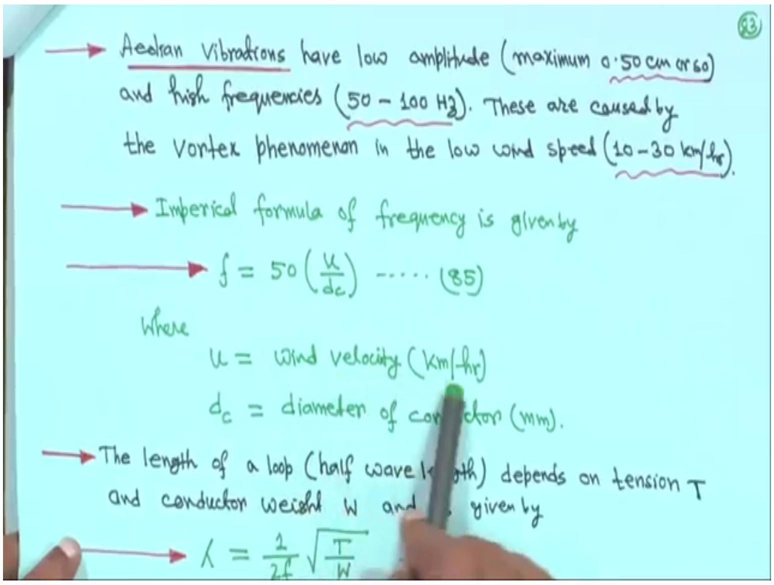

So, this may happen that that, but this kind of vibration resonant vibration or aeolian vibrations right, have to look very low amplitude maximum may be 0.5 centimeter or so; that means, very low and at high frequencies that is in between 50 to 100 hertz these are actually caused by the by the vortex phenomena in the low wind speed right. So, that is 10 to 30-kilometer power hours. So, this wind speed is a low wind speed.

So, empirical formula of frequency is given by, it is an empirical formula that 50 into u upon dc say this is equation 85, where u is the wind velocity kilometer per hour right.

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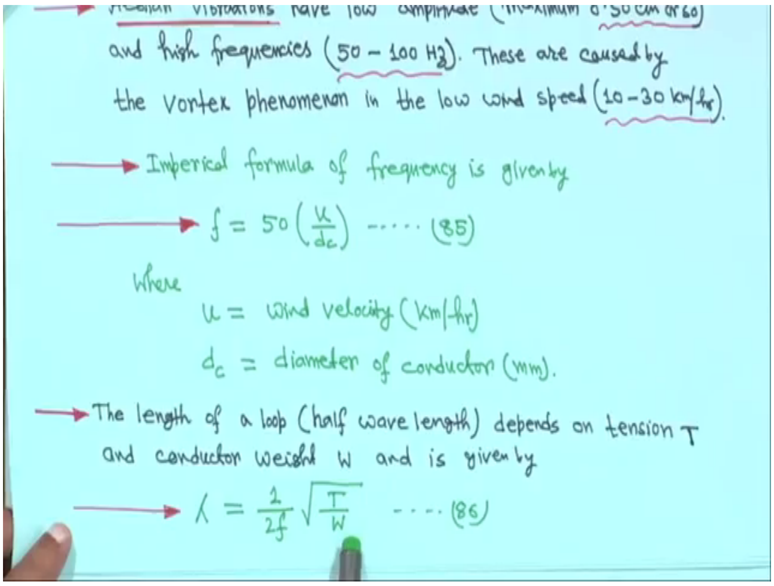

And dc is diameter of conductor in millimeter right. So, the length of loop that is half wavelength right depends on tension T and conductor weight W and is given by lambda is equal to 1 upon 2 a root over T upon W, this one you please keep it in your mind, that lambda is equal to 1 upon 2 a root over T upon w. So, this is equation 86 right.

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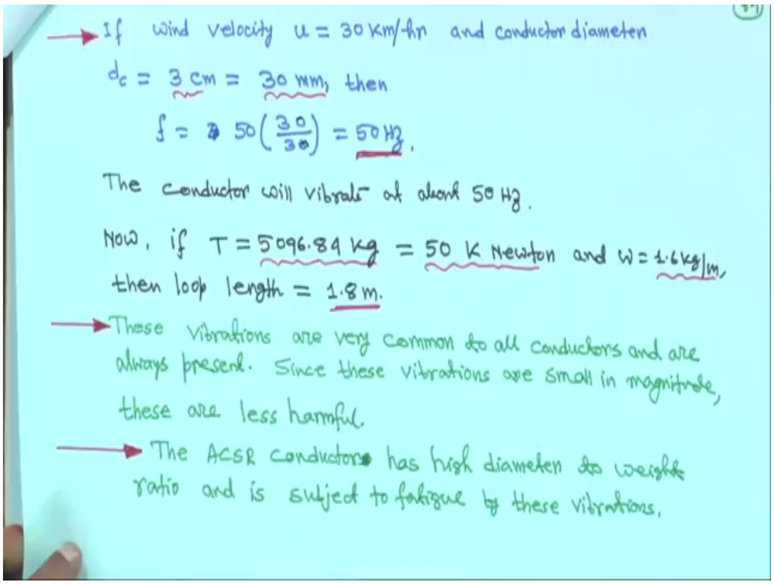

So, if wind velocity say u is equal to 30 kilometer per hour and conductor diameter dc is 3 centimeters say that is equal to 30 millimeter, then f is equal to 50 into 30 upon 30 it will be 50 hertz again right, the just for assumption some data we have taken the conductor will vibrate; that means, at about 50 hertz frequency now if T is equal to for example, say 5096 your 0.84 kg is approximate is equal to 50 kilo newton and W is equal to 1.6 kg per meter the loop length will be 1.8 meter because here using this formula using this formula right, using this formula put T put W put f then you will get that your that your loop length that is lambda 1.8 meter right.

So, these vibration are very common to all conductors, and are always present right, because we always will ruin some your how to call some protects phenomena will be there, since these vibrations as small in magnitude, but these are not that harmful, but the ACSR conductor right, has high your diameter to weight ratio and is subject to fatigue by this vibration.

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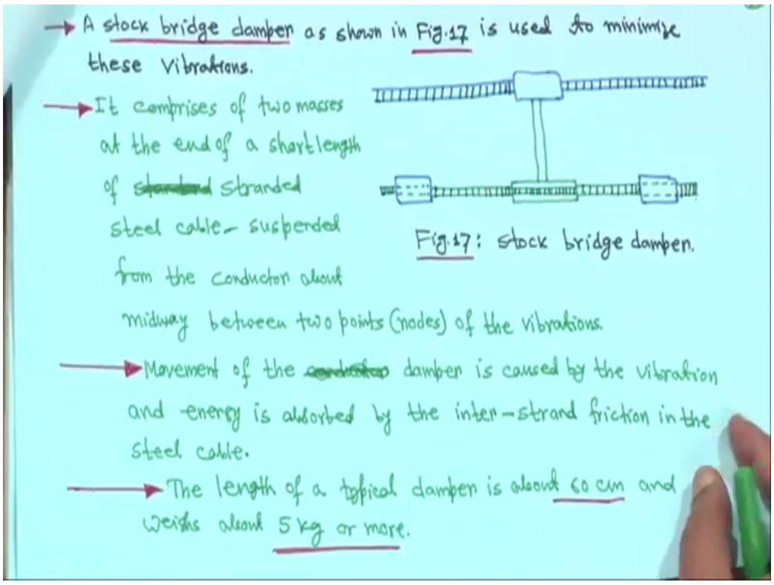

So, now next it is that this figure 7 sorry figure 17 a stock bridge damper as shown in figure 7 is used to minimize this vibration, many times in over a line, you can see some kind of thing right. So, it comprises of 2 masses right at the end of the short length of stranded steel cable, suspended from the conductor about midway between 2-point sets that we call. So, midway between 2 point we call it nodes of the vibrations right.

So, movement of the damper is caused by the vibration and energy is absorbed by the inner strand friction in the steel cable right. So, details are not required for this course, then we have to go for detailed mathematics. So, better not a suitable for this course at least right, some just some general ideas right, but the length of a typical damper is about 60 centimeter and weighs about 5 kg or more occasionally you can see this kind of thing and it transmission line.

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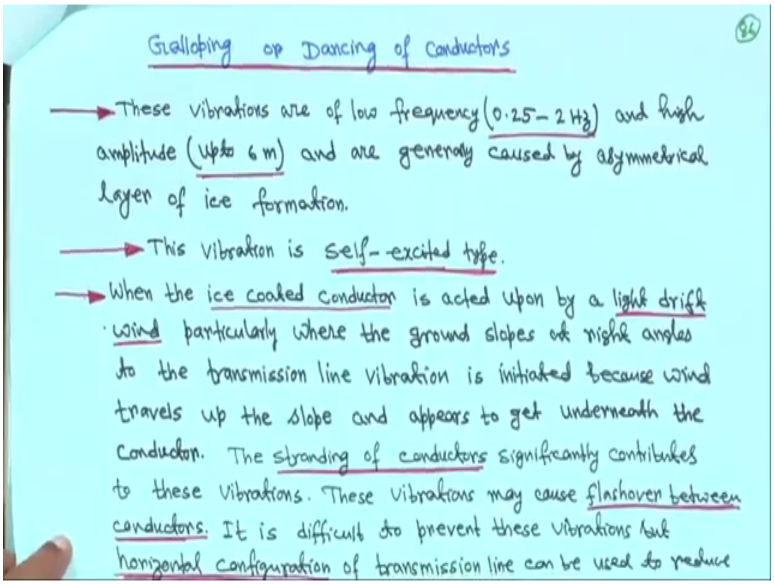

And another is the galloping or dancing up conductor, this is the last thing for the Sag and tension.

So, these vibrations are of at low frequencies that is 0.2522 hertz right. So, this is galloping or dancing of conductor. So, and high amplitude, amplitude is very high up to 6 meter right, and are your generally caused by asymmetrical layer of ice formation, particularly this happens that when ice coating are there around the conductor, but it is not it is not your what do you call uniform around the conductor.

So, these actually cause that you are galloping or dancing of the conductors. So, this vibration actually self-excited type, when the ice coated conductor is acted upon a right your light dip twin, particularly where the ground slopes at right angles to the transmission line vibration is initiated, because we in travels actually of the slope and appears to get underneath the conductor, actually this that is this galloping is creates because of this reason right.

So, the stranding of conduct are significantly contributes to this vibration, particularly during your asymmetrical ice coating, these vibrates and may cause flashover between conductors, I mean if they are practically plays right, I mean instead of horizontal configuration if they are configuration is vertical then there is a possibility of flash over because there is a strong possibility, and it is difficult to prevent this vibration, but horizontal configuration of transmission line can be used to reduce the impact of galloping or dancing of conductor.

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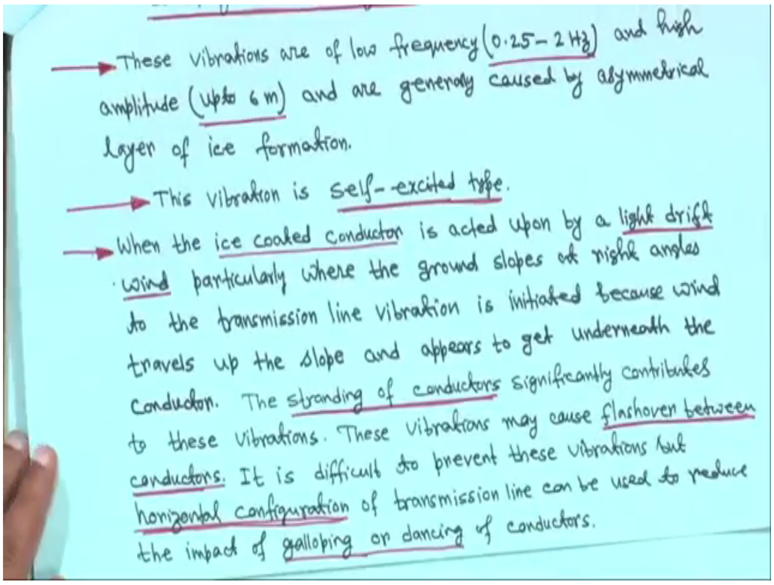

So, in hilly areas that your horizontal spay configuration of conductor is preferable, then you are what you call that vertical space vertical spacing. So, with this with this that Sag and tension chapter will be over, your job will be to go through all the derivations particularly that your what you call when tower sat at a different height, right and other than equal height and second thing is that ice formation as well as the twin pressure when you are considering all sort of things, and little bit you have to keep it in your mind.

I mean formulas and other things because for the exam purpose you have to store everything in your memories. So, things are very simple, but you will find your what we call these are very interesting, if you have any other question or anything you send me mail or put the question in the forum we will try to answer all of your question.

Thank you again we will be back again.