Power System Engineering
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Lecture - 23
Corona (Contd.), And Sag & Tension Analysis

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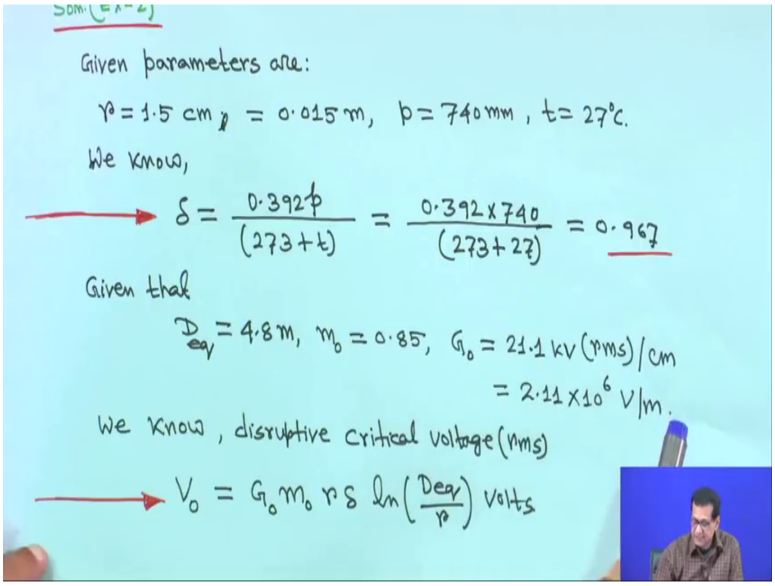

Come to the solution of this problem. This is the just now we have given the problem. Following parameters are given r is equal to 1.5 centimetre that is 0.015 meter. P is equal to 740 mm this is given t 27 degree Celsius. We know this formula delta is equal to again and again not writing the equation these are known to you

0.392p upon 273 plus t. P is 740 and t is 27. It is delta is equal to 0.967. Now also given that Deq is equal to 4.8 because equilaterally space 44.8 meter. D equal it will be 4.8 meter M 0 is given point 85 g 0 is given the 21.1kv rms per centimetre. This can be converted to 2.11 10 to the power 6 volt per meter it has been converted to volt.

We know disruptive critical voltage rms this formula we have also derived. V0 is equal to G 0 then M 0 r delta ln deq upon r volts. This formula is also given. G0 is given M0 r delta Deqr all are known. You substitute here you substitute here.

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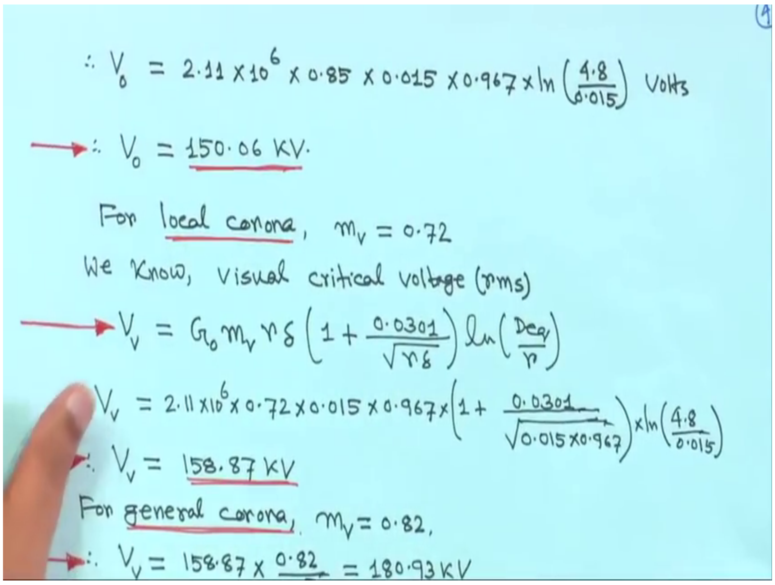

If you substitute then V0 will be 2.11 into 10 to the power 6 into 0.85 into 0.015 into 0.967 ln 4.8 by point 0.015 volts. V0 is equal to 150.06 KV. This is this is this one first you compute using this formula that is your disruptive critical voltage V0.

Next is for local now this thing for 2 things are given one I am calling as a local corona. Another I am calling general corona again this is a question to you what is local corona and what is general corona. This is a question to you. You will write 1 or 2-line answer and you will send it to me.

For local corona look at the parameters carefully everything then we will answer mv is 0.72. We know visual critical voltage rms. This formula is known to us Vv is equal to G0 mv r delta in bracket 1 plus 0.0301 root over this thing r delta into ln deq upon r. All parameters are given it is we converted to volt per meter. Vv 2.11into 10 to the power 6 into mv 0.72 r 0.015 take delta we have computed 0.967 into 1 plus 0.031 divided by r delta 0.015 into 0.967 and this is ln 4.8 upon 0.015

Vv actually v or visual critical voltage is coming 158.87 KV, but remember this is all rms value bracket I am writing here although I have written here also I have written this is your 158.87 KV.

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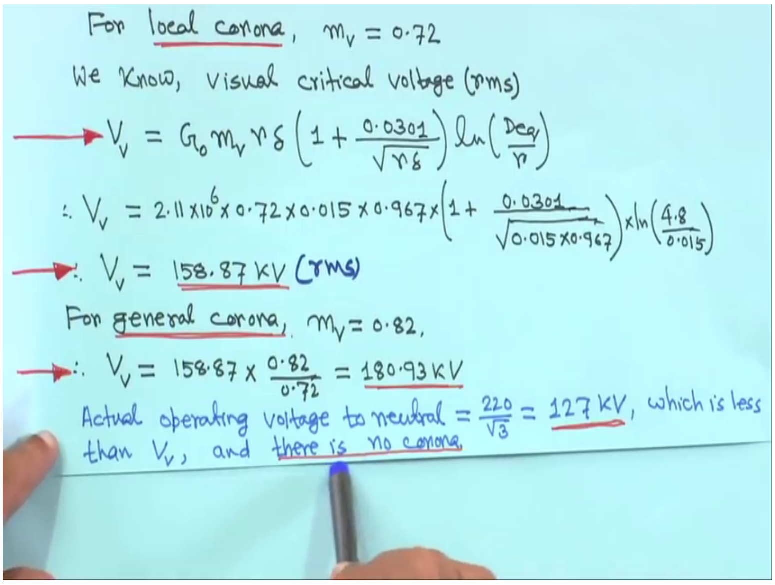

Now, in general corona mv is equal to 0.82 right look for local corona it was 0.72 and for general corona 0.82 from that you will try to tell me these 2 answer what is this what is local corona what is general corona right no need to use further because all are directly proportional. Just use that ratio thing whatever you have got 158.87 it is Vv general corona 158.87, but here mv is 0.82. It is 0.82 divided by here local corona 0.72. Divided by 0.72 is equal to 180.93 KV.

Actual operating voltage to neutral actually 220 upon root 3. 127 KV right because line voltage was 220 KV. 225 root 3 means line to neutral 27 which is less than Vv and there is no corona because this voltage. Less than your what you call that your Vv this one disruptive voltage right or this one critical voltage rather right so; that means, there is no corona there will be cost and then giving this parameter you have to predict from that this thing whether corona will happen or not.

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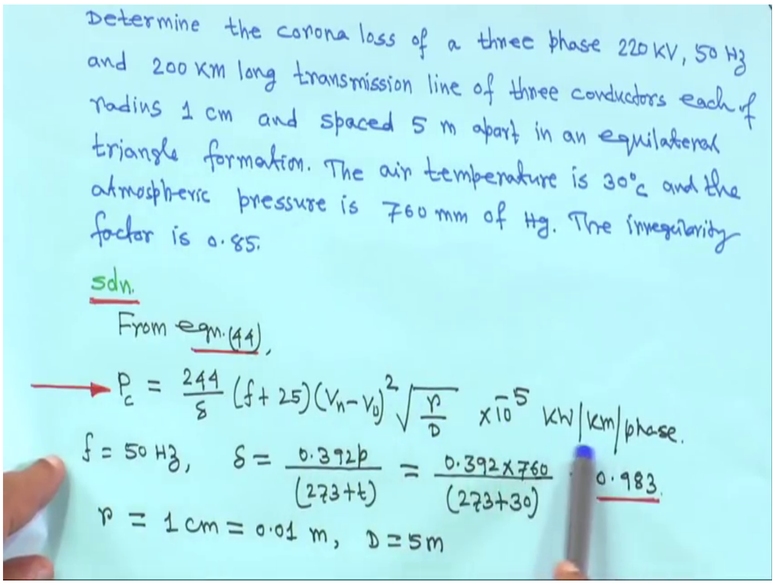

Next is example 3 you determine the corona loss of a 3 phase 220 KV 50 hertz and 200-kilometre-long transmission line of 3 conductor each of radius 1 centimetre and space 5 meter apart in an equilateral triangle formation; that means, again Deq will be 5 meter.

The air temperature is 30-degree celsius and the atmospheric pressure is 760 millimeter of mercury the irregularly factor is 0.85 right. These are the thing what these every time I am taking equilateral triangle that is conductors space.

Now, a numerical I am giving just recall that if you take this horizontal spacing that 5 you know that is horizontal spacing means that between ab say 5 between bc 5 and ac is 10 right b is the middle conductor between a and c and between a and b 5, b and c 5 and a and c will be 10. Then right you will try to find out with all other parameter even same what will be the corona loss and compare? Whatever we are getting this is an numerical to you will solve it.

Now, from equation 44 this is your peeks formula that PC is equal to 244 upon delta in bracket a plus 25 into Vn minus V 0 square into root over r upon capital d into 10 to the power minus 5 kilowatt per kilometre per phase.

Now, f is given 50 hertz delta you have to compute because it is given delta is known. This is known 0.392 p upon 273 plus t p is given 760 that is atmospheric pressure and t is 30-degree celsius. It is coming 0.983.

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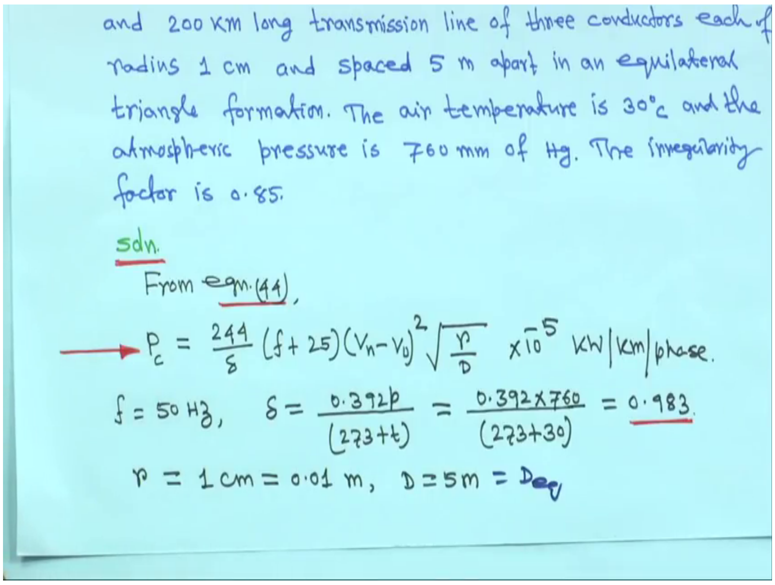

Now r is equal to given one centimetre. 0.01 meter and D will be 5-meter d or Deq same because it is equilateral space 5 meter apart. D it is equal to you can write if you have a this thing D actually is equal to Deq the same thing I have written D here.

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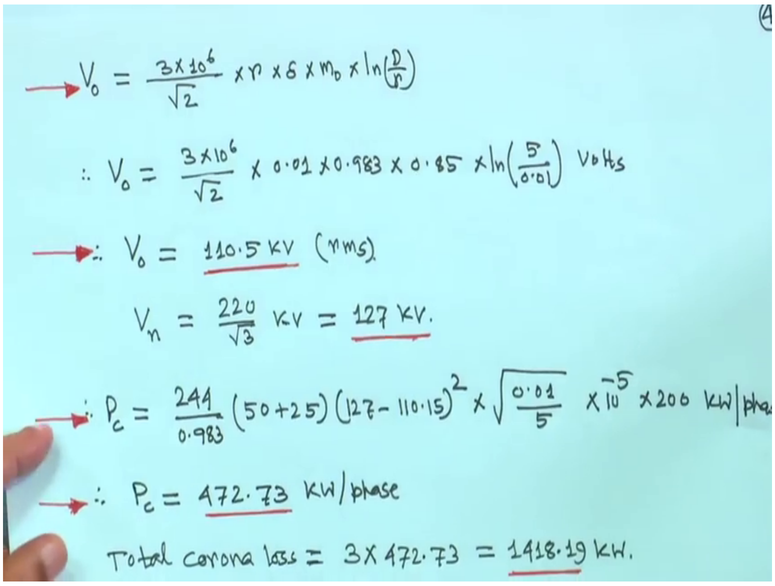

That means, based on that you calculate V0 is equal to 3 into 10 to the power 6 by this formula is known into r into delta into M0 into ln d upon r. 3 into 10 to the power 6 upon root 2 r is 0.01 delta we have computed 0.983 and M0 is 0.85 and d is 5 ln 5 or r is 0.1. It is volts if you compute this one you will get v 0 is equal to 110 point 5 KV rms value this is the rms value.

Now, Vn is equal to 220 upon root 3 KV that is 127 KV so; that means, this one your this thing higher than this one now PC will be 244 upon 0.983 f is 50 hertz. 50 plus 25 the this your peeks corona loss formula it is f plus 25 f plus 25. It is 50 plus 25 into 127 minus 110.15 square 110.0 it is actually 110.5 not 15 it is 5 actually 110.5 square.

Please when you will check it know please check this calculation correct or not because just repeating that all this numerical actually all are your calculated by me only right. If you find any error in calculation anything you are always welcome just that you can you let me know that this is that calculation error I will I will appreciate that right, because all these calculations actually done by me only not by my student I have done everything of my own all these things. You just let me know that if there is any error in any calculation error then I will rectify that.

Into root over your 0.01 by your 5 into 10 to the power minus 5 and it is actually this peeks formula this one is actually kilowatt per kilometre per phase, but line length is 200 kilometre that is why it is multiplied by 200. Therefore, it is kilowatt per phase per kilometre will not be there because it is multiplied by 200 if you do. PC will be 472.73 kilowatt per phase therefore, it is per phase. There are 3 phases. Total coronas will be 3 into 472.73 therefore, it is 1418.19 kilowatt.

Ah some numericals for every chapter as well as possible I am showing you such that you can not it will easy for you to you know study.

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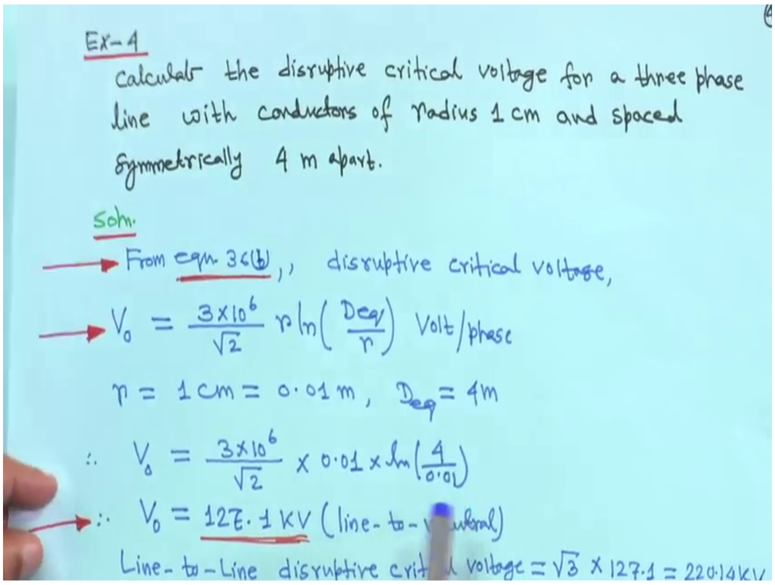

Next is that example 4 here. Calculate the disruptive critical voltage for a 3-phase line with conductors of radius 1 centimetre and spaced symmetrically 4 meter apart.

In this case from equation 36 be the disruptive critical voltage formula is that V0 3 into 10 to the power 6 upon root 2 then r into ln Deq upon r volt per meter. R is equal to 1 centimetre therefore, 0.01 meter and Deq 4 meter it is given symmetrically 4 meter apart.

Therefore, V0 is equal to 3 into 10 to the power 6 upon root 2 into 0.01 into ln 4 upon 0.01 if you calculate this V 0 will be your 127.1 kilovolt that line to neutral voltage therefore, line to line disruptive critical voltage to root 3 into 127.1 is equal to 220. 14 KV. This is that line to line disruptive critical voltage

Next one is. I think this numericals will make your whatever theory we have seen this numericals will help you to understand this.

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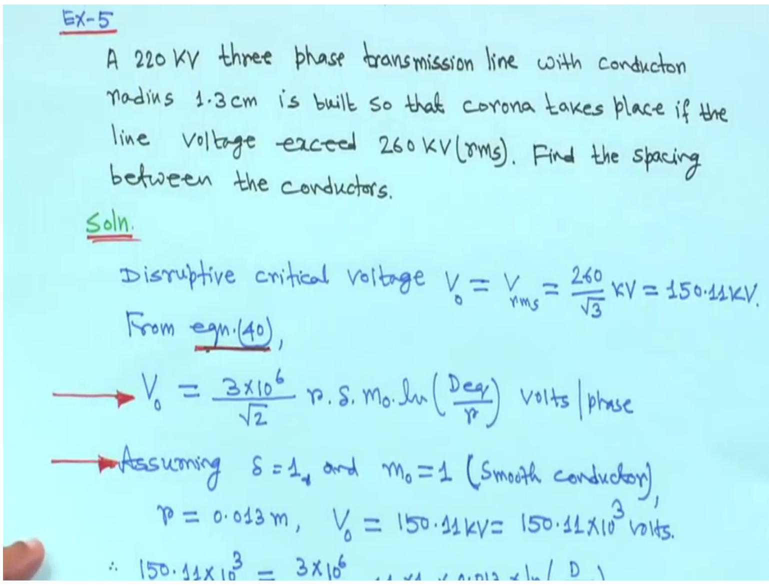

Next is this example this is example 5 a 220 KV 3 phase transmission line with conductor radius 1 point 3 centimetre is built. That corona takes place if the line voltage exceed 260 KV rms find the spacing between the conductors. We have to find out the spacing here between the conductor.

Now, disruptive critical voltage it is rms value this thing your what you call is that your if the line voltage exceed this one 260 KV rms. Find the spacing between the conductor therefore, disruptive your disruptive critical voltage V 0 actually is equal to Vrms that is 260 by root 3 kk because this 150.11 KV. It is your what you call it was given if the line voltage was given. We are making this one as a phase voltage. 2 because all calculations in which you are making based on the phase voltage. It is 260 by root 3 KV 150.11 KV.

Therefore, from equation 40 V0 is equal to 3 into 10 to the power 6 upon root 2 then r into delta into m 0 into ln Deq upon r volts per phase. Now assuming now here you have to assume some assuming delta is equal to one if this parameters are not given. For example, that here density vector delta our aim you assume their unity. If it is not given you have to if not given means you have to assume unity even it is not mention in the question. Question you have to assume that it is unity; that means, I am writing assume the delta is equal to 1 and M0 is equal to 1 that is for smooth conductor.

Therefore, r is equal to given that your 1.3 centimetre that is equal to your 0.013 meter and V 0 is this one. 150.11 KV. It is 150.11 KV is equal to 150.10 to the power 3 volt your converted into volt.

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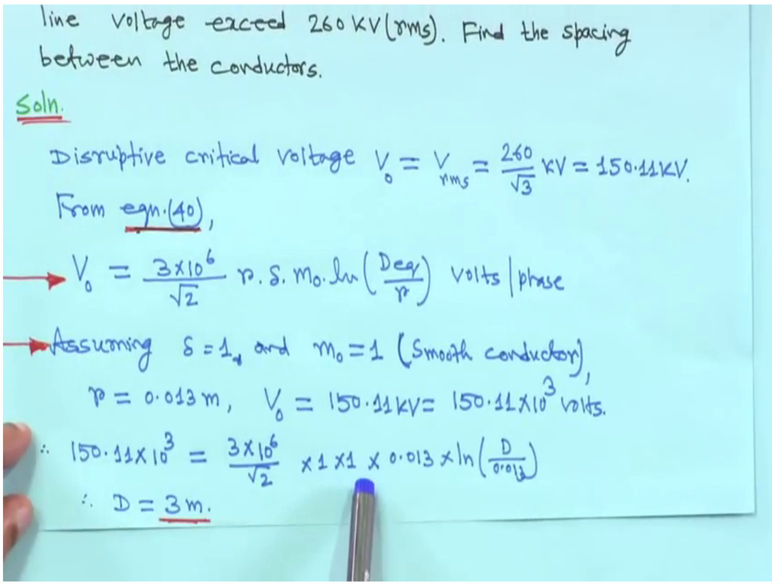

Therefore this 150.11 into 10 to the power 3 this is V0 is equal to 3 into 10 to the power 6 upon root 2 delta and M both are one; delta one into one into r 0.013 into ln d upon point 0.013. If you solve this equation it will give you D is equal to I think exactly 3 meter it will give you if. Check. That that has been asked actually to find the spacing between the conductors. This D is equal to 3 meters.

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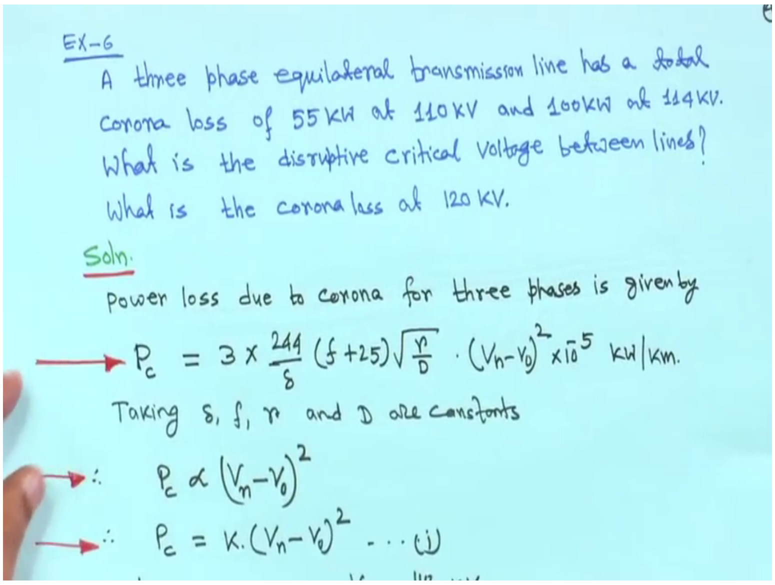

Next another example first theory and then example right now example 6 in this case that a 3-phase equilateral transmission line has a total corona loss of 50 or 55 kilowatt and 110 KV and 155 kilowatt at 110 KV and 100 kilowatt at 114 KV; that means, it is given that when corona loss is 55 voltage is 110 KV and when it is 100 kilowatt corona loss voltage at the time it was 114 KV.

Then what is the disruptive critical voltage between lines and next what is the corona loss at 120 KV these are the things you have to find out. Power loss due to corona for 3 phases given by this is your peeks formula PC is equal to 3 into 244 upon delta a plus 25 root over r by d into V n minus V 0 square into 10 to the power minus 5 kilowatt per kilometre.

Now, this earlier it was kilowatt per phase per kilometre, but here you look. We have multiplied this 1 by 3 here we have multiplied by 3 means that is why power phase is not there, because, whatever peeks formula it was per phase, but you have multiplied it by 3. It is given kilowatt per kilometre.

Now, taking delta f r and d all are constant because delta is constant f is a constant r is constant d is constant. All are constant parameters therefore, look and write that corona loss PC is proportional to that Vn minus V 0 whole square. That mean PC proportional to Vn minus V0 whole square. Because all are constant other parameters are constant delta f r and d all are constant; that means, in general we can write PC is equal to k into vn minus v 0 square say this is equation 1.

Now, it is given that when PC is equal to 55 vn actually 110 by root 3 KV because everything.

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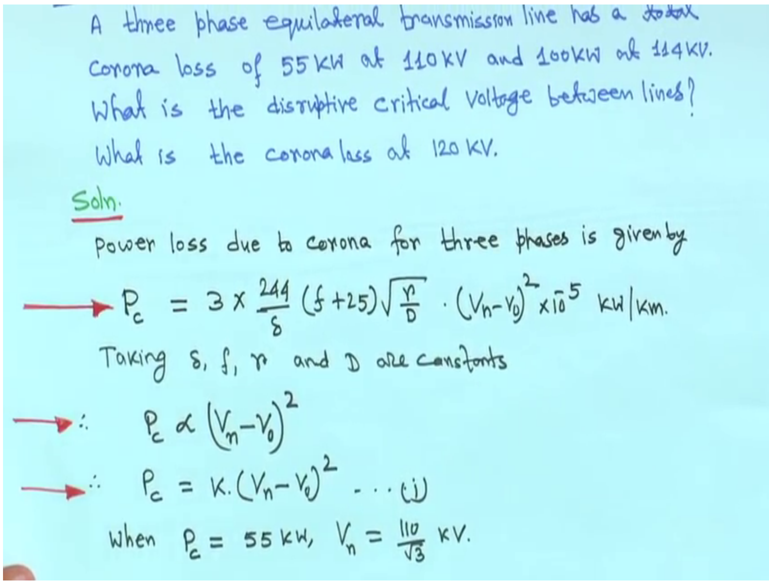

We have to take your what you call that line to neutral voltage. When if nothing is mentioned then you have to assume there line to line voltage if nothing is mentioned.

That is why Vn is taken 110 by root 3 that is line to neutral voltage. Because as it is not mentioned in the problem you have to assume that is they are line to line voltage. When PC is equal to 55 kilowatt. Vn is equal to 100 KV between line to line.

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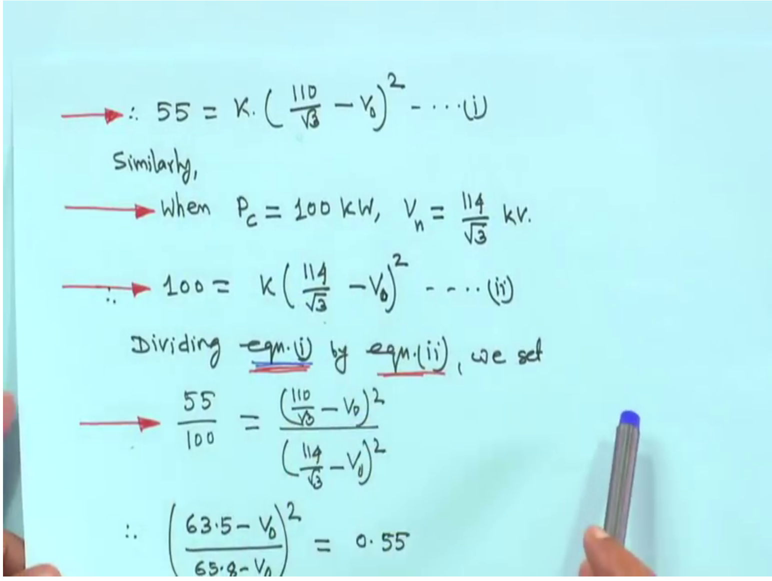

That means, you make it is line to your line to neutral that is 110 by root 3 KV right; that means, you can write 55 is equal to k into 100 by root 3 minus V 0 square. This is equation 1 this is equation 1.

Similarly, when PC is equal to 100 kilowatt Vn is given 104 volt in KV that is line to line. 114 by root 3. Line to neutral you make it and again look using same equation, you can write 100 is equal to k into 114 by root 3 minus V 0 whole square this is equation this is 1 this is equation 2.

Now, divide you equation 1 this equation and this you can divide k and k will be cancel. Dividing equation 1 by equation 2 you will get 55 by 100 is equal to 100 by root 110 by root 3 minus v 0 whole square divided by 114 by root 3 minus V 0 whole square or this equation this equation left hand side right. In fact, this will be 63.5 minus V 0 and this will be 65.8 minus V 0 whole square is equal to 0.55.

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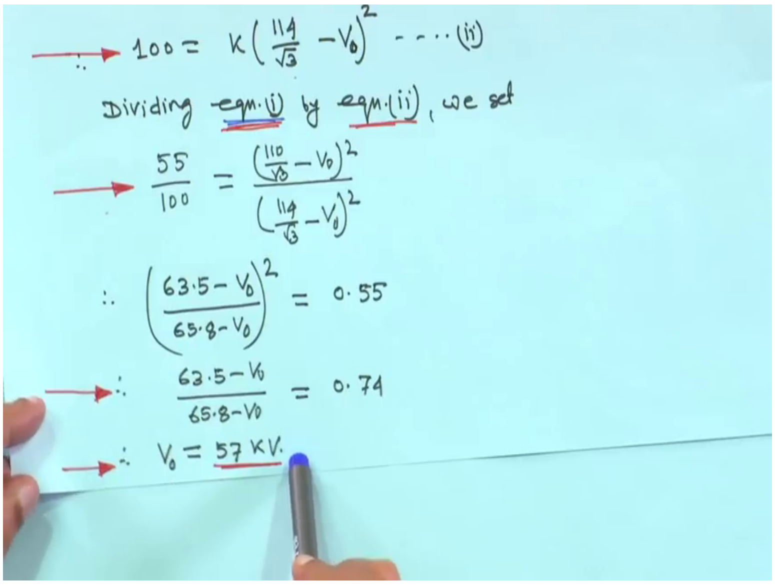

If you solve this one you will get that V 0 is equal to 57 KV. This is square. It is square root is 0.74 after that you solve it you will get 57 KV.

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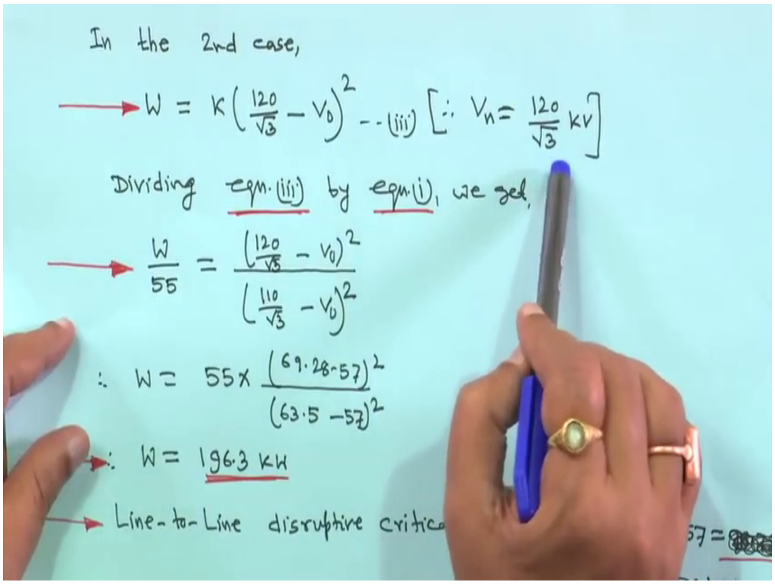

Therefore in the second case second case, we know w is equal to k 120 by root 3 minus 0 square. This one actually known to us this formula is known to us and second case it is ask that if the voltage is 120 KV what is the corona loss. In this this has been converted 120 KV is converted to line to neutral. 120 by root 3 minus V 0 square and it is at bracket I am writing for you Vn is equal to 120 upon root 3 KV this is V n. Dividing equation 3 by equation 1 this is equation 3 divide by equation 1. It will become w by 55 is equal to 120 by root 3 minus V 0 square divided by 110 by root 3 minus V 0 square. But V 0 we have computed 57 KV therefore, W is equal to from this equation 55 into 120 upon root 369.28 minus 57 whole square divided by 63.5 minus 57 whole square.

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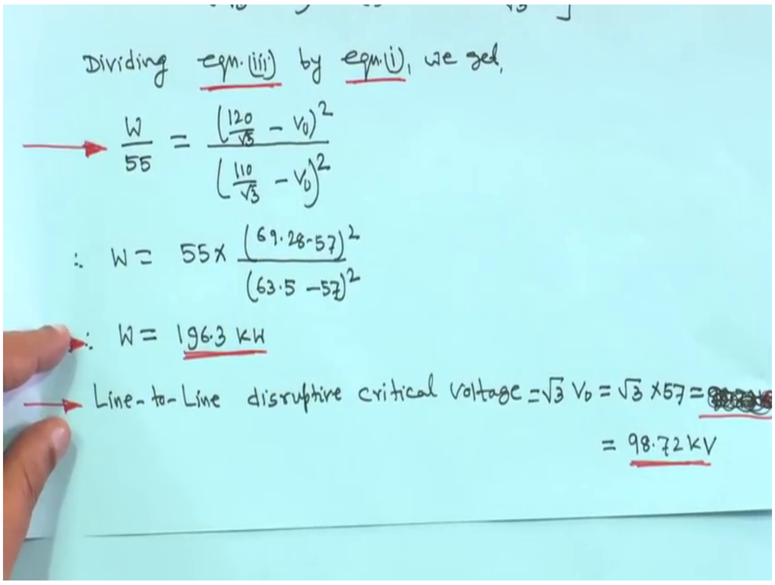

If you solve this w actually become 196.3 kilowatt therefore, line to line disruptive critical voltage will be root 3 V 0. Because, we have got know V 0 is equal to your 57 KV. This is line to neutral this is line to neutral computation then line to line disruptive critical voltage will be root 3 into V 0 that is root 3 into 57. 98.72 KV right.

I hope one more example for you. I hope this is the examples are easier quite easier now.

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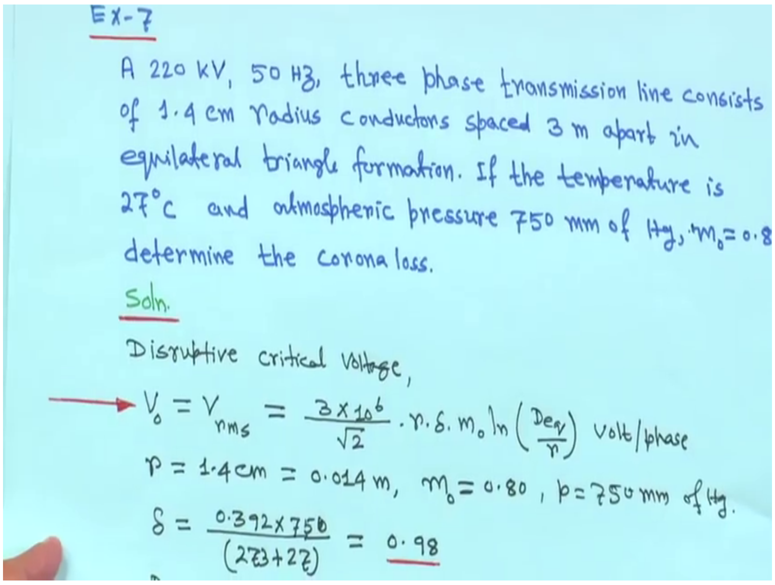

This is the last example for corona example 7 a 220 KV 50 hertz 3 phase transmission line consist of 1.4-centimetre radius conductors space 3 meter apart in equilateral triangle formula formation if the temperature is 27-degree celsius and atmospheric pressure 750 mm of mercury M 0 is given 0.80. We have to find out the corona loss

Disruptive critical voltage this formula we know it is V 0 is equal to Vrms is equal to 3 into 10 to the power 6 upon root 2 into r into delta into m 0 into ln into ln Deq upon r volt per phase r is given 1.4 centimetre that is 0.014-meter M 0 is given 0.80 p is 750 mm of mercury therefore, delta you calculate this formula is known to us this formula is known to us. Delta is equal to 0.392 into 750 the p divided by 270 plus t is 27 is equal to 0.98.

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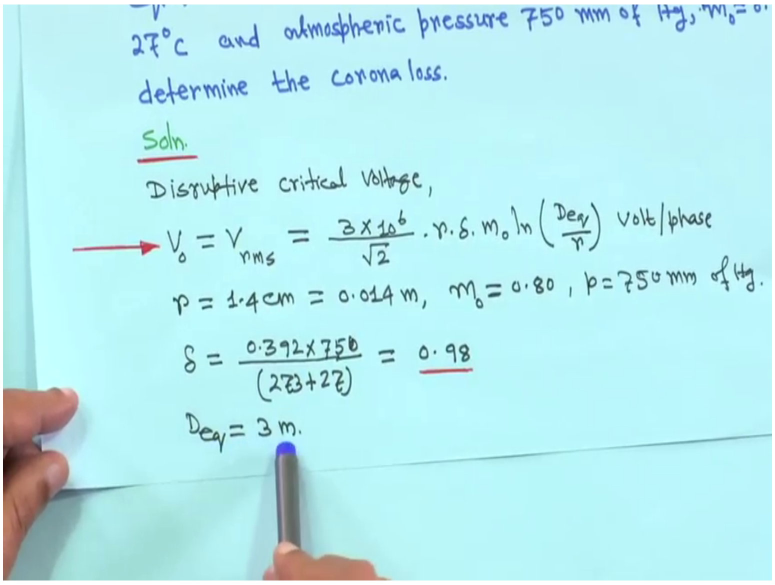

And Deq is given 3-meter Deq is given.

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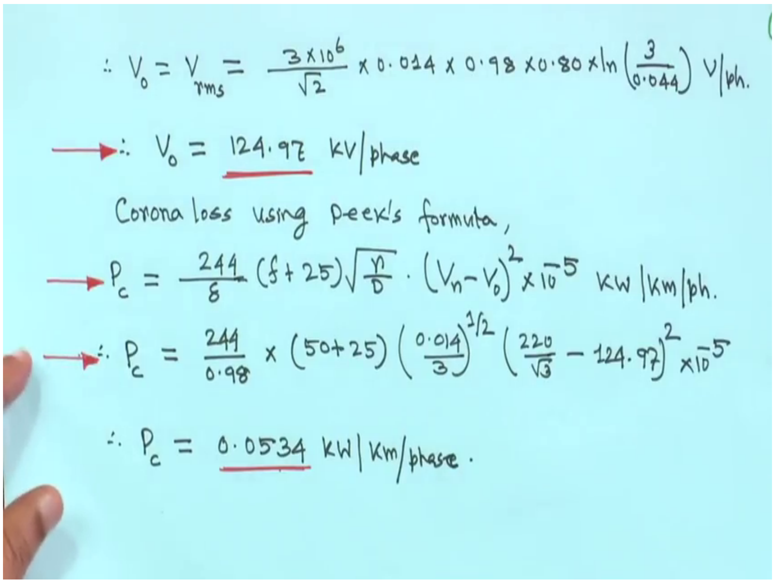

With this with this V 0 is equal to Vrms is equal to 3 into 10 to the power 6 upon root 2 into 0.014 into 0.98 into 0.80 into ln 3 upon 0.044 volt per phase you substitute all the parameters equations are known just you have to keep it in your mind for the exam purpose you have to keep it in your mind

Therefore, V 0 actually 124.97 kilovolt per phase right therefore, corona loss using peeks formula. PC is equal to 244 upon delta into f plus 25 root over r by d into Vn minus V 0 square into 10 to the power minus 5 kilowatt per kilometre per phase; that means, PC is equal to 244 upon delta is given 0.98. We have computed it right f is 50 hertz. 50 plus 25 into root over r by d 0.014 by 3 to the power half I am writing root over then into your 220 upon root 3. Every time you have to converted to line to neutral voltage minus 124.97 whole square because we got this one per phase one 24.9 into 10 to the power minus 5-kilowatt kilometre per phase not writing again here, but here I have written.

PC is equal to 0.0534 your kilowatt per kilometre per phase. If you suppose line is 100-kilometre-long then it will be 5.34 kilowatt per phase if it is a 3-phase line then it will be your 16.0 to I think kilowatt per phase. For 100-kilometre-long line that your what you call that corona loss is quite high. All these things from the design point of view from the design point of view for when that practising engineer. In the design transmission line, they consider all the factors most worse including the worst-case condition based on that they just design the transmission line. With this we will finish corona. This chapter is over the corona loss is over.

Next now next thing is that analysis of sag and tension. Just before starting the sag and tension of the transmission line when sag and tension will be over next we will go for distribution system your load flow. Which is not newton laplacian or Gaussian two methods only I will try to tell you and you will find it is it will be very effective for example, that your because nowadays which because of renewal sources or dispersible or non-dispersible digits the distribution system getting more and more important.

After this sag and tension, you will find it is basically your analyst sag and analyst of transmission line mathematics are involved here and after that you will find the distribution load flow capacitor then little bit voltage stability lower frequency control and of course, unit commitment. All these topics are of highly you know interesting. This sag and tension also you will find you know very interesting topic when we will come into the mathematics and you will see how is it.

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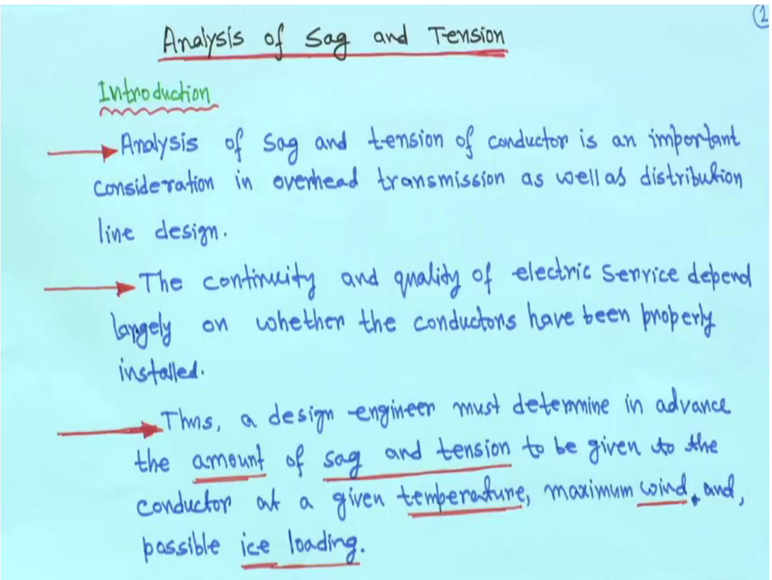

Analysis of sag and tension this is this is quite known thing to you. Particularly you have seen that long transmission line when it is it is connected between your 2 towers right in summer you will find that it is a catenary safe that that conductor is taking something like your what you call your boat type of safe we call catenary safe. It is not never be horizontal right because of it is weights and winds pressure.

We have to find out the maximum sag in summer you can find due to temperature the temperature is very high; that means, sag may increase and winter temperature is low the sag will be less. We will see that sag and tension including the effect of your snow-covered conductor and as well as your what you call that that temperature variation. Just have a look for different of different type of conductor your what you call tower in the plane area or tower crossing the river not at the same altitude or in the hill area also not at the same altitude. What should be the sag and tension. It is a it is a little bit longer chapter. Just see this initially little bit little bit of introduction and then we will come to the mathematics.

First is some introduction. Analysis of sag and tension of conductor that it is important consideration in overhead transmission as well as distribution line design both transmission as well as distribution both transmission as well as distribution, but transmission is more important right more important.

The continuity and quality of electric service depend largely on whether the conductors have been properly installed. Thus, a design engineer must determine in advance the amount of sag and tension to be given to the conductor at a given temperature maximum wind and possible ice loading all these things you have to consider 1 is that maximum temperature. I will when they design this I means that compute sag and tension they consider the extreme cases that is your temperature maximum wind and possible your ice loading all these things they consider.

And in order to in in in order to specify you’re the tension to be used in stringing.

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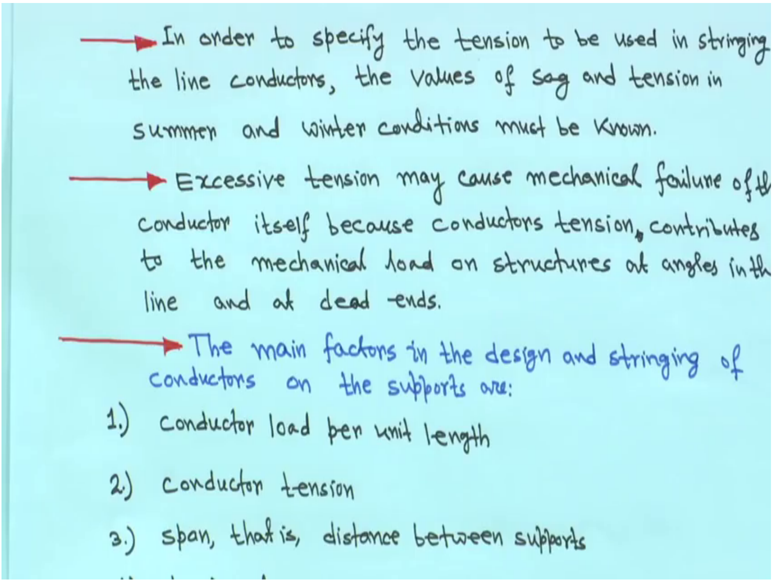

The line conductors the value of the values of sag and tension in summer and winter condition must be known. Because, I told you in summer that expansion that of conductor will be more. Sag will be more we will come to see that and winter it will be less. Excessive tension sometimes may cause mechanical failure of the conductor itself, because conductor tension contributes to the mechanical load and structures at the angles in the line and at dead ends. Many issues are there so many your what you call mechanical things you have to consider particularly for connect your what you call installing conductors at both the towers.

And particularly when you are using say vertical configuration. You have to be very careful, but horizontal configuration is, but vertical configuration because sag will be there. One has to be very careful that it should be uniformly all the all the 3 phase conductors. The main features in the design and your stringing of conductors on the support are I mean in the design and you are basically you have to you have to connect the you are have to conductors on the both the towers.

First thing is conductor load per unit length; that means, conductor itself you know it will be very it you have you have seen the distance between the towers such 100 metres or 200 meters it depends or you know your what type of voltage level you are using and the tower height altitude.

In that case, the conductor load for you conductor is very heavy conductor. That also we have to consider. Conductor load per unit length second is conductor tension also we have to consider the span that is distance between the 2 support 2 tower

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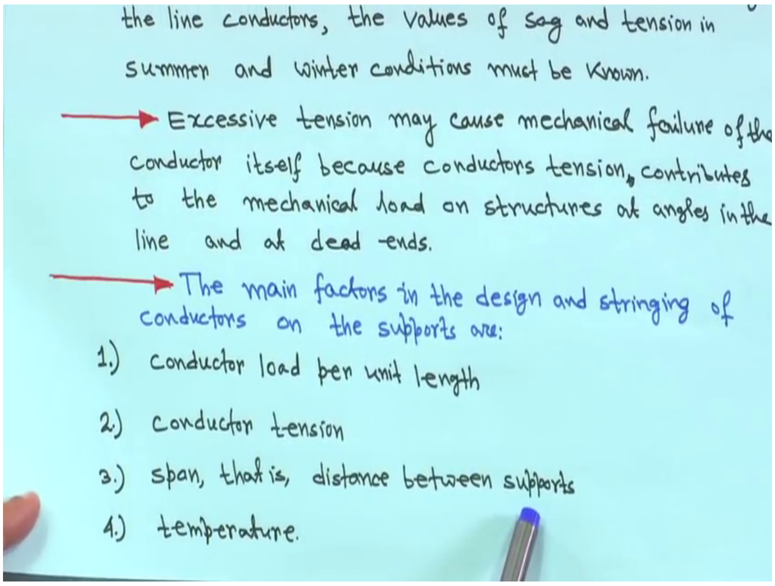

You have to consider and temperature of course, you have to consider. All these all these factors you have to consider.

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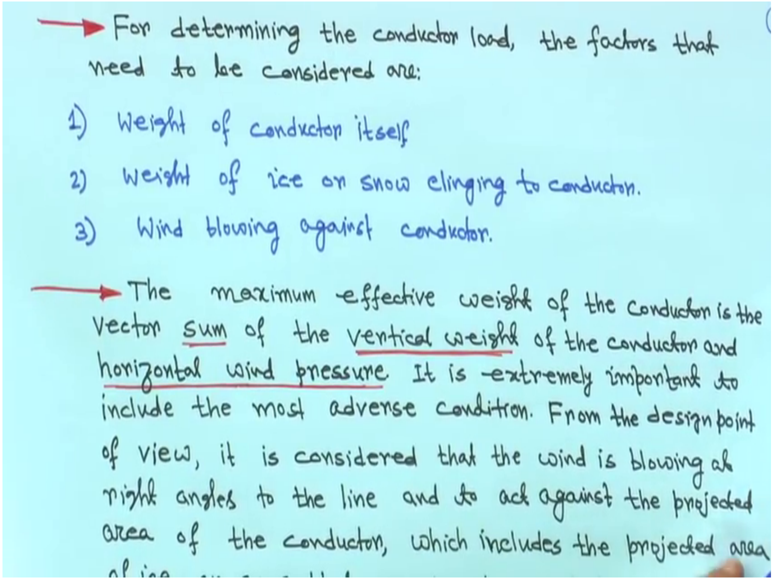

Next is your for determine the conductor load the factors that need to be considered that w8 of the conductor itself that your first thing then weight of ice or snow clinging to conductor. Particular in the hilly areas there is a there maybe there is a possibility it will happen that ice or snow formation on the conductor. That also you have to consider and wind blowing against conductor this also we have to consider later. We will see for mathematical derivation this wind blowing against conductor.

Therefore, the maximum effective weight of the conductor is the vector sum of the vertical weight of the conductor that we will see at the type of mathematical derivation and the horizontal wind pressure both. We have to consider it is extremely important to include most adverse condition. I mean we have to consider the adverse scenario from the design point of view it is considered that that the wind is blowing at right angles of the line right and to act against the your projected area of the conductor. Which includes the projected area of ice or snow that may be clinging to it I mean everything we have to consider.

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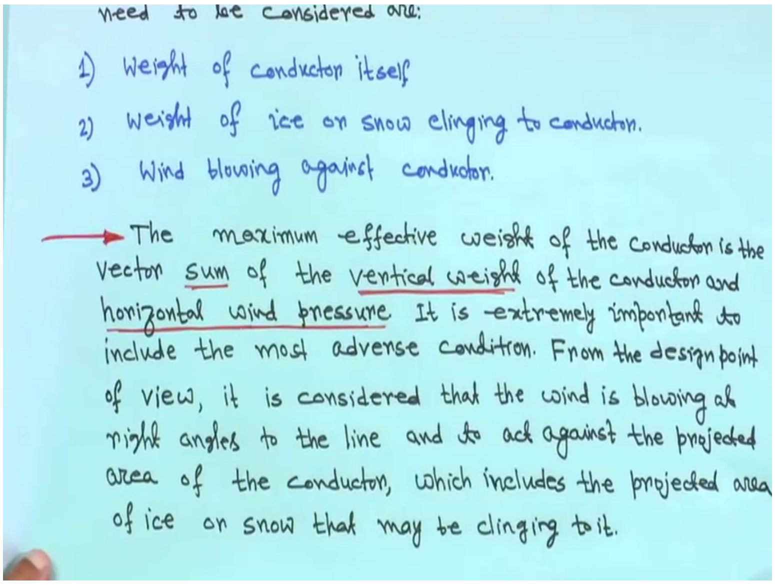

And whenever we are your this thing that the wind is blowing at right angles of the line and to act against the projected area of the conductors. I mean just to consider the extreme cases we have to consider all this conditions. When we will go for mathematical derivation we will come to this.

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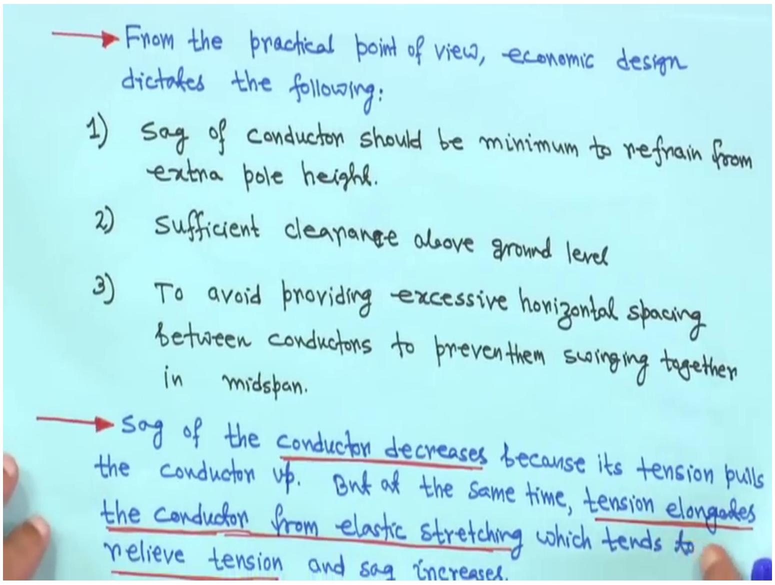

From the practical point of view economic design dictates the following one is sag of conductor should be minimum to refrain from extra pole height. I mean if your sag is low then tower height or pole height will be less, but tip sag is more then tower height will be more because you need some minimum ground clearance.

Then sufficient clearance the that is the things second line sufficient clearance of a ground level then third point is to avoid providing excessive horizontal spacing between conductors to prevent them swinging together in midspan. I mean you have to avoid providing excessive horizontal spacing between conductors to prevent them swinging together in midspan. I mean these are the thing you have to consider another point is that the sag of conductor decreases.

Because, it is tension pulls the conductor up because when you are connecting the conductors on the both the towers. It tensions actually pulls the conductor up, but at the same time the tension elongates the conductor from your elastic stretching which tends to relieve tension and sag increases. Very interesting that look the sag of the conductor decreases because the tension pulls the conductor up that is fine.

But at the same time tension elongates the conductor from elastic stretching which leads to relieve tension and sag increases these are the factors later we will see mathematically because we have to consider also we have to consider your what you call that conductor tension actual cross section everything we have to consider.

Thank you very much again we will be back again.