Power System Analysis
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Lecture – 14
Capacitance of Transmission Lines (Contd.)

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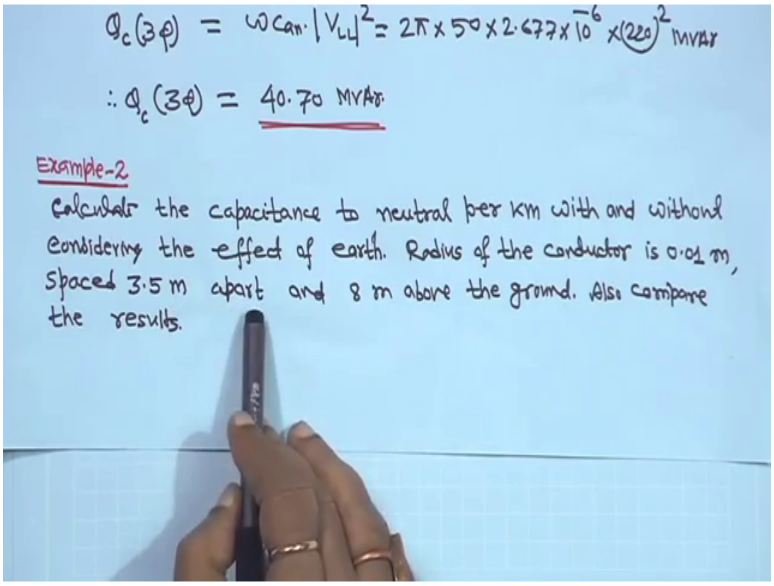

So, next one we will take few example right next one is that calculate the this is example 2 calculate the capacitance to neutral per kilometer with and without considering the effect of earth right radius of the conductor is 0.01 meter spaced 3.5 meter apart and 8 meter above the ground also compare the result then we will compare the result means with and without the effect of the earth right. So, here no need to draw the; you are what you call that contactor configuration right. So, it is you apply equation 44.

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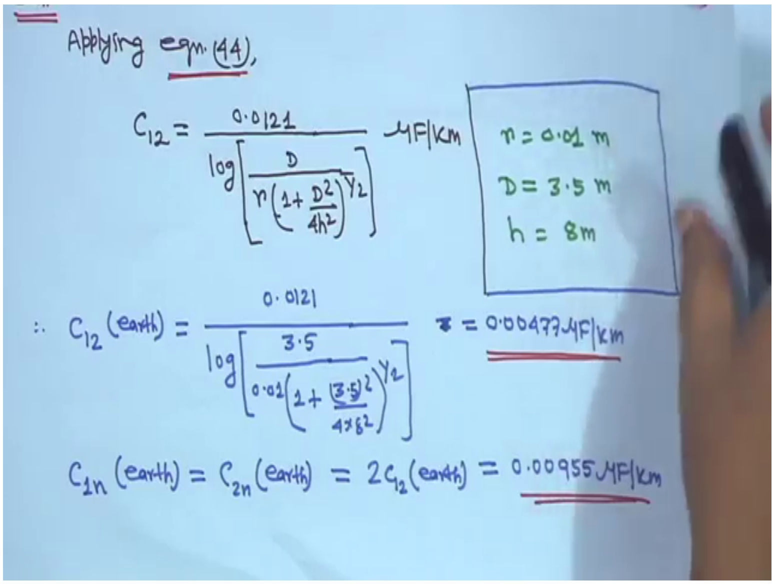

So, that is basically C 12 is equal to 0.0121 upon log divided by log d upon r into 1 plus d square upon 4 h square to the power half microfarad per kilometer r is given 0.01 meter d is also given that spacing 3.5 meter and height 8 meter that is the conductor height from the ground this is given. So, here you C 12 when I am writing C 12 earth because this equation actually while effect of the earth is considered. So, 0.0121 divided by log 3.5 that is your d then r 0.01 bracket 1 plus 3.5 square divided by your 4 into h 8 square to the power half.

This comes actually 0.00477 microfarad per kilometer right and if it is your C 1 to 2 that is between 2 conductors, but if it is neutral C 1 earth is equal to c 2 n earth is equal to 2 C 12 this formula you have seen earlier C 1 n is equal to C 2 n is equal to 2 C 12, but effect of earth is considered. So, that is why C 1 n bracket I writing earth c is equal to C 2 n in bracket writing earth is equal to 2 C 12 earth. So, this is the C 12 value.

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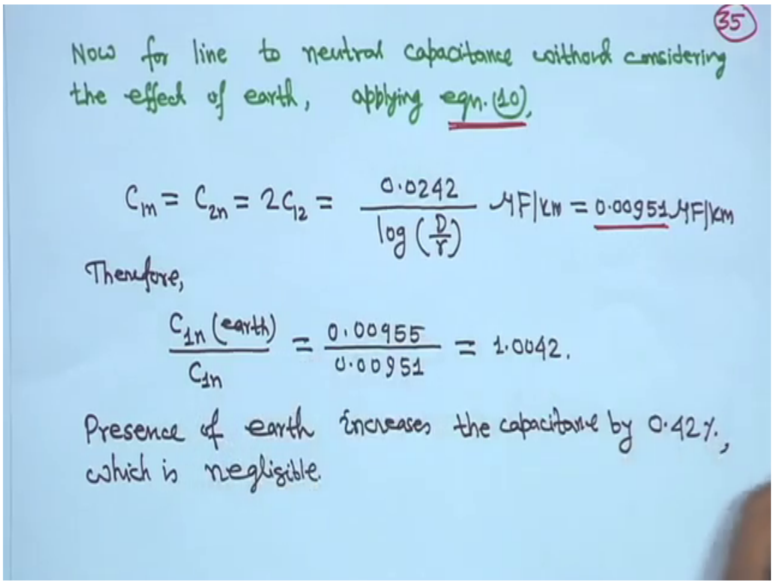

So, it will be multiplied by 2. So, it will be 0.00955 micro farad per kilometer this is the value where the effect of earth is considered right now for line to neutral capacitance without considering the effect of earth you apply equation 10 already derived; so, C 1 n is equal to C 2 n equal to 2 C 12 is equal to 0.0242 by log d upon r right. So, microfarad per kilometer d is known 3.5 meter r is 0.01 meter right. So, you will get 0.00951 microfarad per kilometer.

Therefore you take the ratio C 1 n earth divided by C 1 n. So, C 1 n earth we got this much this is C 1 n earth you got this much 00955 right. So, if you take the ratio it is it will come 1.0042; that means, presence of earth increases the capacitance by 0.42 percent only which is negligible; that means, presence of earth increase the capacitance, but that increases negligible right. So, this is that you are what you call that; that means, for all the practical purposes for computing capacitance one can ignore that effect of your; what you call that earth right perhaps you will find similar findings for the 3 phase also. So, that is up to you I have given that thing that you should derive that right.

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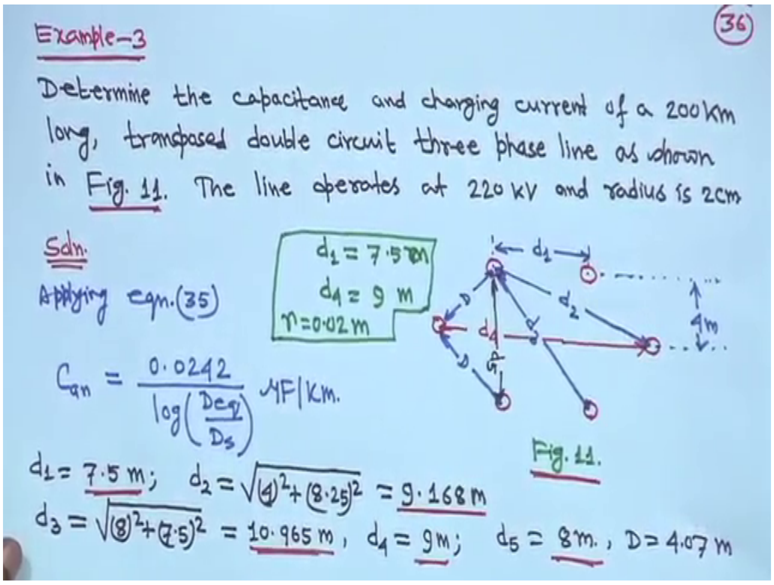

Next you come to another example; example 3. So, in that case you determine the capacitance and charging current of a 200 kilometer long transposed double circuit 3 phase line as shown in figure eleven; that means, this is your figure 11 right the line your operates at 220 KV and radius of the conductor is given 2 centimeter right. So, this is that what you call it is given that your line is your transpose.

So, this is the configuration we have just now we have derived all these your expression right for the 3 phase double circuit transpose line same mathematical expression we will use. So, d 1 is given 7.5 meter this is actually given right d 4 also given 9 meter, here if I try to make it here it will become very clumsy and r is equal to 0.02 meter these distances are given and these this distance this height from here to here this is also given 4 meter here to here 4 meter here to here also 4 meter here to here 4 meter here to here 4 meter right. So, accordingly you have to calculate all other distances.

So, if we apply equation 35 that is C a n is equal to 0.0242 divided by log D e q upon D s microfarad per kilometer this is actually from equation 35 right. So, d 1 is given that is 7.5 meter then d 2 is equal to root over 4 square plus 8.25 square right. So, from here also from here you can find out what is your d 2 right what will be your d 2. So, this height is your 4 and d 4 is given your; what you call d 4 is given 9 meter. So, from that you can find out that what will be your d 2 right I mean you take like this make a right angle triangle and then calculate the distance and make it? So, d 2 is equal to 9.168 meter all these things I have told earlier again I am not telling that how this 0.25 will come right. So, this is just you make it no only d 1 is given 7.5 and d 4 is given 9 and this height is 4 from that easily you can find out what will be your d 2 right.

So, next is that d 3 similarly d 3 also will be root over 8 square plus 7.5 square right it will become 10.965 meter d 4 is given 9 meter d 5 will be 8 meter because this is a vertical height. So, here it is 4 plus 4 8 meter and d and similarly calculate d this d both are same so, but you calculate this d it will be 4.07 meter right. So, first all these distances you compute right.

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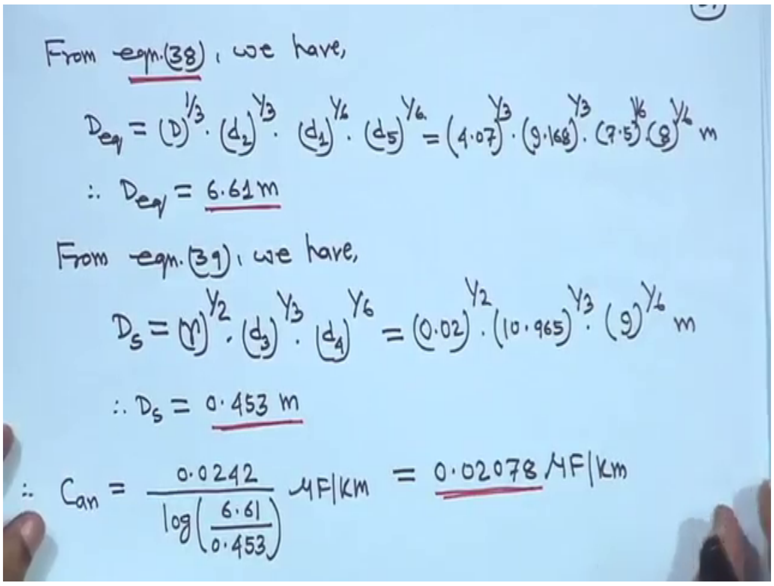

Therefore, from equation 38 we have seen that D e q is equal to d to the power one third d 21 third d 1 to the power 1 sixth d 5 to the power 1 6. So, substitute all these values right. So, you will get D e q is equal to 6.61 meter right similarly from equation 39 already we have derived we have D s is equal to r to the power half d 3 to the power one third d 4 to the power 1 upon 6 substitute r d 3 and d 4 here. So, 0.02 to the power half into 10.965 to the power one third into 9 to the power 1 upon 6 meter that will give you D s is equal to 0.453 meter. Now C a n will be now that formula 0.0242 divided by log 6.61 upon 4.453 micro farad per kilometer that is equal to 0.02078 microfarad per kilometer right.

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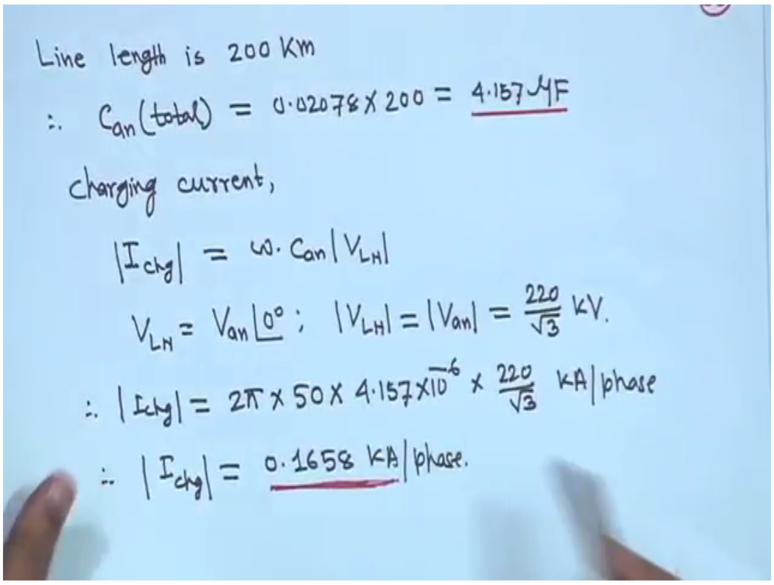

Now, line length line length is given 2 hundred kilometer therefore, C a n the total will be 0.02078 multiplied by 200, it will give 4.157 microfarad right. Now magnitude of the charging current I am putting mod I charge chg charging current is equal to omega into C a n into V line to line capacitor is your phase to neutral. So, that is why it is also voltage to be taken as line to neutral magnitude right.

So, line to neutral voltage is in general V a n angle your 0 degree V a n is referral mod of V a n is equal to mod of a V n is equal to 220 upon root 3 KV because these 220 kilo volt line. So, it is line to neutral voltage therefore, magnitude of charging current is equal to 2 pi f omega is equal to 2 pi f fifty hertz system into 4.157 into 10 to power minus 6 it is micro farad that is why it is 10 to power minus 6 farad into 220 upon root 3 kilo ampere per phase. That means, I charging current that is magnitude of charging current will be 0.1658 kilo ampere per phase; that means, charging current actually is not very small that is equal to 0.1658 kilo ampere per phase means 165.8 ampere right per phase. So, this is how to calculate the charging current right.

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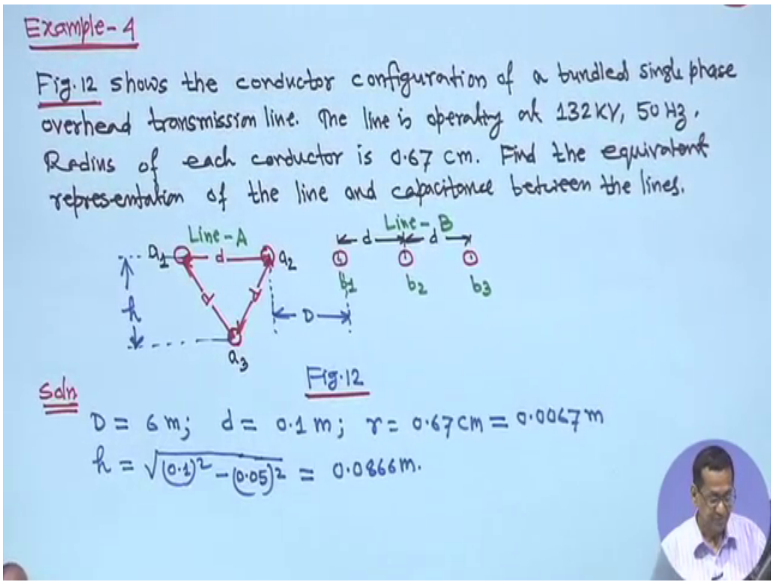

Now, next one is we have a different configuration. So, this is figure 12 this is figure 12. So, figure 12 shows the conductor configuration of a bundled single overhead transmission single phase overhead transmission line the line is operating at 132 KV and 50 hertz right. So, this is 132 KV line radius of each conductor is given 0.67 centimeter both side right here also radius 0.67; this side also right find the equivalent representation of the line and capacitance between the line you have to find the equivalent representation as well as the capacitance of the line this is actually equilateral triangle because d d d all distance same. So, this is equilateral and this is horizontal spacing right. So, in this case your capital d right. So, this d; that means, a to 2; this is actually let me tell you this is 3 conductors are there in phase a. So, bundled conductor. So, a 1 a 2 a 3 and here 3 conductors are there horizontal spacing b 1 b 2 b 3 right distance between a 2 and b 1 I mean from here to here it is given as d right.

So, this distance is d is given that is a 6 meter that is given right here the numerical here I have not written all this, but this d is given 6 meter and d is equal to your what you call this d this d is equal to also given it is 0.1 meter this is given and r is equal to 0.67 centimeter that is 0.0067 meter radius of the conductor this side as well as this side right then you have to find out h is equal to this is the h is equal to find out this height you this you find out because this you require actually right. So, if you find out. So, you will find root over it is 0.1 square minus 0.05 square because d is equal to your what you call 0.1 meter this; this d right 0.1 meter you draw a vertical line here you draw a vertical line here right; that means, that is your h. So, h is equal to root over this distance square d square minus d by 2 square. So, minus 0.1 square minus root over 0.05 square is equal to 0.0866 meter. So, this is your h right next you have to find out that D S A and D S B right I mean of this side this side as well as this is for line a this is for line b. So, this side you have to find out.

So, basically it is a this configuration actually series equilateral triangle right. So, D S A that is your D S A it will be for this one actually r d square to the power one third right. So, you need not consider because it is a symmetrical spacing an equilateral triangle just one conductor you make it. So, one is your in general you know that it will be if you consider this conductor it will be like your d a 1 a 1 into d a 1 a 2 into d a 1 a 3.

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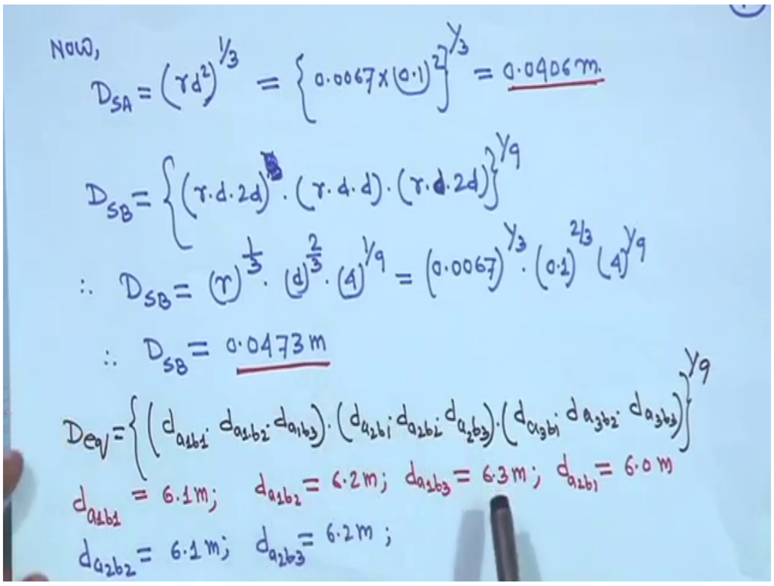

So, d a 1 a 1 is r and d a 1 a 3 this is d and this is also d; so, r d square to the power 1 third because 3 distances right. So, that is actually D S A. So, is equal to similarly for here are all same; so, ultimately if you take r d square into r d square into r d square to the power 1 by 9. So, ultimately it will become r d square 1 upon 3 right. So, 0.0670067 into 0.9 square to the power one third, so, 0.0406 meter right similarly for this one also it will become D S B if you take any one. So, D B if you take this one it will be d b 1 right d b 1; 1 into your d b 1 2 into d b 1 3 if you repeat for other 12. So, it will be same. So, that is why directly you can write that sorry other 1 that r d r into d into 2 d for when you consider your V 1 V 2 right.

Similarly, if you sorry first one is this is your D s b; so, d b v if you consider d b 1 your b 2 b b 1 b 1 b 1 rather. So, it will be r then b 1 to b 2 into d and b 1 to b 3 it will be 2 d right this is one then when you come to mid conductor it is d b 2 b 2 that is r and d b 2 b 1 d into b 2 b 3 also d right similarly when you come to this one this one and this one same. So, it will be r into d into 2 d to the power one by 9 because 3 3 3 altogether 9 combinations. So, it is 3. So, n square it is 9 here it is symmetrical that is why you are writing 1 1 by 3, but here it is not symmetrical right.

So, it will be r d into 2 d into r d d into r d into 2 d right because we want to b 3 or b 2 3 on this one and this one product same. So, to the power 1 9, so, after simplification it will come r to the power one third into d to the power 2 by third into 4 to the power 1 by 9 right. So, in that case it will become 0.0067 one third into 0.12 third into 4 to the power 1 by 9 because 2 into 2 4 that is why separately taken as 4 to the power 1 by 9 right therefore, D S B will be 0.0473 meter right.

Now, now you have to calculate D e q; that means, all sort of combinations you have to take right here also 3 conductors here also 3 conductors. So, 3 into 3 9; that means, all possibilities will be you have to consider. So, D e q is equal to d a 1 b 1 into just for your understanding everything has been made it here d a 1 b 2 into d a 1 b 3.

Next you continue a 2 d a 2 b 1 d a 2 b 2 d a 2 b 3 next you consider a 3 d a 3 b 1 d a 3 b 2 d a 3 b 3 to the power 1 by 9 right. So, all the distances you compute d 1 b 1 how much 6.1 meter all these distances you please all the preliminary things I have made it here all these distances you can easily compute right. So, if you compute because previously I have shown how to make all these things right. So, d a 1 b 1 will come 6.1 meter d a 1 b 2 will come 6.2 meter d a 1 b 3 will come 6.3 meter right now d a 2 b 1 will be 6 meter d a 2 b 2 will be 6.1 meter and d a 2 b 3 will be 6.2 meter right. So, once you similarly this is straight forward.

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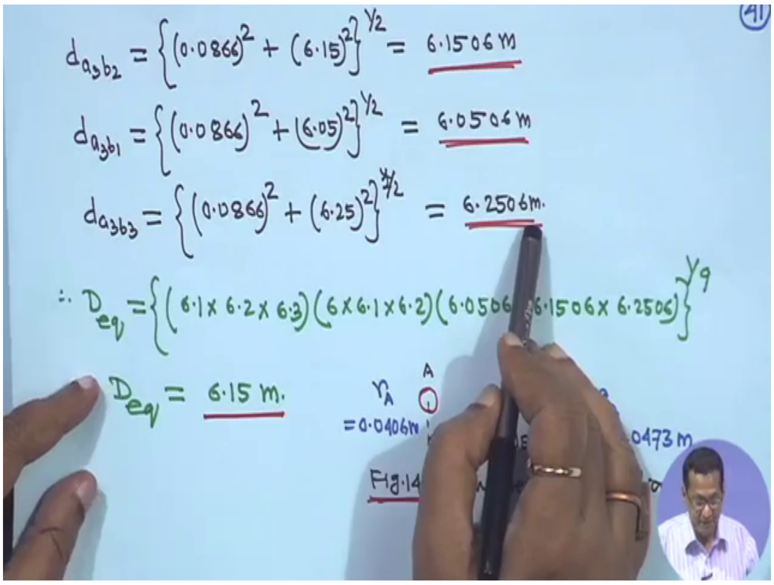

Now, similarly if you consider d a 3 b 2 it will be I mean d a 3 b 2 means you make it there and this will be right angle triangle right all these things you calculate similarly d a 3 b 1 again you from here to here you compute and similarly your d a 3 b 1 and d a 3 b 3 d a 3 b 3 d a 3 b 2 d a 3 b 1 all these 3 cases 3 right angle triangles you make and accordingly you calculate right. So, d a 3 b 2 will be 0.0866 whole square plus 6.15 whole square to the power half it will be 6.1506 meter similarly d a 3 b 10.0866 whole square plus 6.05 whole square to the power half 6.05606 meter.

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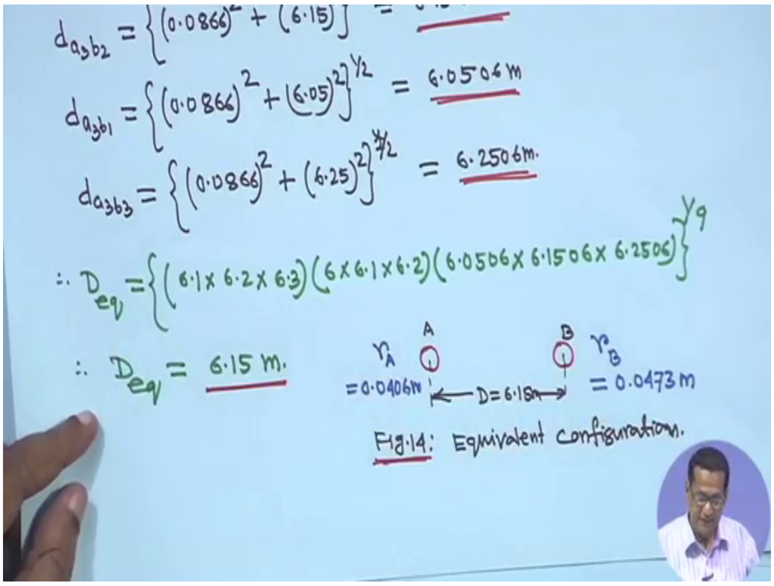

And similarly d a 3 b 3 is equal to 0.0866 whole square plus 6.25 whole square to the power half 6.2506 meter. Now then this D e q in this expression in this expression in this expression you substitute all these distances right all these data I will substitute. So, all have been substituted here all have been substituted here to the power 1 by 9 if you calculate D e q will become 6.15 meter right.

So, your; that means, it will be 6.15 meter and next is your what you call then what will be the equivalent configuration equivalent configuration is that distance for D S A and D S B you got D S A you have got 0.0406 meter right as if as if this is the radius of this is radius of conductor right which is equivalent to this bundled conductor right. All these 3 conductors are there its equivalent radius will be 0.040406 meter for this group right; that means, line a 3 conductors are there on equilateral spacing right and this horizontal spacing similarly your D S B is equal to your 0.0473 meter.

So, as if this side can be represented by a single conductor whose radius is 0.0473 meter right and distance between 2 D e q d e q is equal to just computed it here it is D e q is equal to 6.15 meter. So, this is equivalent 6.1, this is the equivalent configuration now I have a question to you now although we are using bundled conductor it is radius is very if you take its radius is 0.67 meter right and here if you take of course, you can see that here it is 0 0 this thing what you call 0 0 6 7 and it is 0 4 radius has increased, but instead of using this equivalent thing we use this one there must be some advantages right.

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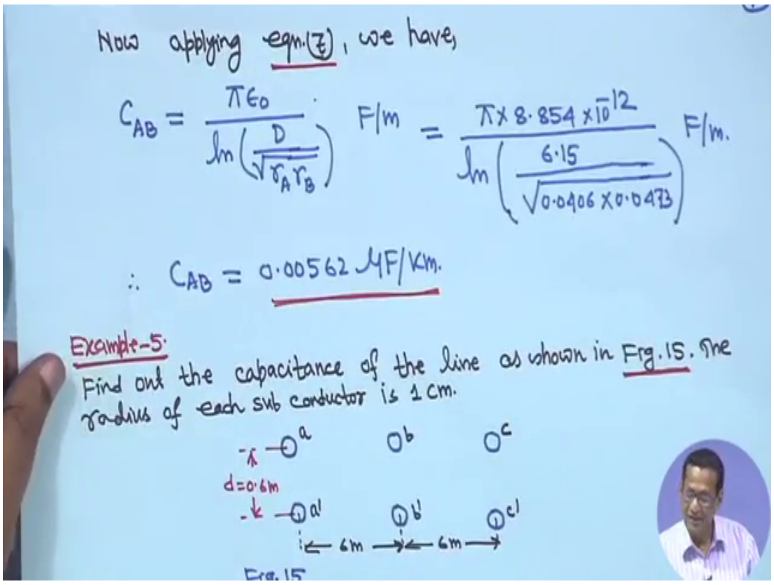

There is the question to you; what are those advantages instead of making this kind of single conductor configuration right. So, this is the equivalent configuration right as if 2 single conductor right. So, now, applying equation 7 applying equation 7 you have c a b is equal to pi epsilon 0 upon l n d root over r a r b in that equation it is given pi epsilon 0 d upon root over r one r 2 if I recall correctly farad per meter you can go back to the equation 7 and it will be taken like this. So, substitute d that your this your this thing instead of d I can make it; it is D e q right. So, this will be pi and epsilon 0 is 8.854 into 10 to power minus 12 right l n your 6.15 divided by r a root over r a into r b that is your basically D S A into D S B this equation actually there should not be any confusion right.

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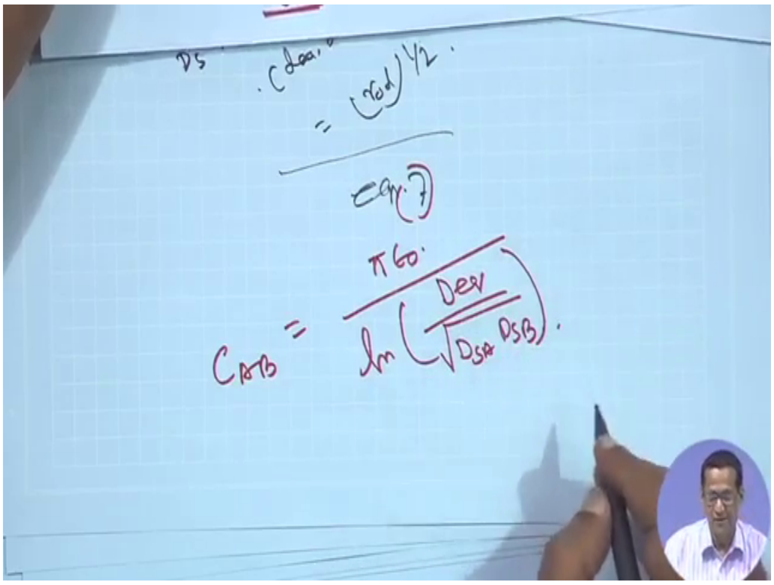

This equation that equation 7 that equation 7 can be written as this is equation 7 it can be written as C a b is equal to pi epsilon 0 right l n D a q by root over D S Al D S B right this way it can be written that is why this is actually equivalent r a and r b this is from here I am writing this is equivalent r a and r b that is nothing, but this is D S A and this is D S B right. So, therefore, if you make this one you will get that your 0.00562 microfarad per kilometer. So, I hope you have understood this right how to make only thing is that calculation should be careful of calculating all the distances correctly right.

The next one is that find out the capacitance of the line as shown in figure 15; this is figure 15 right the radius of each sub conductor is one centimeter right. So, a b c a a dash b b dash c c dash; that means, in each phase 2 conductors are there and horizontal spacing and between these 2 conductors distance is 0.6 meter right and between these any 2 phase conductors a dash b dash or b dash c dash it is 6 meter right these things given. So, you have to find out the line capacitance.

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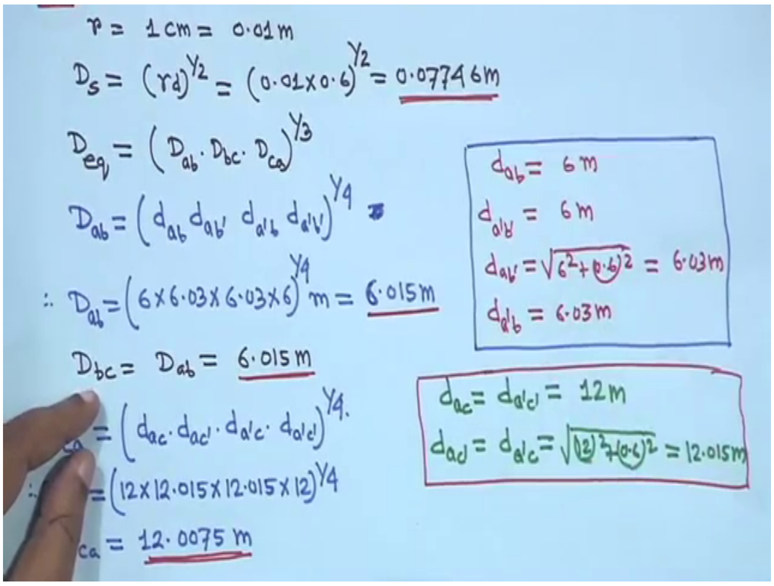

So, r is equal to given 1 centimeter is equal to 0 0.01 meter D s easily you can calculate r d to the power half is equal to you will get 0.07746 meter D e q will be D a b, D b c, D c a to the power one third now you know how to calculate a b b c c a D a b d b c D c a. So, it will be D a b is equal to D a b D a b dash into d a dash b dash into a dash b into d a dash b dash to the power 1 by 4 D a b 6 meter d a dash b dash 6 meter D a b dash is calculated root over 6 square plus your 0.6 square.

So, all these things you calculate all the distances you calculate and you will get d a dash b also d a b dash and d a dash b is equal to 6.03 meter this is also same 6.03 meter right and d a c is equal to d a dash c dash is equal to 12 meter and d a c dash is equal to d a dash c is equal to root over 12 square plus 0.6 square is equal to 12 0.01 5 meter from this configuration from this configuration you can compute all right. Therefore, D a b you calculate it will become 6.015 meter and from the symmetry from the symmetry D a b is equal to D b c right. So, it is same. So, it is 6.015 meter only D c a you have to calculate D a c into D a c dash into d a dash c into d a dash c dash to the power 1 by 4 all combinations I told you one inside find out all combinations and to the power 1 by 4 because in each phase 2 conductors are there. So, when you considering the your mutual distances between them.

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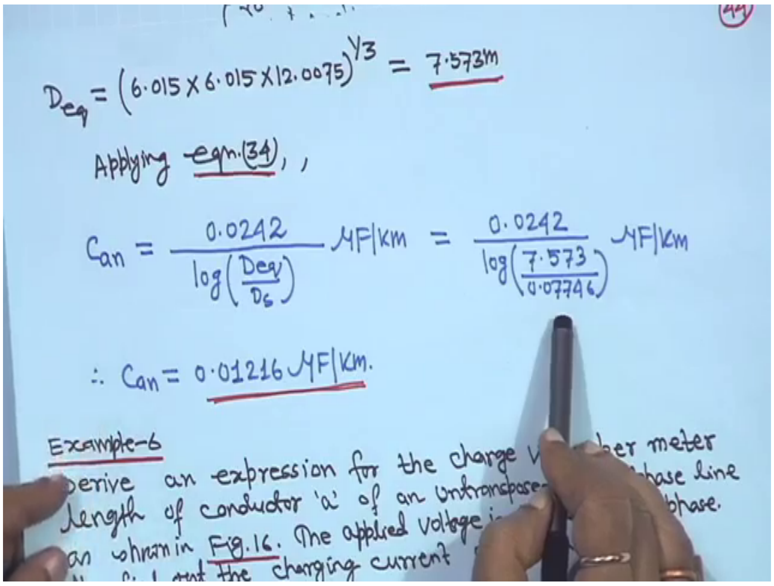

So, combination between will be 2 into 2 4. So, it is 1 by 4 substitute all these distances all you have got it is 12.0075 meter right therefore, D e q directly that formula already D a b, D b c, D c a, D a b, D b c, D c a to the power one third it is coming 7.573 meter then apply equation 34 you will get C a n is equal to 0.0242 log D e q upon D s right is equal micro farad per kilometer substitute D e q and D s right if you solve you will get 0.01216 micro farad per kilometer solve the varieties of problems I showed.

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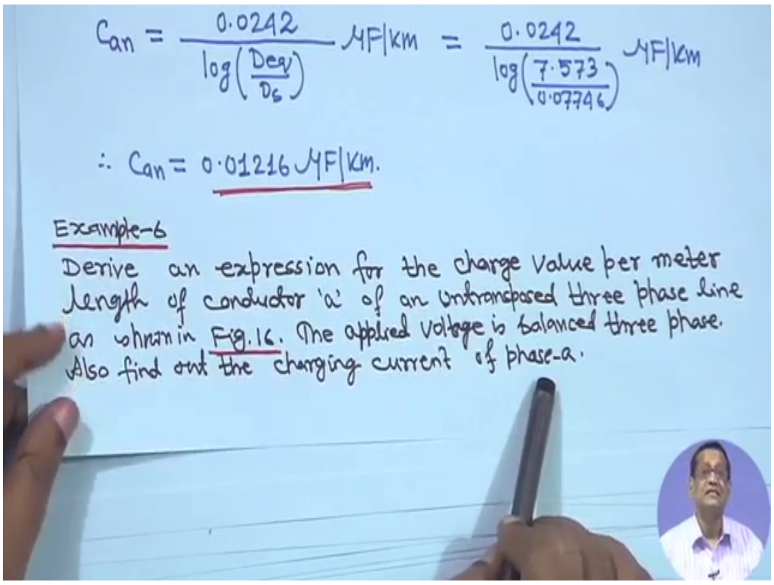

And another one it is not a difficult one, but simple one that derive an expression for the charge value per meter length of conductor a of an un-transposed 3 phase line as shown in figure 16 I will show you the figure 16 the applied voltage is balanced 3 phase also find out the charging current of phase a right. So, you have to derive an expression for the charge value per meter length of conductor a of an un-transposed 3 phase line as shown in figure 16 the applied voltage is balanced 3 phase also find out the charging current of phase a you have to find out the charging current of the phase a.

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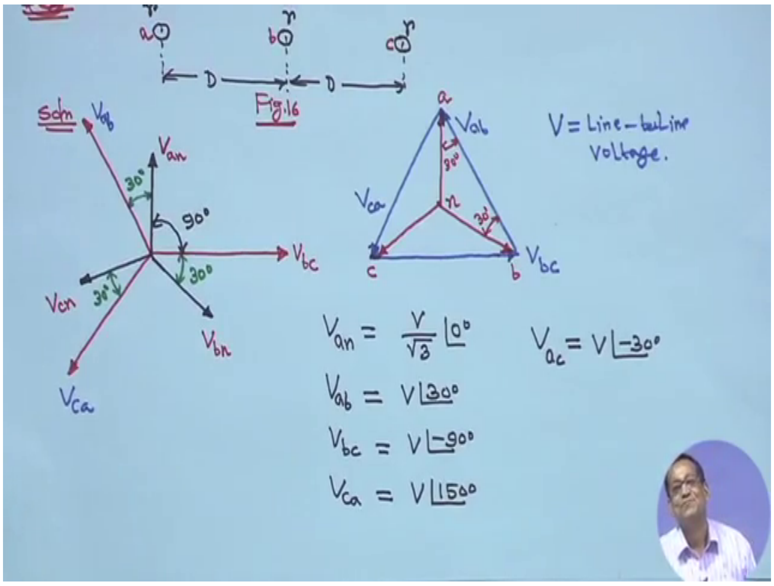

So, this is that this is the configuration horizontal configuration radius of each conductor is radius of each conductor is r right and this is a b c distance between this your d any 2 your phase conductor d here also d right.

So, earlier you have seen that your V b c V c a and V a b right for line to line voltage right. So, this we all we have seen and accordingly I when we have seen V a b plus V a c is equal to 3 V a n when we proved that at that time we have seen no same diagram this is your V b c here it is b is the tip because b this V b c arrow is here for b c right V a b and similarly your V a b. So, this is V a b; that means, parallel to this V a b parallel to this V a b V a b here is the tip V c a V c a c is here V c a c is here right and when you when you this is a balanced system. So, neutral is here when you join these all these things this is V a n this is V b n and this is V c n right.

So, this V a n V b n V c n just put it here V a n this is V a n V b n this is V b n and V c n this is V c n. So, this way first you make this Phasor diagram; that means, if V a n is the reference if V a n is the reference one then V a n is equal to V by root 3 angle 0 degree because we assume V a b magnitude V a b is equal to magnitude V b c is equal to magnitude V c a is equal to V right line to line voltage magnitude. Therefore, my V a n will be V upon root 3 angle 0 degree because if you take V a n as the reference right therefore, your V a b; that means, V a b will be V angle 30 degrees because V a b actually leading V a n by 30 degree. So, V a b is equal to V angle 30 degree V a b case it is line to line voltage this line to line voltage leading this your what; you call this voltage V a n by 30 degree. So, V a b is equal to V angle 30 degree.

Similarly, V b c that is your V b c actually from V a n it is lagging by 90 degree that is why V b c is equal to it is line to line voltage. So, no question of root 3 here or here V b c is equal to V angle minus 90 degree because it is lagging from this right and similarly V c a is equal to V angle 150 degree right; that means, this is V c a this between V a b and V c a is 120 degree plus 30. So, 150 degree, V c a is leading V a n by 150 degree that is why we have written V c a is equal to V angle 150 degree similarly V a c your V a c will be V angle minus 30 degree it is c a if you want V because this is needed V a c will be V angle minus 30 degree the reason is simple.

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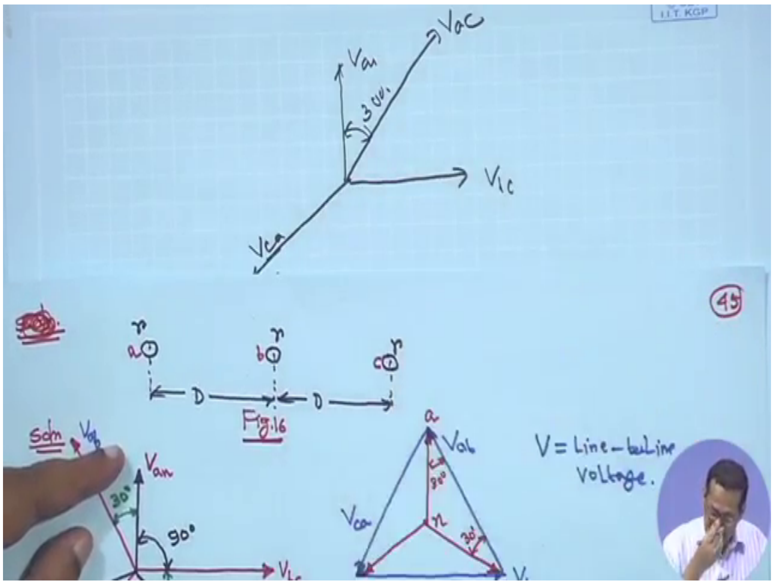

Suppose this is your V a n this is V a n this is this was your line to line voltage say V c a right and this one your V b c now it is V c a if I make it other way. So, it will be V a c just a C 1 80 degree; that means, this angle this angle is 30 degree right. That means, your V a c is lagging your lagging from V a n by 30 degree that is why V a c is line to line voltage that is why V a c is equal to V angle minus 30 degree that is why we have taken V a c is equal to V angle minus 30 degree. So, it is understandable right.

Thank you.