Power System Engineering
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Lecture – 36
Load flow of radial distribution networks (Contd.)

So, after second iteration we have just seen that, voltage V2 is 0.98578 angle is of course, in distribution system very small.

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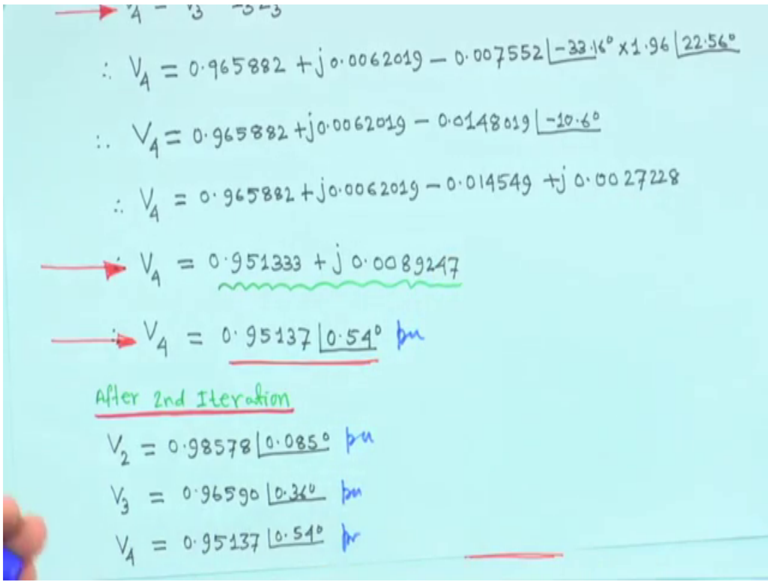

So, 0.085-degree V3 is equal to 0.96590 angle 0.36 degree and V4 is equal to 0.95137 angle 0.5 these, are all in per unit, right? All calculations are in per unit, right? Everywhere I have not written per unit. So, here again you can see that all the angles are leading angle and I ask you also that why instead of negative, why this positive angle is coming? Answer is very simple, but you please find out, what is a I mean why it is coming leading angle for this example right?

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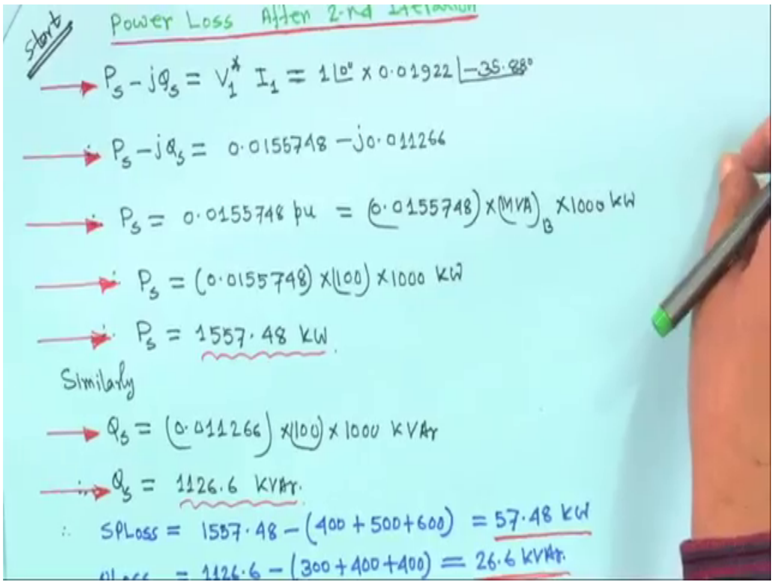

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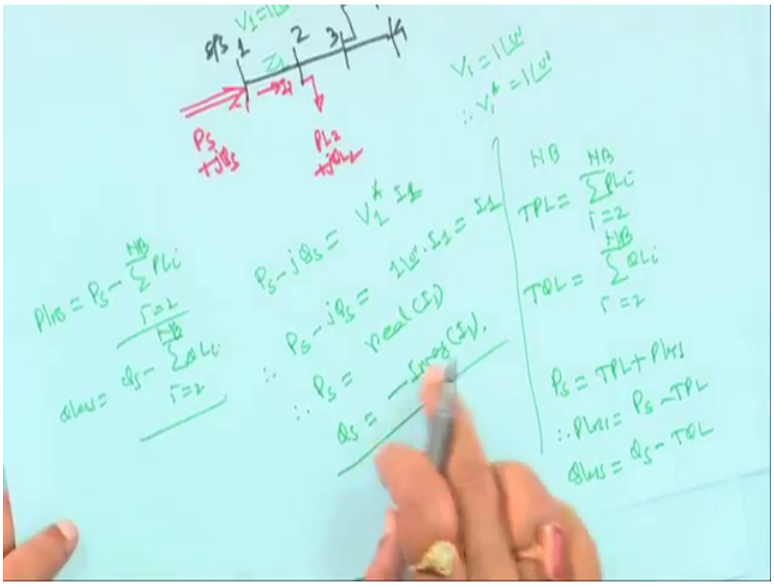

Next is that power loss calculation, right? What will be the power loss? There are mainly your 2, 3 ways of computing power losses, right? One is that, suppose you have a distribution network I will show you the 2 different ways, right? At least 2, 3 ways, this suppose you have a power network distribution network like this, this is your substation, this node is 1, suppose this is 2 3 4 5 and 6 this is the distribution network, right? And current flowing through this first branch, very first branch this is you say I 1 everywhere load is there, I mean everywhere for example, here it is P l 2 plus j Q l 2 say similarly here, P l 3 plus j Q l 3 and so on, everywhere loads are there I am not showing here, buy everywhere loads are there.

Suppose net injected power is power coming to the substation, this substation actually power coming from the grid to the substation, suppose it is P s plus j Q s, right? And it is a your impedance of this branch very first branch say it is Z 1. So, whatever, but from the load flow studies, you know this your how to call that branch current I 1 and this voltage substation voltage is known to you, this voltage is V 1 is equal to in this case one angle 0 we have taken.

So, then this current is also known from the load flow studies, then what you can do is, you can write this equation P s minus j Q s is equal to V 1 conjugate I 1 this is the power coming from the grid to a substation. So, you can write that, the I you have studied, in the load flow studies P l minus j Q l is equal to V conjugate I. So, P s minus j Q s is equal to V 1 conjugate your I 1, this is the current this I 1, right? And the I 1 current is known to you, then V 1 is equal to 1 angle 0 degree therefore, V 1 conjugate is also 1 angle 0 degree; that means, my P s minus j Q s is equal to your 1 angle 0 degree into I 1 is equal to I 1 everything is in per unit therefore, P s is equal to real part of I 1, right?

And Q s is equal to minus imaginary part of I 1, because it is P minus j Q. So, P s minus j Q. So, it is minus imaginary of I 1; that means, this P s and Q s coming from the greed, are entering into this your what to call substation and; that means, this power is equal to whatever loads are there, whatever suppose you have N B number of nodes and you have all the P L Q l is known. So, what will be the then total load.

Say total load will be T P L will be your sigma I is equal to 2 to N B and this is P l I this is the total load and total reactive load, this is real power load it is Q l I equal to 2, to N B right; that means, this is the injected power and injected power P s actually is equal to total power T P L plus total power loss right; that means, P loss is equal to P s minus total real power load.

Similarly your Q loss is equal to Q s minus total reactive power load; that means your P loss is equal to the power injected at the substation, that is P s minus that total T P L right? That is total real power load, this is the P loss and Q loss is equal to Q s minus I is equal to 2 to N B Q l I this is the power loss, right? So, this is in per unit, whatever you will get P s or loss everything is in per unit. So, you have chosen 100 M V A base therefore, as soon as you these quantity you multiply for example, P s P s as soon as you multiply P s is equal to real part of I 1 this is your P s.

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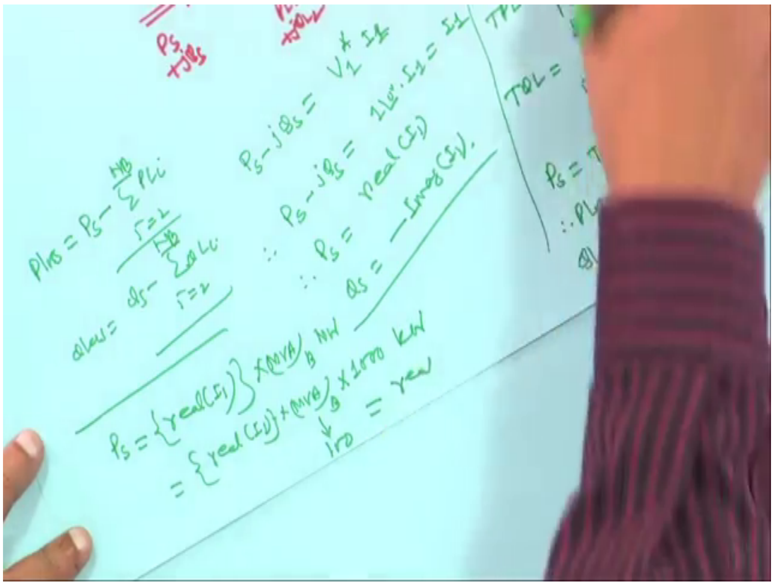

If you multiply it by M V A base then it will be megawatt, then this quantity if you multiply by 1000 it will be kilowatt, right? Therefore, real of I 1 into M V A base into your 1000, that is kilowatt and M V A base is 100; that means, this quantity this whole quantity hold on I am writing here this whole quantity P s, right? Is equal to real of I 1 then into 100 M V A base into 1000 this is kilowatt; that means, P s is equal to real of I 1 into 10 to the power 5 kilowatt.

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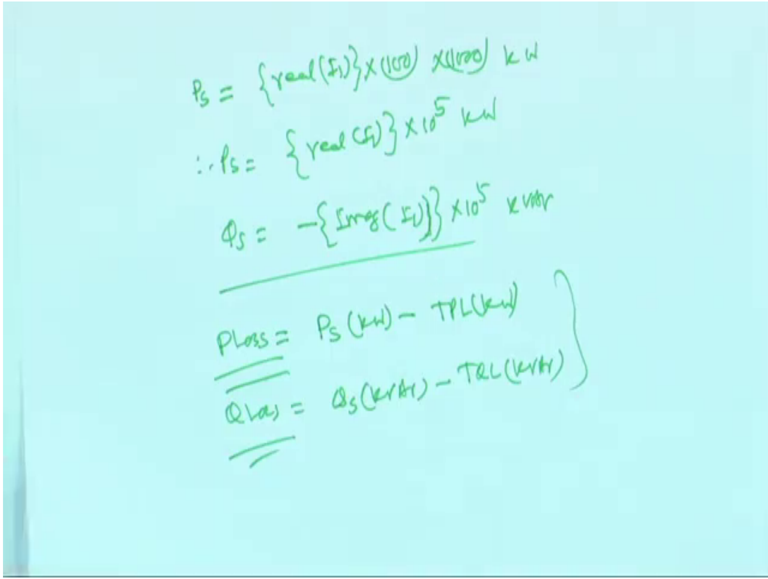

Similarly, Q s also will be minus imaginary of I 1, right? Into 10 to the power 5 kilo hour, right? So, this way this is one way, another way I square unless you can compute. So, this way, you can compute; that means, your power loss that real power loss P loss is equal to, if you put like this that is your P s, suppose if it is in kilowatt minus total load T P L that is also in kilowatt, that will be P s loss right that that; that means, T P L sum of all the your real power load, similarly Q loss also it is Q s, if it is in kilo hour minus T Q L then your kilo hour.

So, this is P loss and this is Q loss, right? So, this way you can compute, same way I have made it here for you, that power loss after second iteration, of course this is not exact, because we have to move few for few iterations another 1 or 2. So, here also you are writing P s minus j Q s is equal to V 1 conjugate I 1. So, I told you V 1 is 1 angle 0. So, V 1 conjugate 1 angle 0 and this I 1 is actually g after second iteration we have seen it is 0.01922 angle minus 35.8 degree; that means, P s minus j Q s is equal to 0.0155748.

I have taken up to 6 7 decimal places for more accuracy, but for assignment or for exam purpose if something like is there, I will suggest you consider only up to 4 or 5 decimal places, do not go beyond that right? Minus j 0.011266 right; that means, P s will be real of this one is 0.155758 per unit is equal to this is the value, into multiplied by M V A base into 1000 kilowatt just in showed you, but M V A base is 100. So, it is P s is equal to 0.0155748 into 100 into 1000 kilowatt, that is total input power to the substation real power 1557.48 kilowatt, right?

Therefore, similarly Q s will be, this is your Q s is equal to minus your imaginary of this one. So, didn't generally Q s will be just compare the real and imaginary. So, Q s is 0.011266 into base M V A 100 into 1000 kilo hour right? Therefore, Q s will be 1126.6 kilo hour; that means, this is power input and load is; that means, total power loss P loss is I am writing sum of power loss, previous thing I wrote P loss are s P loss same, sum of power loss is equal to total your power loss that is 1557.48, just now we got this one minus the total load that, P L 2 plus P L 3 plus P L 4. So, it is in kilowatt.

So, 57.48 kilowatt similarly Q loss will be 1126.6 kilowatt minus Q l 2 plus Q l 3 plus Q l 4 whatever load was there. So, loss is coming 26.6 kilo hour, after your second iteration, right? This way loss can be computed. So, here a during the iterative process, I didn't check any convergence thing or anything, because there I have to one more iteration. I request you to do the next iteration, of yourself right? So, that is why iteration means that what we the loss was the difference of the loss in successive iteration and take their absolute value, and if it is less than said 10 to the power minus 3 or minus 4 in terms of kilowatts say, then you assume the solution has converged.

But when we will take I square all loss I will show you also I square all loss for 3, there are 3 branches when I take I square all loss you find there is a difference is there, because it is not a converse solution right? Still one or 2 iteration required.

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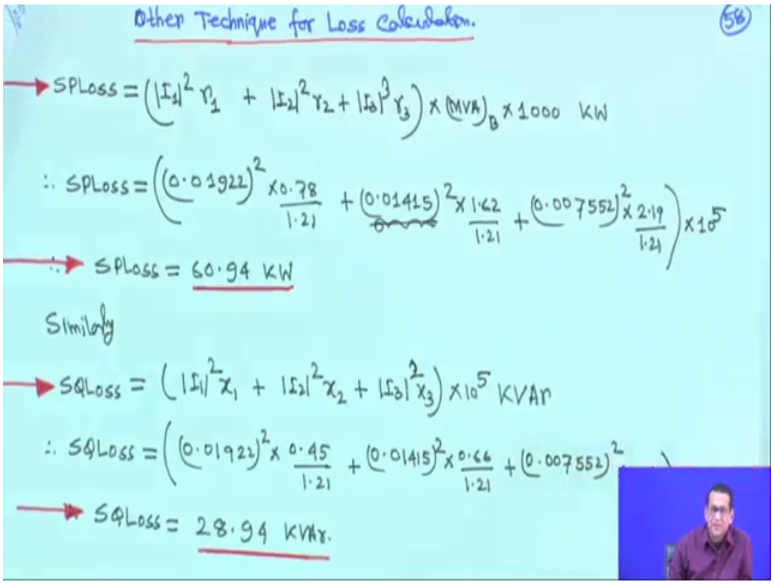

So, another thing is that your I square r. So, there are 3 branches. So, it is mod I 1 square r 1, plus magnitude I 2 square r 2, plus magnitude I 3 square r 3, everything is a per unit multiplied by M V A base multiplied by thousand kilowatt, right? So, magnitude is 0.01922 square and your r 1 is it actually value was 0.78 ohm.

So, I have divided by their base in impedance 1.21, right? Similarly, here also this is the I 2 square this is the magnitude of I 2, all you have calculated after second iteration into this is a exact value of up to 1.62 ohm by base impedance 1.21, similarly here also these the magnitude of current square current square into 2.19 up 1.21, when M V A base is M V A base is 100. So, multiplied by 10 to the power 5 therefore, total power loss here it is coming 60.94 kilowatt, but here it was 57.48 kilowatt.

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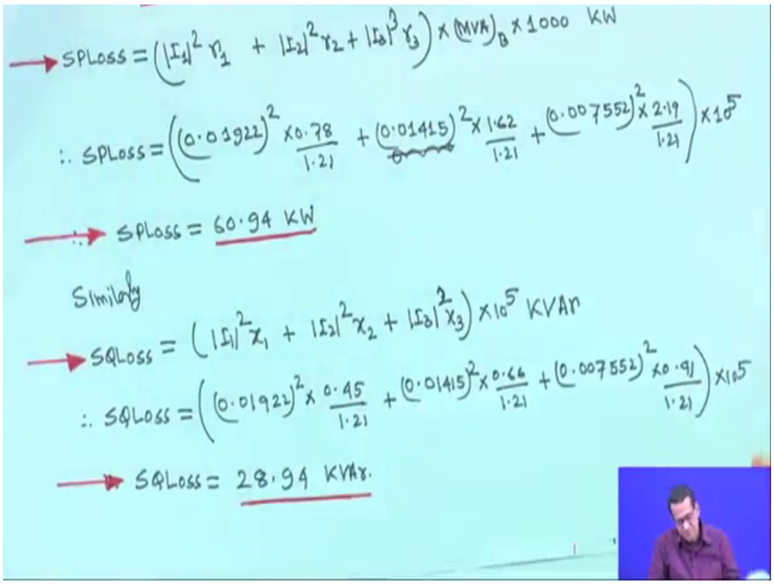

What these difference is? Because the solution has not yet converged, when you take say another iteration or another 1 or 2 iterations. So, in solution will converge, you will find the calculating these way this loss or calculating these way this loss both will be same identical right?

Similarly, that total Q loss I there is magnitude I 1 square x 1, I 2 square x 2, plus I 3 square x 3, into 10 to the power 5 kilo hour, right? So, all the I 1s this thing this value is converted to per unit, all it is values and you substitute all this values, all this values are substituted our magnitude of I 1 magnitude of I 2 and magnitude of I 3 and then square, right? And these are all x 1 value it is ohmic values divided by their base impedance 1.21 1.21 1.21 into 10 to the power 5.

So, total Q loss is 28.94 kilowatt, but here if you look it is 26.6 kilo hours slight difference is there, because their solution has not yet converged that is why, this is the your how to call this, that is why this difference using this method, but I suggest you do the third iteration, you will find this 2 will be very close to this one and finally, solution will converge right? So, this is actually using your method 1. So, this is the calculation for method 1 load flow.

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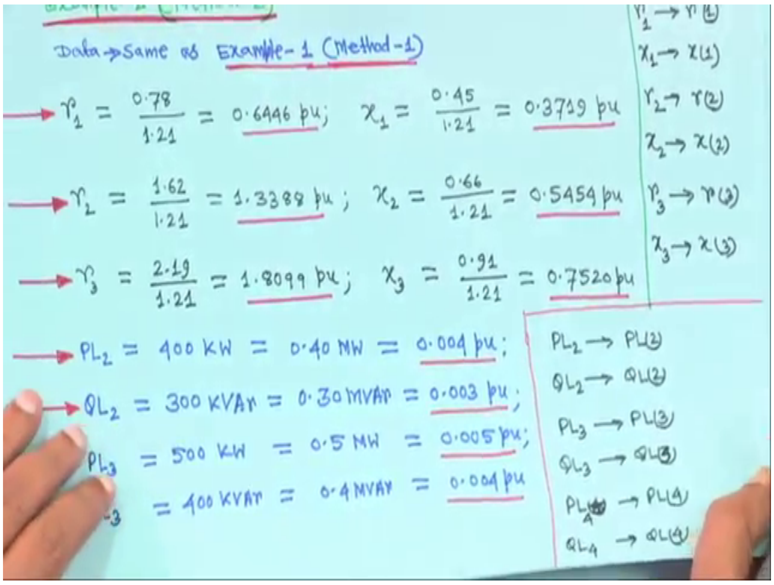

Now, example 2 that is method 2 this is actually, same data we will take for the purpose of comparison same data we will take. So, data same as example 1 or method 1, but here everything rewriting because r 1 is converted to per unit, r 2 r 3 all are converted to per unit, right? Then x 1 x 2 x 3 all are converted to per unit, everything is in per unit and meaning is same r suffix 1 r bracket 1 x 1 is equal to x bracket 1 they are all same that is why, but still I am making it here, that when you are writing mathematics, we are using this one.

If you write code, you will use this one, right? But question is that I am just making it like this, similarly P L 2 Q L 2 all up to P L 3 Q L 3 P L 4 Q L 4 all are same, this P L 2 this P L 2 all are same. So, there should not be any question of confusion, right? So, P L 2 is 4 100 kilowatt divided by 1000.4 megawatt divide by base M V A. So, 0.004 per unit initially also for example, one all this are given similarly Q L 2 is 300 kilowatt is equal to 0.003 per unit similarly P L 3 is 500 kilowatt that is 0.5 megawatt that is 0.005 per unit and Q L 3 is equal to 400 kilowatt that is 0.4 megawatt. So, 0.004 per unit, right? And similarly, P L 4 is equal to 600 kilowatt is equal to 0.005 per unit and Q L 4 is 400 kilo hour is equal 0.004 per unit, right?

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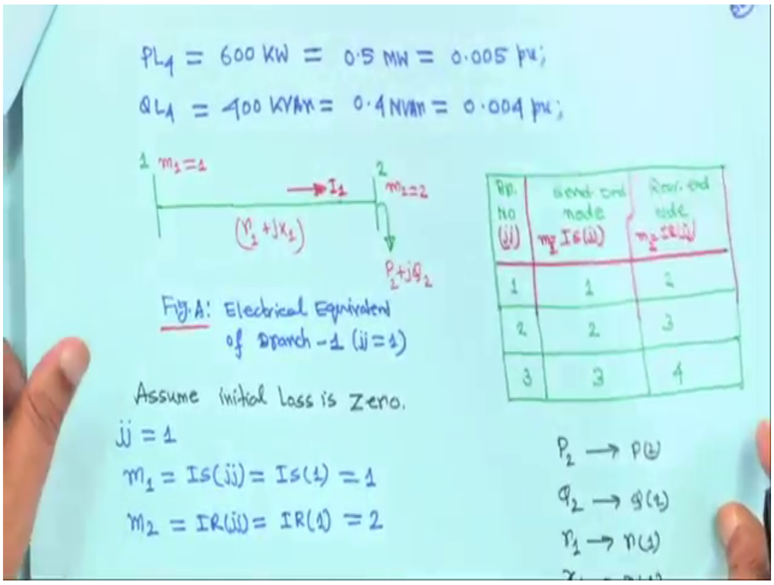

Now, that this the same example for one this a branch number 1 2 3 sending and receiving end, sending and receiving end, sending and receiving end, right? Here also meaning is same P suffix 2 and P bracket 2 all are same, similarly Q 2 r 1 except the everything meaning is same right? That is, they are identical same thing. So, for when is a for second method initially, we have to assume that loss is 0, that mean we assume initial loss is 0 means, that all the all the branch power losses are 0; that means, real power losses and reactive power losses in all the branch you assume initially it is 0 right?

Therefore, for j jis equal to 1, when j j is equal to 1 sending end node is m 1 is 1, m 2 is equal to 2 right? Therefore, m 1 is equal to 1 m 2 is equal to 2 all this things are written here right?

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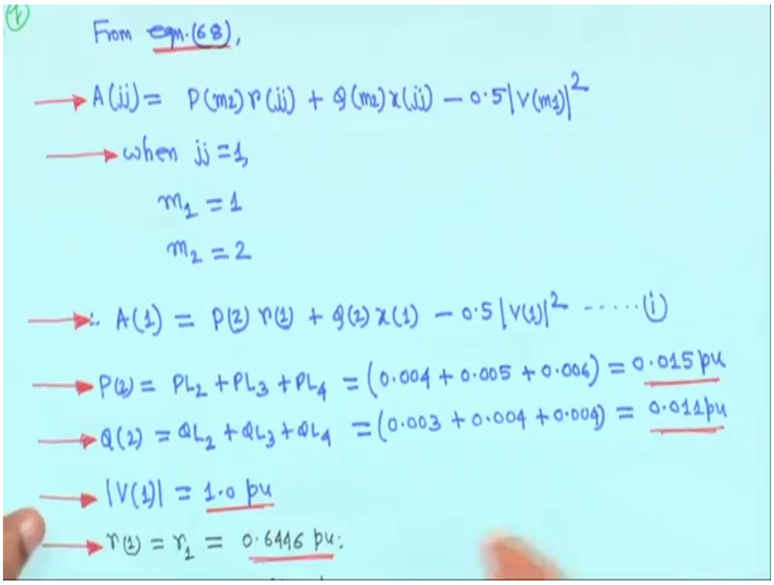

Then from equation 68 if we go to equation 68. Then you will see equation 68 is this one, we wrote A j j is equal to P m 2 r j j plus Q m 2 x j j minus 0.5 into magnitude V m 1 square, when j j is equal to 1, just now we have given m 1 is equal to 1 m 2 is equal to 2; that means, A 1 is equal to P 2, here you substitute here you substitute j j is equal to 1 and m 2 is equal to 2 here and m 1 is equal to 1 here you substitute. So, A 1 is equal to P 2 r 1 plus Q 2 x 1 minus 0.5 magnitude V 1 square this is a equation only numerical equation 1. So, initially loss of all the branches are neglected therefore, total load fed through this node will be P L 2 plus P L 3 plus P L 4 just repeating this.

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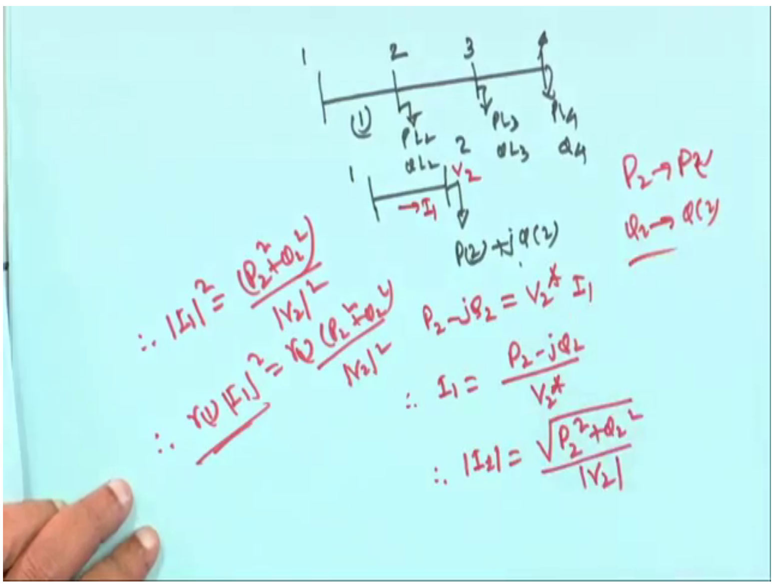

Look, we have taken a very small example, right? This is the electrically equivalent of branch 1 and 2. So, this is branch 1 I node 1 2 3 4 electrically equivalent this is your branch 1, right? So, here everywhere load is there P L 2 Q L 2 P L 3 Q L 3 P L 4 all this things have been explained before, and this is the branch 1 and this is the branch 2. Then what is the electrical equivalent? It will be P 2 plus j Q 2, right? So, beyond this node this 2 branches are there, but we have assumed losses are 0, then what is the total load fed to this node? It will be P 2 will be here you have load here you have load here you P L 2 plus P L 3 plus P L 4.

Because everywhere that, P L 2 plus j Q L 2 P L 3 plus j Q L 3 plus P L 4 plus j Q L 4 load is there. So, P 2 will be P L 2 then plus P L 3 plus P L 4 similarly, Q 2 will be Q L 2 Q L 3 plus Q L 4 Q L 2 plus Q L 3 plus Q L 4, right? That loss is neglected so; that means, my P 2 will be P L 2 plus P L 3 plus all in per unit, you make 0.004 plus 0.005 plus 0.006, that will be 0.015 per unit, right?

Similarly, Q 2 will be is equal to Q L 2 plus Q L 3 plus Q L 4, is equal to 0.003 plus 0.004 plus 0.004 that is 0.011 per unit, voltage at the substation it is known, because it is 1 angle 0. So, magnitude V 1 is equal to 1 this is known right? And r 1 r 1 is equal to this r 1 I told you this per unit 0.644 per unit and x 1 is equal to x suffix 1 that is 0.3719 per unit. So, all these all these data put here, in this equation and calculate what is the value of a 1?

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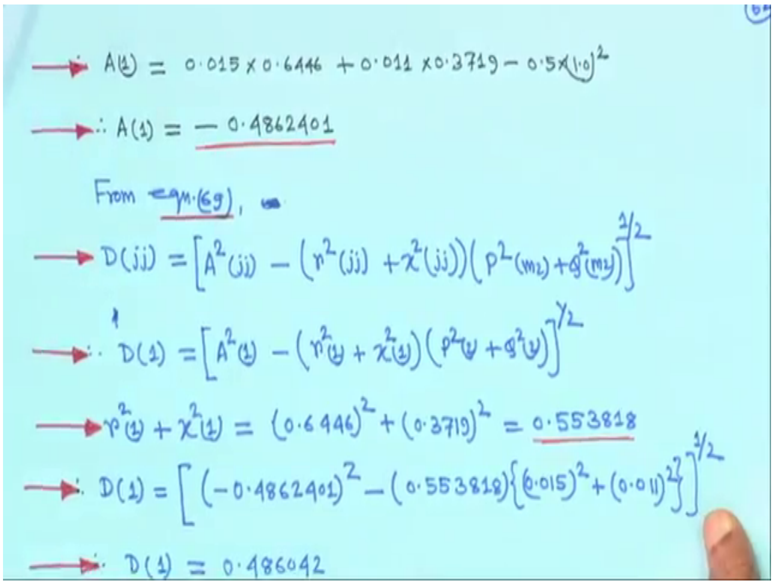

So, if you do. So, A 1 will be 0.115 into 0.6446 plus 0.011 into 0.379 minus 0.5 into v 1 square, that is 1 square it will become a 1 will become minus 0.4862401, right? And similarly, from equation 69, another term was that D j j. So, D j j is equal to a square j j minus r square j j plus x square j j into square m 2 plus Q square m 2 bracket close right? To the power half.

Therefore, j j is equal to 1 therefore, D 1 is equal to a square 1 minus r square 1 plus x square 1 and m 2 is equal to 2, for j j is equal to 1 therefore, P square 2 plus Q square 2 to the power half therefore, you first you calculate this term, r 1 square plus x 1 square. So, r 1 square plus x 1 square is equal to this 1, right? 0.6446 square plus 0.3719 square is equal to 0.553818, I suggest I have taken up to 6 decimal place or so, but for the assignment purpose everything, I will tell you that you should take only up to 3 or 4 decimal place I mean if you for 5538 you can make it approximation 0.554, right? So, I have taken exact 1, then D 1 is equal to we have calculated just now A 1 minus 0.4862401.

So, it is minus 0.4862401 whole square right? Because it is square right? Minus then r square plus r 1 square plus x square you have made it 0.553828. So, substitute here, and then it is P 2 square 0.015 square plus 0.011 square and to the power half, if you simplify this D 1 will become 0.486042. So, A 1 is minus of this thing, very close only there sign difference is there, but this term and this term they are very close, right? Up to first 3 decimal places this 2 are almost same right? But there is a negative sign here, every iteration you will find magnitude wise this 2 term will be very close right? But, here it is negative sign.

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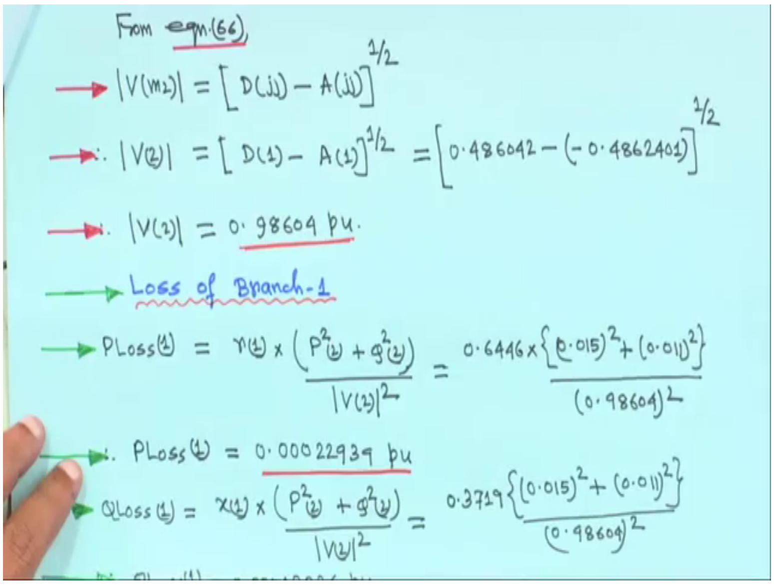

Next is calculation of voltage magnitude. So, from equation 66, we know that voltage magnitude V m 2 is equal to D j j minus A j j half right, but for j j is equal to 1 m 2 is equal to 2, this is the very first iteration going on. So, V 2 magnitude V 2 is equal to D 1 minus A 1 to the power half, this all this thing continuing for j j is equal to 1, branch 1 A 1 is equal to 1 m 2 is equal to 2, right? So, you substitute that D 1 is 0.486042 minus, this minus and A 1 is minus in bracket it is minus point 0.486042.

So, minus minus plus actually, to the power half if you simplify, magnitude of V 2 will come 0.98604 per unit. So, V magnitude of V 2 is obtained, now once V 2 is obtained. So, loss of branch 1, that is P loss 1 r 1 into P square 2 plus Q square 2 upon V 2 square, this also I have showed you right? How to calculate the losses. So, in this diagram this is the current I 1 and this is the voltage magnitude V 2 therefore, this already I have explained, but once again I am showing, P 2 minus j Q 2 is equal to V 2 conjugate I 1, right?

Therefore, I 1 is equal to P 2 minus j Q 2 upon V 2 conjugate therefore, magnitude of I 1 is equal to root over P 2 square plus Q 2 square upon V 2, right? And therefore, magnitude of I 1 therefore, magnitude of I 1 square is equal to P 2 square plus Q 2 square right? Divided by V 2 square right or for branch 1 power loss, if you want r 1 then I 1 square is equal to r 1 in bracket, I am putting P 2 square plus Q 2 square upon V 2 square right?

So, this is real power loss similarly, if you multiply x 1 with this term then that will give you reactive power loss. So, here P 2 everywhere I am telling, this P 2 means this bracket P 2 Q 2 means this bracket Q 2 like this right? Therefore, when you compute the your what you call the loss of branch 1, it is p loss 1 that is loss of branch 1 is equal to r 1 into P 2 square plus Q 2 square upon V 2 magnitude square.

So, r 1 is 0.6446 into P 2 is 0.015, first iteration is going on plus 0.011 square divided by 0.98604 square. So, P loss 1 will be 0.00022939 per unit, right? Similarly, Q loss 1 will be x 1 into P 2 square plus Q 2 square upon V 2 square. So, it will be 0.3719 0.015 square plus 0.011 square by 0.9860, actually this term remains same only here, it is multiplied by r here it is multiplied by x right? Therefore, Q loss 1 is 0.0013234 per unit, this is per unit only later we will convert to the real unit, because we have to go for the iteration right?

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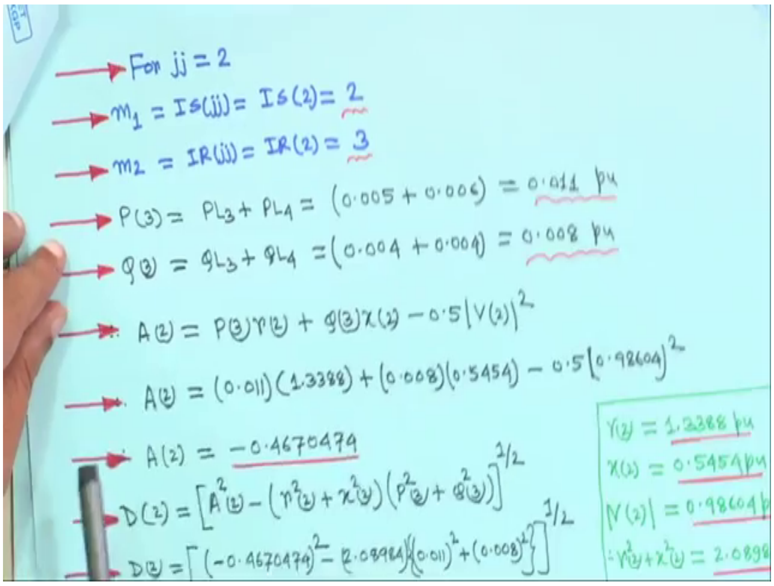

Similarly, first iteration is continuing. So, similarly for j j is equal to 2 m 1 is equal to 2 all this have been explained, and m 2 is equal to 3 therefore, P 3 will be now actually it will be P L 3 plus P L 4, same the total initially loss are all neglected. So, P 3 is equal to P L 3 plus P L 4 and whatever loss you have calculated this is for loss of branch 1 not branch 2 or 3, right? Therefore, P L 3 plus P L 4 is this much 0.011 per unit and your Q 3 is equal to Q L 3 plus Q 4 that is your 0.008 per unit, right? So now, from the same equation for j j is equal to j j is equal to 2, you calculate A 2 now, from this equation only whatever from equation 68, only put j j is equal to 2 here only here only right here only.

So, in that case you will get A 2 is equal to P 3 r 2 plus Q 3 x 2 minus 0.5 V 2 magnitude square. So, substitute all the values all the values you substitute. So, A 2 will be 0.011 into 0.3388 plus 0.008 0.5454 minus 0.5 and this is the voltage magnitude V 2 square. So, 0.98640 square. So, A 2 is becoming minus 0.4670474, right? This is A 2, all r 2 x 2 V 2 r up to square plus x 2 square everything is written here, re calculated and I am writing here.

For such that when you will we you will go through these slide, at that time readily available in front of you, that is why I have written. Similarly, from this equation that again your D j j equation I come that is equation 69, this is your equation 69 these D j j here put j j is equal to 2, right? Accordingly, it will be your P or what you call that m 2 is equal to 3, it will be Q 3 P P square 3 plus Q square 3 and it is r square 2 plus x square 2.

So, D 2 will be a square 2, minus your r square 2 plus your x square 2 in the P square 3 plus Q square 3, to the power half, right? Therefore, put all these values it is D 2 is equal to minus 0.4670474. When you will do assignment and repeating I am, that we assignment on example, if something is there you will take only up to 3 or 4 decimal not more than that right? Minus this is r 2 square plus x 2 square r 2 square plus x 2 square in per unit I have computed here, I have computed here right? So, substitute and it is your P 3 square plus Q 3 square right? P 3 is given Q 3 is initially given right? So, if you make D 2 will be 0.466633 this is D 2, right? Then V 3 then magnitude of V 3 it will be your D 2 minus A 2 half to the power half, right?

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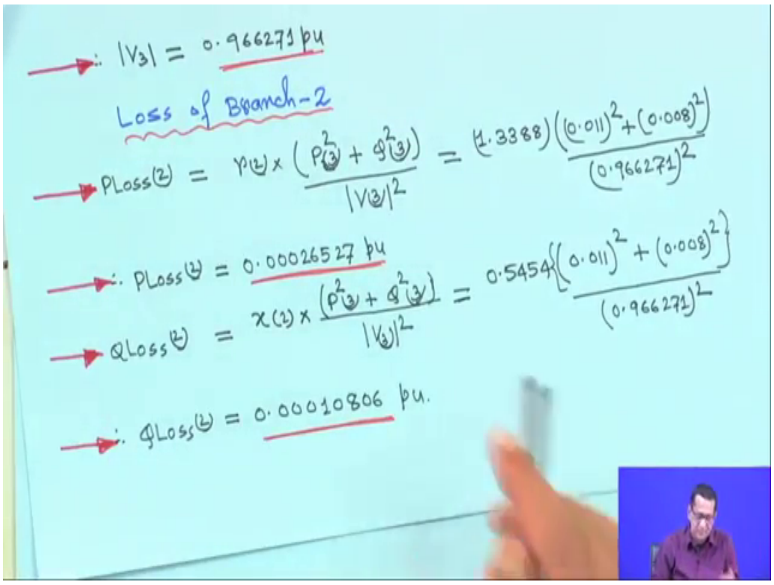

Again, from this, whatever we have computed this voltage equation this is coming, that is I thing it is 66, this is equation 66 from this here it is coming from this equation, right? Therefore, your V 3 will be your D 2 minus A 2 to the power half, substitute 0.466633 minus in bracket minus 0.4670 whatever it is 474 to the power half. So, magnitude of V 3 will be 0.966271 per unit, right? Then will be loss of branch 2.

Thank you we will be right.