Lecture - 35
Load flow of radial distribution networks (Contd.)

Now algorithm for method 2.

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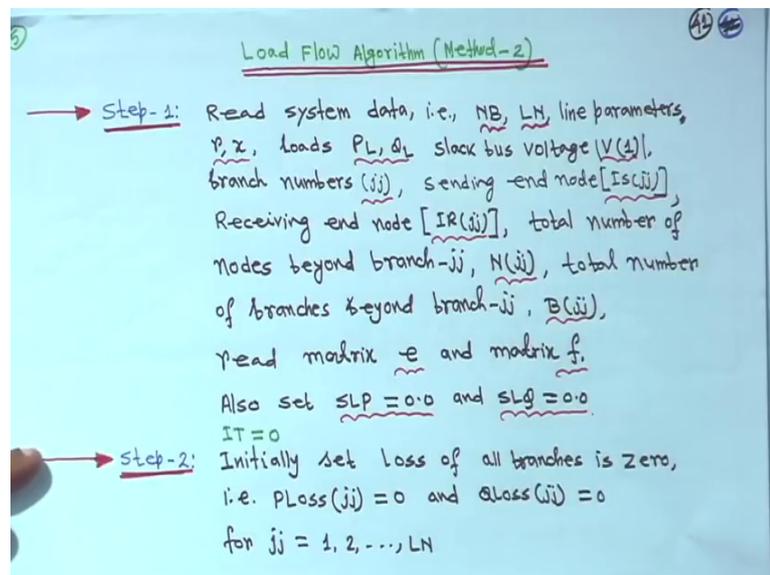
So, I have written everything. For example, when we will please see yourself once. If you get any term I have missed so, please let me know. But these 3 algorithm I have made it for you only. So, first you have to read the system data the NB is the number of nodes total number of node. LN is the number of branch, then line parameters that is your r x, loads PL and QL at every node.

Then slag bus voltage V 1. Your magnitude of course, here angles are not required so, what I can do is, I can make it is a magnitude. The voltage magnitude, and then branch number jj, that table you have to these thing. Sending end receiving end also, sending end node is jj receiving end node IR jj; all tabular form I have given to you. Then total number of nodes beyond branch jj that is N jj I have given. Total N jj also you have to all these things you have to read it in the computer.

You prepare data take any network and do this. And total number of branches given branch jj; that is, B jj also in this case you have to read, in the previous algorithm this was not there. And read matrix e same as V 4, but algorithm matrix f was not there, but you have to read this one also. Also said the total initially total power less is 0 because convergence criteria and SLQ is equal to 0. But when I will take the iteration thing, I have to show only 2 iterations, because not more that.

So, at that time I cannot show you the convergence thing, but you if you do the third iteration; when I will solve it for you at that time I will tell you to do that,. After the second iteration, I will ask you to do the third iteration, when you read this lecture,. So, you said iteration count is equal to 0, it is green; I have written I 2 is equal to 0.

Now step 2 initially set loss of all braches is 0, initially for the second method loss of all branches is 0; that is, P loss jj is equal 2, and Q loss jj is equal to 0. For all branches jj is equal to 1 to LN, LN is the total number of branches.

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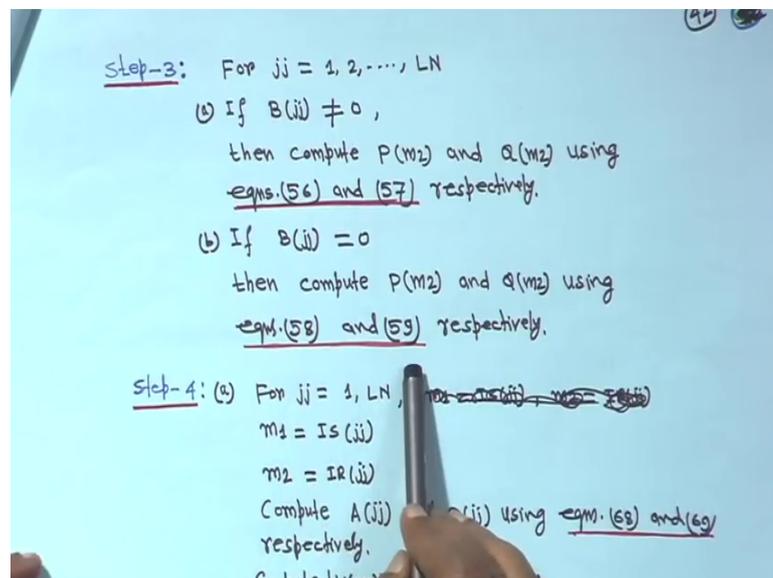
So, step 3 for jj is equal to 1 to LN is the total number of branches, if Bjj not is equal to 0, then compute Pm 2 and Qm 2 using equation 56 and 57 respectively. This is actually loss term you have to include in those branch. These 2 equations I have given. And if Bjj is equal to 0, this is b part, then compute Pm 2 and Qm 2 is using equation 58 and 59 respectively. So, they are also I have given, I am sure I am sure 58 and 59 basically it is a single term.

But sigma term I have written in sigma form, but later next step I have showed that basically this is a single term. First you make it.

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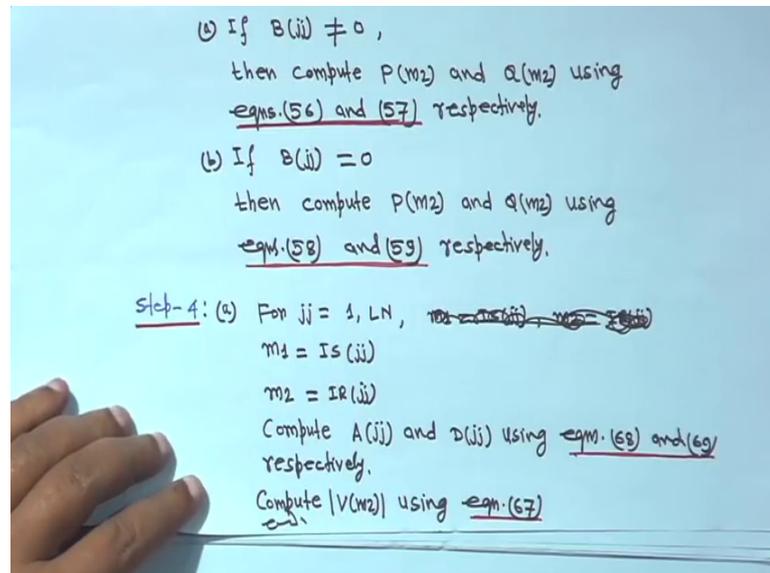
Then step 4, a part for jj is equal to 1 to LN, m 1 is equal to is jj m 2 IS equal toIRjj you compute A jj and D jj, all these expressions are given, using 68 and 69 respectively. One A jj D jj done, then compute Vm 2 you magnitude Vm 2 using equation 67. Then you compute the voltage magnitude, because first these expression given after that these 2 are given. The this loop will be closed end. So, here if you want I can put it some end. So, this is you computation of this A jj D jj for jj is equal to 1 to LN. Then it is b part for jj is equal to 1 to LN.

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When this is down compute P loss jj and Q loss jj using equation 72 and 73 respectively. This is also, your what you call, this is also given. And c part then compute total power loss. So, if sum of the power equation which is not shown, but just are just are written in mathematics form; that compute all the branch power loss is at loss, jj is equal to jj is equal to 1 to LN P loss jj and similarly total Q loss, SP loss means sum P loss, that is why I am making SP loss SQLoss is equal to jj 1 2 LN Q loss jj total reactive power thing. Then initially total loss you said it to 0. So, DP is equal to I am not putting any iteration number algorithm.

Just waiting the step, but it is a understandable. So, difference is absolute of P loss minus SLP and DQ is equal to Q loss minus SLQ absolute you take.

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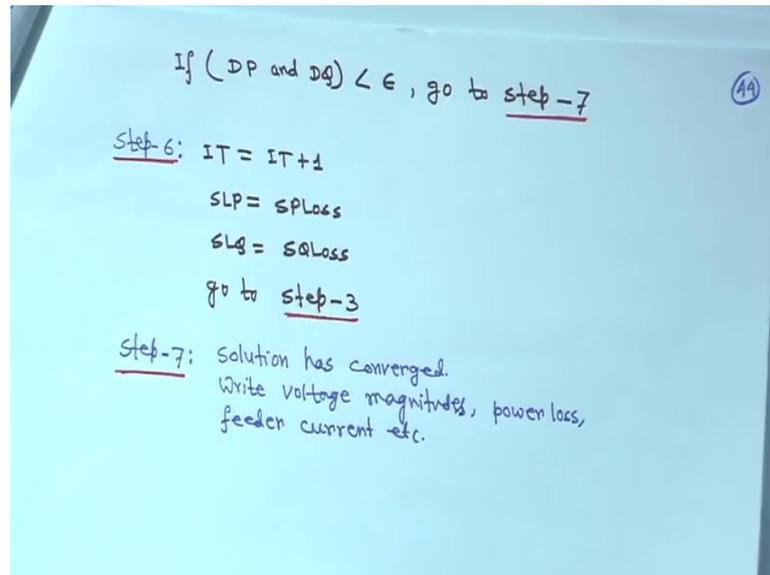
And if both less that epsilon, epsilon some convergence criteria you said, if it is a per unit loss, you can say 10 to the power minus 4 will be sufficient. Or even minus 3 also will be sufficient. Then go to step 7. Then solution has converge write voltage magnitudes power loss etcetera, etcetera. The otherwise increase the iteration count it is equal to 1, you replace SLP is equal to SP loss SLQ is equal to SQLoss, and go to step 3; that means, you come to step 3 here you come. And it will go.

So, if this for this load flow, there is only few steps are there very simple. And for this case for a realistic size of what you call distribution network generally we will found it will converge in hardly 3 to 4 iterations, but note that it is not like a Newton Raphson method that Jacobean and other thing nothing is there actually network is radial that is why it is radiality structure of the network has been exploited to form such algorithms.

But if you want to solve that your the same network radial network is in Newton Raphson method that also can be solve, what recommendation is that is Copper Newton Raphson method. Decouple and first decouple first decouple will be never converge and decouple also that there is no chance that it will converge. Because we will find that this radial network they are very weak this is weak network if one branch is coming may be another branch are a may be another 1 or 2 branch leaving.

So, those things are beyond the scope, but in this course although we will see this method 1 and method 2, but not the Newton Raphson method. So, do not try to solve for this course anything on Newton Raphson method. So, this is the algorithm.

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Now we will take an example first we will take the example of method 1. So, in this case we did not take any lateral branches otherwise in the classroom it is not possible so if you take lateral Branches so number of nodes will be increase and which is very difficult actually time-consuming process, but when we will put the assignment doing this course we will give you some only key for nodes example we will give, but we try to as 1 node an 1 node as a lateral branch 1 branch as a lateral branch.

So, anyway so these examples I have taken that this is for method only method 1 same example we will we solve using the method 2, such that you will know the deeper residue to in these 2 methods. So, this is substation this voltage is V 1 V 2 V 3 V 4 and impedance is Z 1 Z 2, let me tell you one thing where are a V suffix 1 and V bracket one that same thing that when putting in the diagram instead of bracket I making like this such that it will take less place and looks it does not look clumsy. So, this impedance of this this is branch one current is I 1 green colour 1.

This is I 2 capital and this is capital I 3 branch current and this is impedance Z 1 Z 2 and Z 3 branch impedance. And every load is there PL 2 plus j QL 2 so current going through this load is iI 2. PL 3 plus jQL 3 going to current going through this load actually or load

is drawing current iI_3. Similarly, iI_4 that current going to the load is iI_4 as a PL_4 plus jQ_{l4} data, substation voltage is a slag bus. So, V_1 is one angle 0 is taken per unit actually per actually this is you take it is 11 kv feeder and base voltage here are it is a 11 kv feeder you take. So, substation voltage V_1 actually 11 kv real unit and base voltage you take 11 kv and base MVA that is 100. So, sometimes we can you write this one is equal to MVA base, is equal to 100 there here V_1 is equal to 11 by 11 that is 1 per unit.

So, that is why V_1 is equal to 1 angle 0 that is 1 per unit. Z_1 it is given 0.78 plus j 0.45 ohm, this is these are all ohmic value you have to convert it to per unit values. Z_2 is equal to 1.62 plus j 0.66 ohm and j 3 is equal to 2.1 and plus j 0.91 ohm. Loads are given here I have written I thing everything is readable I am reading for you load here PL plus jQL_2 is equal to 400 plus j 3 and it KVA, this is kilowatt this is kilowatt, but when it you combine combination this is you called KVA. So, PL_3 plus jQL_3 is equal to 500 kilowatt plus 400 kilowatt.

So, 500 plus j 400 we consider this KVA and PL_4 plus jQL_4 is equal to 600 plus j 400 KVA. So, these are the load. It is given, but this one is this is actually PL_2 is 400 kilowatt, QL_3 is 500 kilowatt, QL_4 is 600 kilowatt and QL_2 is equal to 300 kilowatt, QL_3 400 kilowatt and QL_4 is 400 kilowatt where that combination is KVA. Base impedance ZB is equal to KVB square by MVA base. So, voltage base is your 11 kv so it is 11 square upon 100. So, base impedance is 1.21 ohm so this impedance you divide by ZB 1.21 you divide. Then it will be converted to per unit first.

Therefore Z 1 is equal to per unit if you make that is your 0.78 plus j 0.4 upon ZB. So, 0.78 plus j 0.4 upon 1.21. So, it is current 0.7442 angle 30 degree. This one you have to make it again r 1 plus j x 1. I did not do it here, but later I have taken this value similarly Z 2 we will get 1.4456 22.16 degree this is given in the own value divided by basin impedance, similarly Z 3 per unit value is equal to 2.1 in plus j 0.9 or often it is 1.96 upon 22.56; that means, your r 1 per unit actually 1.6 to upon 1.21.

Sorry r 2 and h 2 is equal to 0.66 1.21, similarly for r 1 similarly for r 1 x 1 for r 3 x 3. So, this is you impedance per unit conversion than the load. Load is given in K here.

So, you have; that means, first make it to mv a then divide data by 1000. So, it is become 0.4 plus j 0.3 m here. This way you make it then KVA transfer to MVA, and then you divide this thing by base MVA 100 you divide this PL 2 plus jQL there 0.4 was j pointed by 100.

So, it will be 0.004 plus j 0.003 per unit. Similarly, QL 3 plus jQ l 3 is 500 plus j 400 KVA. You can write this one as 0.4 plus j 2 for MVA divide this by 100. So, PL 3 plus j 3 will be 0.005 plus j 0.004 per unit.

Similarly, PL 4 plus jQL 4 is equal to 600 plus j 400 KVA is equal to 0.6 plus j 0.4 that is MVA divided by 100. So, PL 4 plus jQL 4 will be 0.006 plus j 0.004 per unit. Then separately I think separately I have written next PL 2 and QL 2.

Therefore, your PL 2 is equal to PL 2 plus jQL 2 if you write it will be 0.004 plus j 0.003 is equal to 0.005 angle 36.87 degree per unit. So, that because why I am written, they conjugated this one because when we will conclude the load current this PL 2 minus jQL 2 is require.

So, that is why PL 2 minus jQL 2 is 0.005 angle minus 36.87 degree. Similarly, PL 3 plus jQL 3 is equal to 0.005 plus j 0.004 that is equal to 0.0064 and they will 38.66 degree per unit. So, it take the conjugate. So, PL 3 minus jQL 3 will be 0.006 per angle minus 38.66 degree. This conjugate as I am taking because we need to compute the load current. SimilarlySimilarly, PL plus 4 jQL 4 is equal to 0.006 plus j 0.004 is equal to 0.0072 and then 33.69 degree per unit therefore, PL 4 minus jQL 4 is equal to 0.0072 angle it will become minus 33.69 degree per unit. So that means, loads impedance all computating part any time they are conjugate I have taken.

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Now for voltage start so V 2 is equal to V 3 is equal to V 4 is equal to V 1 into 1 angle 0, all about initial voltage of all the nodes we start with 1 angle 0, but ultimately because you have to find out your what you call that initial current at the node 2. So, I 2 will be PL 2 minus jQL 2 upon V 2 conjugated, but node 2 load current at node 2 node 3 and node 4 you have to compute. So, small i 2 is equal to PL 2 minus j equal 2 upon V 2 conjugate.

So, PL 2 minus jQL 2 you got it 0.005 you have computed minus 36.87 degree by 1 angle 0. Conjugate 1 angle 0, 1 angle without conjugate same thing. So, 0 0.005 angle minus 36.87 degree. So, i 2 is equal to actually 0.004 minus j 0.003 per unit this is for load current at node 2. Similarly, at node 3 i 3 is equal to PL 3 minus j equal 3 upon V 3 conjugate so anyway it is a slag voltage starts. So, voltage 1 angle 0 and 0.0064 angle minus 38.66 so that is actually same thing 0.0064 angle minus 38.66 degree.

So, this i 3 is equal to then 0.005 minus j 0.004 per unit, this is load current at node 3. Similarly load current at node 4 small ii 4 QL 4 minus jQL 4 upon V 4 conjugate. So, it is 0 0.0072 angle minus 33.69 degree upon 1 angle 0. So, that is actually 0.0072 angle minus 33.69 degree and that is i 4 is equal to 0.006 minus j 0.004 per unit this is actually what you call that all initial load currents you have computed. I did not put any iteration number as a super script or anything, but iteration one iteration 2 this way you will

proceed, such that things will look you know these things will look better on the what you call in the paper.

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Now current through branch I 1, look at this your just hold on this example look at this example I 1 is equal to i 2 plus i 3 plus i 4 small i 2 plus small i 3 plus small i 4. So, i 1 is equal to i 2 plus I 3 plus i 4. So, this is i 1 this is i 2 this is your sorry this is i 2 this is i 3 and this is i 4. So, some type all it will become 0.015 minus j 0.011 here and not making in bracket. That mean it is same just for the your classroom exercise I made it like this. So, if you read it will become 0.0186 angle minus 36.25 degree per unit,.

Similarly, i 2 current through this branch i 2 is equal to small i 3 plus small i 4. So, i 2 is equal to small i 3 plus small i 4 that is i 3 is this much i 4 is this much previously in previous slide you have computed all. So, if you make it i 2 is equal to ultimately it will come 0.0136 angle minus 36.03 degree per unit,. And last one that is i 3 same current going to the load i 3 is equal to i 4. Because there is no other branches beyond that. So, i 3 is equal to small i 4 is equal to 0.006 minus j is 0.004 is equal to 0.0072 angle minus 33.69 degree,. So, all initial load current then these are all the initial branch currents are also computed.

Now voltage calculation, from this one V 2 is equal to V 1 minus i 1 Z 1 from this first branch. So, V 2 is equal to V 1 minus I 1 zone V 1 1 angle 0 minus I 1, I 1 is this much your the I 1 is this value so put it here into your Z 1, Z 1 we have computed earlier. From

here only Z 1, Z 1 is computed here. Z this is Z 1 this is Z 2 this is Z 3 all have been computed. So, put here Z 1. And you simplify you multiply then simplify then what will happen all I have written here for you can check. V 2 will actually will become 0.98625 plus j 0.0015 is equal to 0.98625 angle 0.087 degree per unit look this angle is small here I put a question to you that you will answer I will not answer, generally when you are solving any transmissions network or these that you will find that voltage angle generally you will having as when in negative it becoming negative.

Distribution case it may happen that it may be negative it may be positive also why this is happening?. why this positive angle is coming? Whatever will be it is very small I told you that is negligible, but why this positive angle is coming? Look the see the problem carefully and then you tell. Data look at the data and from that what you what is your observation and based on that you would tell me the answer, if you write the answer then I will appreciate when will go through this but angle is coming positive 0.087 degree, actually intentionally I have taken like this such that that negative also can come. It depends on the something right so that something is there in the problem. So, you have to answer this. So, I am leaving it for you at the beginning. So, then we will compute again your V 3. So, V 3 actually straight forward V 3 will be when V 2 minus I 2 Z 2.

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So, this, but this V 2 now you have computed. Do not use for voltage calculation do not use that slag voltage us the immediate that voltage which have got now, these voltage

you have got V 2 immediately these V 2 you should use in his expression for current calculation all their flag voltage start require, because you have to calculate the load current without that you have no other way, but when you calculating V 2 this V 2 you put it this V 2 you got it this one you put it here.

So, and minus I 2 is this much already calculated before and Z 2 is this much right. So, multiply and simplify then we will get your after making all simplification I suggest to make all these things then V 3 is equal to we will get 0.96718 angle 0.36 degree. Here also it is positive. Angle is positive it is per unit. Similarly, your V 4 is equal to V 3 minus ij 3 this this V 3 you use that is this values. So, that is 0.96717 plus j 0.0062 minus your I 3 is this much you have computed before 0.0072 angle this one into Z 3 also in per unit you have computed this one multiply and simplify. If you do so then V 4 will become 0.95333 plus j 0.00892 so 0.95334 angle 0.53 degree.

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. So, this is V 4 after fist iteration; that means after first iteration these are my 1 voltage V 2 is equal to this one V 3 is equal to this one and V 4 this one.

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Using these voltage now we will compute the new value of the load current in the second iteration, in the second iteration now using this voltage, now you compute i 2 is equal to PL 2 minus jQL 2 by V 2 conjugate these values unchanged PL 2 QL 2 will be unchanged.

Then V 2 will be change. So, it is your V 2 is this much it is conjugate will be minus 0.087 degree I have taken that and after simplification. After this one we get is equal to this one you write and then you get 0.00406 minus j 0.003035 per unit this is i 2 in the second iteration.

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Then i 3 is equal to you PL 3 minus jQL 3 upon V 3 conjugate this V 3 you use so it is 0.0064 angle minus 38.66 degree divided by 0.96718 angle minus 0.36 degree it will simplify it will it is the thing and then if we make that a real and imaginary part i 3 is equal to 0.005192 it minus j 0.004101 per unit. Similarly, i 4 is equal to PL 4 minus jQL 4 upon V 4 conjugate, these voltage you use. If you do so, it is coming this one this is already known. So, divided by this V 4 conjugate 0.95334 angle minus 0.53 degree is equal to this much take it this value in i so it will be 0.006322 minus j 0.00413 per unit. So, initial load currents are computed a second iteration with this load current now you compute the branch current.

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So, I 1 capital I 1 is equal to small i 2 plus small i 3 plus small this you already you have computed just now. You substitute on and then you add it up it will become actually I 1 capital I 1 is equal to 0.01922 angle minus 35.88 degree per unit. Similarly, I 2 is equal to. i 3 plus i 4 right. So, this is your what you call i 2. So, i 3 and i 4 you substitute and simplify it will become 0.01415 angle minus 35.55 degree. So, and last one I 3 is as a last node. So, I told you earlier I 3 will be simply is equal to i 4 it is 0 0.007552. And then this one so, and all these capital I in the second iteration you got it.

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With this the voltage calculation you have to proceed. So, voltage calculation for second iteration V 2 is equal to V 1 minus I 1 Z 1 V 1 voltage was known to assist slag bus voltage 1 angle 0. I 1 is this much you are computed and Z 1 already known to us. So, multiply and simplify. You will get V 2 is equal to just you do it yourself hope all these calculations are correct, but from my side I have to tell you it is see once. Hope I have made all these collection correction because all these your what you call all these things have been solved by me only. So, if there is any error you calculation error anything you just let me know and if you find anything I appreciated that.

So, then V 2 is equal to 0.98578 angle 0.085 degree, similarly V 3 is equal to V 2 minus I 2 Z 2 already you know that circuit diagram. So, V 2 is this much this V 2 you use here minus I 2 already we have this much. 0.01415 angle minus 35.55 degree into this is the impedance. That is the Z 2 it is already we have computed. So, it simplify you will get V 3 is equal to 0.965882 plus j 0.0062019 and or V 3 is equal to 0.96590 angle 0.36 degree.

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Next is that V 4.

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So, V 4 is equal to again V 3 minus I 3 Z 3 this V 4 V 3 as now we have got it, right in the previous page I have shown you minus

This is I 3 into this is Z 3. So, you just multiply and simplify. You will get V 4 is equal to 0.951 triple 3 plus j 0.089247. So, V 4 is equal to 0.95137 angle 0.5 degree. So, after second iteration this is my voltage magnitude. It is 0.98578 0.96590 0.95137. What I suggest I have done up to second iteration. So, in the class room this is sufficient I will request you please do one more iteration third iteration because after 2 iteration generally in this method solution does not converge generally convergence I cannot show you here because only 2 iterations have there you make 3 iterations.

So, you see the difference of the losses total losses how you will calculate the total losses I will tell you something here. That how to calculate losses, this power loss after second iteration.

faster I will explain it here suppose you have a network radial network.
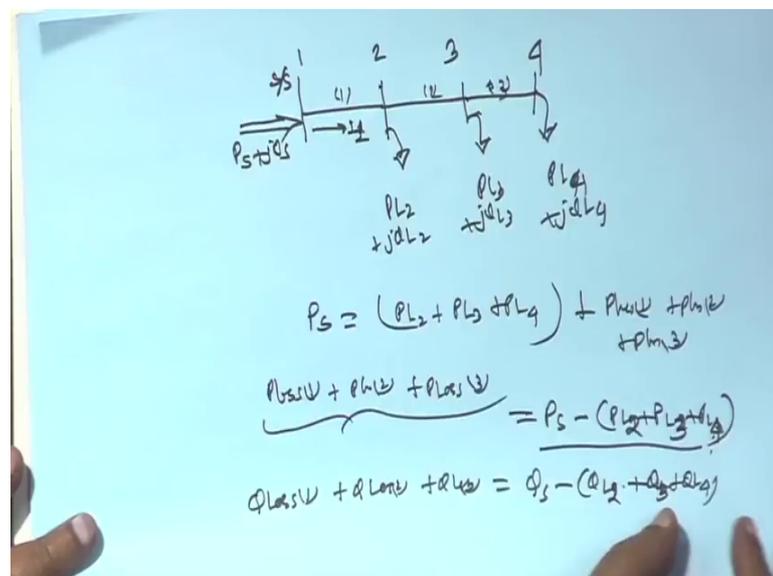
So, it is a network. It is a radial network you have taken 4 node example 1 2 3 4, 4 node example we have taken everywhere loads are there I am not showing anything loads are there loads are there this is your PL 2 was jQL 2 this is PL 3 plus jQL 3 this is PL 4 plus j QL 4. And this is substation this is substation.

And power is being injected here, power is being injected here. This is your Ps plus jQs this is come this power which coming from the grid and going to the distribution

network, this is substation earlier we have explain everything and these are the branches these are the 3 branches are there 1 2 3, then what is the power injected to this substation it will be actually it will be total load plus the loss; that means, Ps is equal to your PL 2 plus PL 3, plus PL 4 this is the power injected. This substation this is the load it because it will be loss also; that means, P loss branch 1 plus P loss branch 2 plus P loss branch 3 this is the power incoming power from the substation.

Similarly, that means, your total loss P loss 1 plus P loss 2 plus P loss 3 that is the total loss of the network, right is equal to your Ps minus subtract all the loads PL 2 plus PL 3 that will close so total loss will be Ps minus this thing similarly for reactive also Q loss 1 plus Q loss 2 same thing Q loss 3 because substation I have to supply total reactive load plus reactive loss. So, Q loss 3 is equal to Qs minus QL 1 plus sorry it is actually QL 2 QL 3 it is 4 actually 2 3 4 sorry it is 2 3 4. So, here I have written.

So, it is Ps minus PL 2 plus PL 3 plus PL 4 then it is Qs then QL 2 then QL 3 then your QL 4; that means, whatever injected power subtract the load that is your total loss this thing is understandable. So, how to calculate how to compute this from this diagram only you will write from this diagram. So, current flowing through this branch is say I 1 this is I 1.

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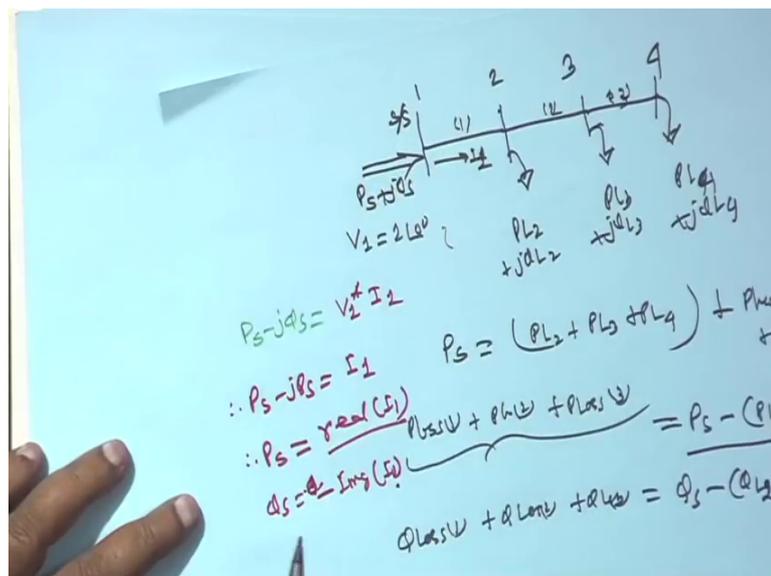
Therefore, what you will do this is substation voltage V 1 is general if it is different does not matter it is 1 angle 0. If it is 1 angle 0; that means, you can write that power injection

Ps minus jQs is equal to, is equal to your V 1 conjugate then this I 1 this is the current in this branch capital I 1, I 1. V 1 with 1 angle 0 so; that means, conjugate is also 1; that means, Ps minus jQs is equal to actually I 1 right; that means Ps it is in per unit; that means, substation power Ps is equal to a real part of I 1. And substation power Qs is equal to your minus imaginary. I 1 because minus sign is there that is why you take Qs is equal to minus imaginary of I 1. Whatever it will come multiplied by this corresponding base value and everything you will get a real quantity is the power injected from the substation. Then what will be the loss if you have so many nodes and these thing therefore, your total P loss

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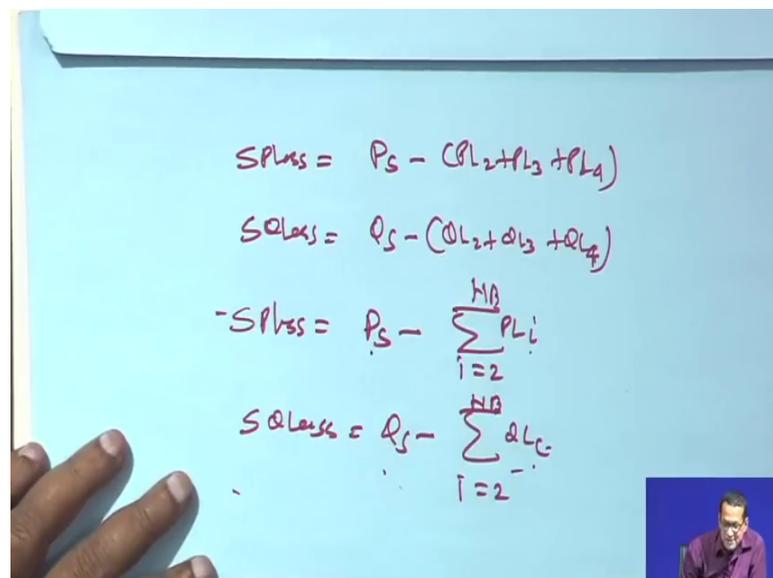
SP loss will be is equal to Ps minus PL 2 plus PL 3 plus PL 4. Similarly, SQLoss will be your Qs minus your QL 2 plus QL 3 plus QL 4. This is small letter in general SP loss is equal to power injected at the substation Ps minus suppose your N number of nodes. So, i is equal to 2 to NB we can make PLi similarly S total Q loss will be is equal to Qs minus you i is equal to 2 to NB the QLi injected power minus the total reactive load injected power real power minus total real load, real load is equal to this P loss Q loss. This way we can calculate the your what you call the substation your power loss. I first substation injected power then power loss of course, another thing is there that every branch

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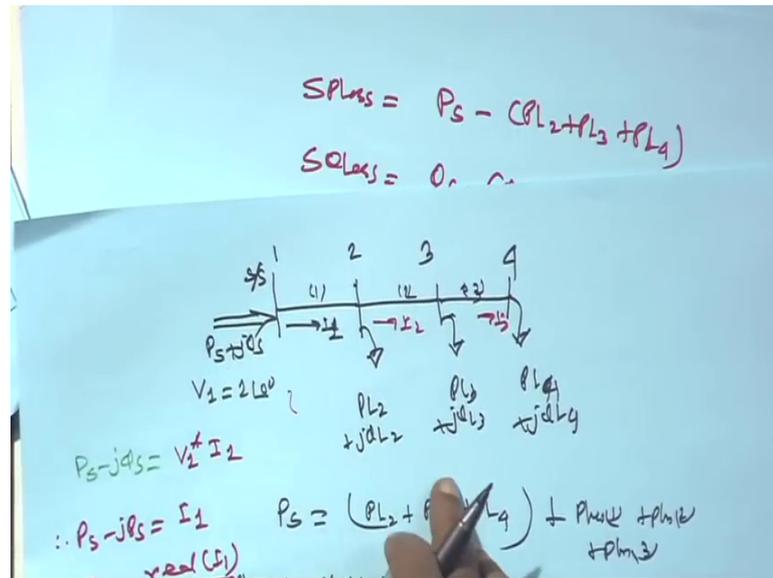
r 1 x 1 r 2 x 2 Z that is I here it is current I 1 that is I 2 here it is a I 3. So, I 1 square r 1 plus I 2 square r 2 plus I 3 square 3 that is also value and this one also value, but this one is the ijs 2 i think i think you have to appreciate that this is the easiest one.

Thank you again we will be back.