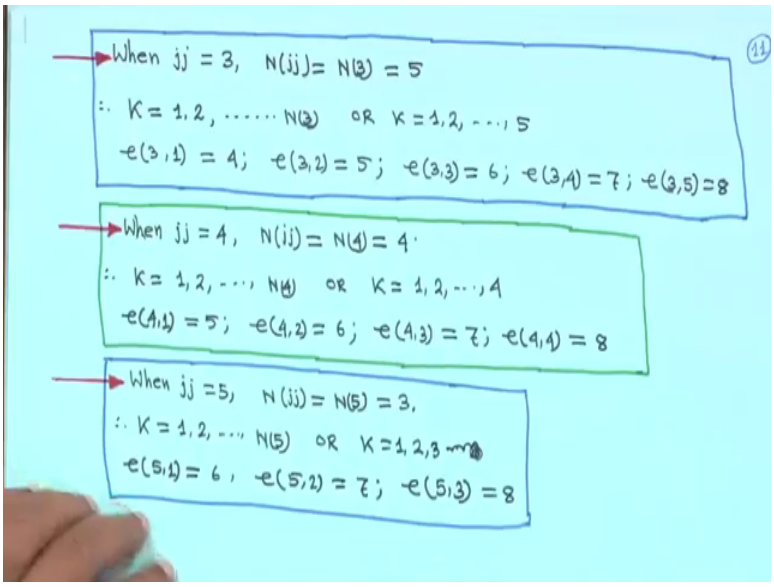
Power System Engineering
Prof. Debapriya Das
Department of Electrical Engineering
Indian Institute of Technology, Kharagpur

Lecture - 31
Load flow of radial distribution networks (Contd.)

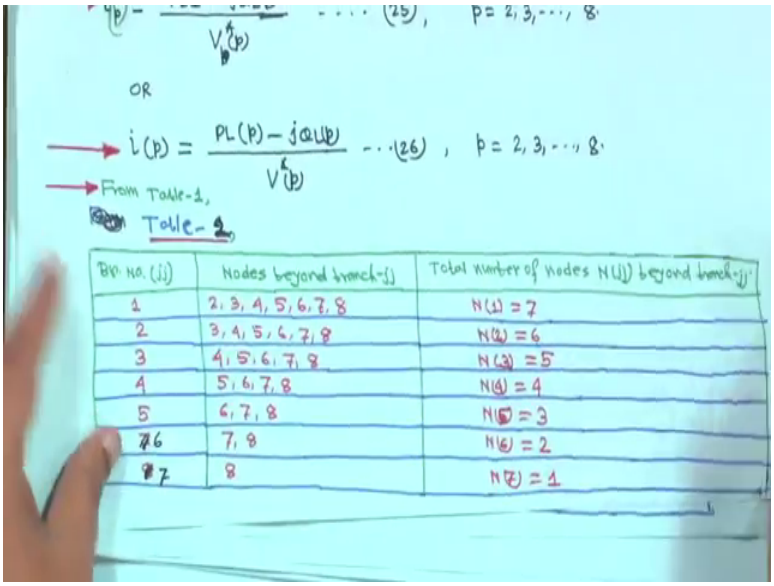
Now look for your understanding each and everything, I have make it; such that you will not face any problem right.

(Refer Slide Time: 00:18)



When jj is equal to 3, N jj is equal to N 3 is equal to 5.

(Refer Slide Time: 00:26)

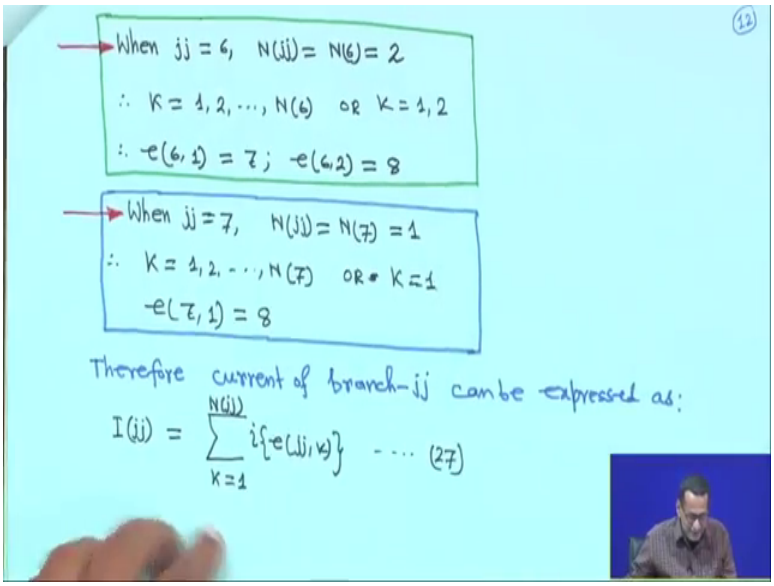


Look at this table when jj is equal to 3, N jj N 3 is equal to 5, because you have 5 nodes 4,5,6,7,8. So, e 3 1 will be 4, e 3 2 will be 5, e 3 3 will be 6, e 3 4 will be 7, and e 3 5 will be 8, look your when jj is equal to 3, N jj N 3 is equal to N, 3 is equal to 5, then your K is varying 1 2 up to N 3, that is or K is equal to 1 2 up to 5 therefore, e 3 1 is equal to 4, e 3 2 is equal to 5, e 3 3 is equal to 6, e 3 4 is equal to 7, e 3 5 is equal to 8.

Similarly, when jj is equal to 4, when branch 4 jj is equal to 4, N 4 N jj is equal to N 4 is equal to 4, and nodes are 5, 6, 7, 8 therefore, e 4 1 will be 5, e 4 2 will be 6, e 4 3 will be 7, and e 4 8 sorry e 4 4 will be 8, right therefore, when jj is equal to 4, N jj is equal to N 4 is equal to 4. So, K is equal to 1 2 up to N 4, or K is equal to 1 to 4; that means, e 4 1 is equal to 5, e 4 2 is equal to 6, e 4 3 is equal to 7, e 4 4 is equal to 8 right.

Similarly, when jj is equal to 5 N jj is equal to N 5 is equal to 3. So, when jj is equal to 5 N j j this is N 5 is equal to 3, and you have that is your jj is equal to 5. So, e 5 1 is equal to 6, e 5 2 is equal to 7, e 5 3 is equal to 8; that means, your K is equal to 1 to N 5, N 5 is equal to 1 2 3 only 3 elements right therefore, e 5 1 6, e 5 2 is equal to 7, e 5 3 is equal to 8 right.

(Refer Slide Time: 02:14)



Similarly, everything I have made for you such that there would not be any confusion, when jj is equal to 6, then N j j is equal to N 6 is equal to 2; that means, K is equal to 1 to N 6 a general 1, or K is equal to just 2 element 1 to 2; that means, when jj is equal to 6; N 6 is equal to 2 and 2 element 6 1 is equal to 7, e 6 1 is equal to 7, and this 1 actually 6 2 is equal to 8 right.

And similarly, last one when jj is equal to 7, N jj is equal to N 7 is equal to 1, when last 7 when jj is equal to 7, N 7 is equal to 1 and only 1 node. So, 7 1 is equal to 8 right; that means, e 7 1 is; that means, this is actually is your e jj K matrix, this we have to read it into the computer right, I am not writing again separately for you, this is actually e jj K matrix, this nodes beyond run jj this data you have to feed it to the computer, this we have to read right 2,3,4, here it is main figure that is why it is very simple.

But when we arbitrary node also it will work, you take in between a total node is 8, but you take any number of node you can easily identify, looking at that you have to just make those advance numbers sending end node, receiving end node, total number of nodes, beyond branch jj and total number of nodes right, your number of nodes your node count beyond branch jj and total number of nodes right. So, this is your e jj K matrix this data you have to read in the computer right.

So, according to the diagram, whatever you will be plot, but here you should not make any mistake, there is no chance of mistake if you have the diagram you can easily make

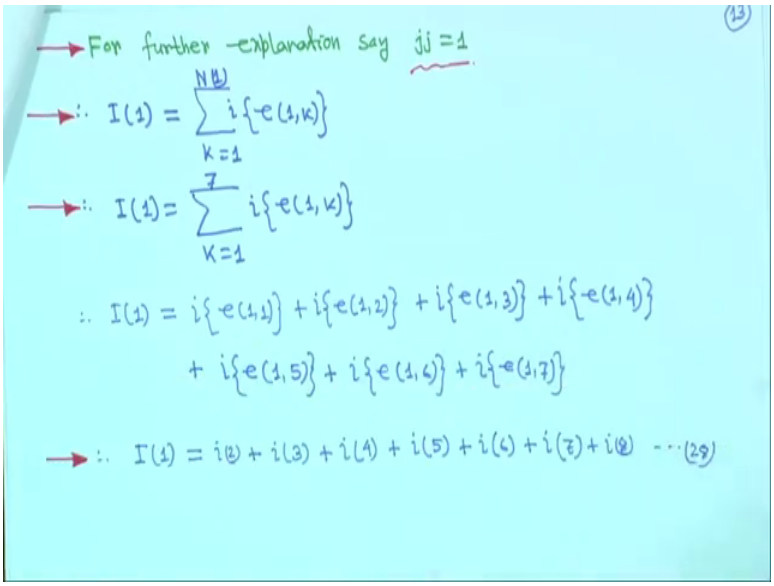
like this the way I told you right. So, there is no chance for me any mistake any mistake right therefore, that current of branch jj can be expressed as like this, therefore that branch current jj, ijj it is a generalized form look, how we are writing ijj capital I jj is equal to sigma, K is equal to 1 to N jj in bracket we are putting that matrix element ejj K this is equation 27.

Now, how it will work how; that means, for branch; that means, for branch 1 branch 2, from this expression everything will be computed because these ejj K matrix as long as you are reading it into the computer, you are feeding it into the computer as a data, all these things you have to put it in a data right.

So, generally the branch current these things are very simple actually, little bit if you are look at the mathematics and little bit coding if you know these things are very simple actually. So, K is equal to 1 to N jj, but let me let me tell you one thing in the exam purpose you will be given only calculator a hand cals calculation, no question of coding, but if you if anybody when reading this thing this data numerical will be solve if anybody write codes, and get the solution, I will appreciate you like anything right very simple it is.

So, the therefore, your current of branch jj right, current of branch jj can be expressed by this expression, this sigma I j j capital is equal to K is equal to capital I jj is equal to, sigma K is equal to 1 to N jj, i small i in bracket it is e jj K matrix, this is given now why we have given this loop ; that means, once e matrix is read, and initial values of i is are computed I told you how to come to in voltages are known, then automatically branch current from these simple mathematics can easily be computed right.

(Refer Slide Time: 05:48)



How it will be done, for further explanation I have made it again right, for say jj is equal to 1 we have seen know then jj is equal to 1, means from this equation 27 jj is equal to 1 means i 1 capital I 1 is equal to K is equal to 1 to N 1, then i small i in bracket e 1 K right; that means, at N 1 we have seen 7, from this table N 1 is given 7, N 1 is 7 right, you put N 1 here is equal to 7, and this matrix so, in jj is equal to 1, this matrix will be this is for branch 1, jj is equal to 1 that is matrix will be e 1 K, and this matrix already we have read in the computer, these are the data this data is known right.

Actually our turn nowadays, so many your languages are available for writing code, right many software packages are available, but I am having old when our time we used to write code in Fortran 77, later Fortran 95 right, and those things till date now my age is there, but till date I know those coding your thing how to make it right, but anyway question is that, if you write the code nowadays so many languages are available right c, c plus plus, c sharp, right.

So many things are there, but you have write c plus, then c plus plus, then c sharp, many other languages are also available, now when you want right whatever it is, but you have to give anywhere this data first you have to read this data right, and data reading also a very simple thing nowadays, whatever I saw my student they writing code when they are running in front of me using laptop, right things are very simple now coding nowadays

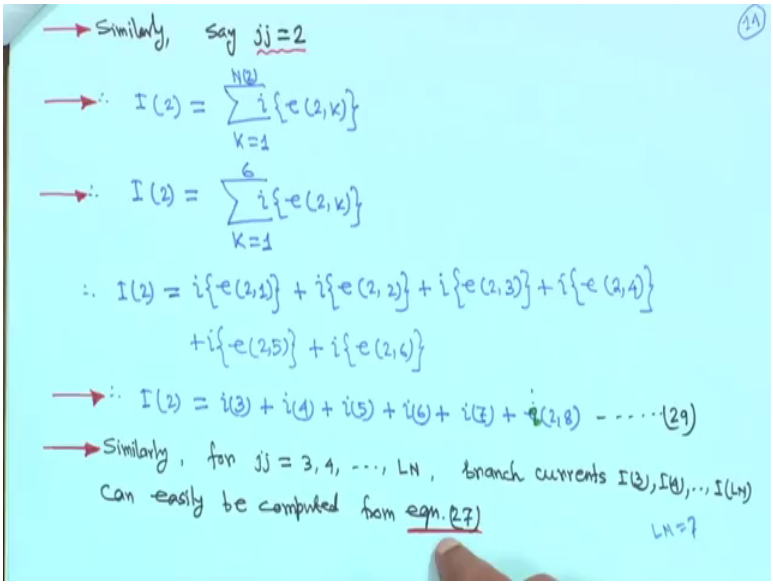
has become very simple, only you have to learn 2 different things, like and c, c plus plus, where c sharp, but students always tell me the c sharp is very good right.

Anyway, the way you want, if you write a any coding or anything on that, and if you send me the result by email rather than footing in forum by email, I will really appreciate that right.

So now that that mean K is equal to varying 1 to 7, right now; that means, capital I 1 is equal to that first I am for you want to clear your clarification, I am writing I in bracket I writing e 1 1 plus because, i jj is equal to 1 and K is varying 1 to 7. So, ie 1 2, plus ie 1 3, plus ie 1 4, plus ie 1 5, plus ie 1 6, plus ie 1 7, this way I am writing breaking then, that e 1 1, this data you have read in the computer. So, e 1 1 is equal to 2, e 1 2 is equal to 3, e 1 4 is equal to 4, e 1 5 is equal to e 1 4, is equal to 5, e 1 5 is equal to 6, e 1 6 is equal to 7, and e 1 7 is equal to 8; that means, if you put it capital I 1 is equal to i 2 plus, i 3 plus, i 4 plus, i 5 plus, i 6 plus, i 7 plus, i 8 it is coming you know from this simple expression right.

So, for this one simply you can put it into the code right, for jj i mean if you put in a 2 for loop, that is all for jj is equal to 1 to l n, and for K is equal to 1 to jj, solve ijj at the ln that is all automatically it will take right, because already e matrix already read in the computer. So, automatic it will take right.

(Refer Slide Time: 09:33)

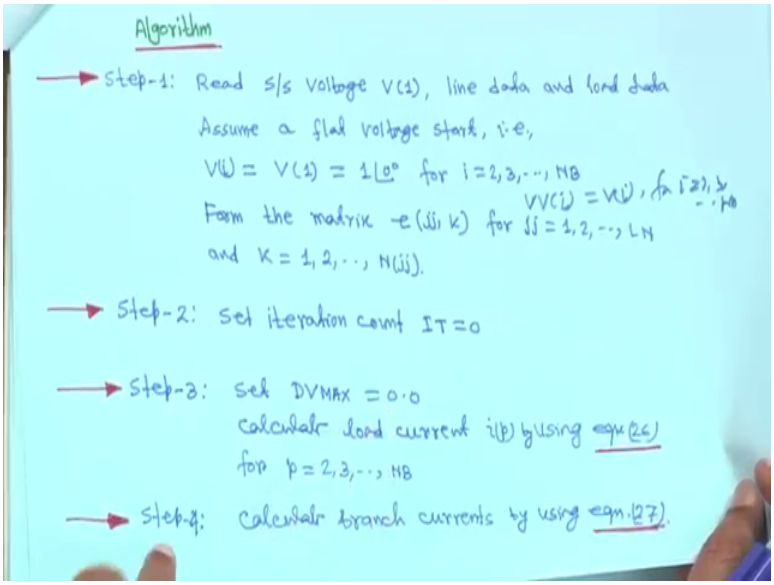


So, similarly for i 2 for everything I have written for you, such that you should understand this right. So, so jj is equal to 2 i 2 is equal to K is equal to N 2 ie 2 K right so; that means, K N 2 is equal to 6 we have seen right, and K is equal to 1 ie 2 K, because jj is K it is 2 K, and now K is varying from 1 to 6. So, capital I 2 is equal to ie 2 1, plus ie to 2 the plus ie 2 3 plus, ie 2 4, plus ie 2 5, plus ie 2 6. So, e 2 1 all this data read it is 3,4,5,6,7,8, all this data read in the computer therefore, i 2 is equal to i 3, plus i 4, plus i 5, plus i 6, plus i 7, plus it is when it is e matrix you know, it is I actually it is i 2 8, right it is i right therefore, this is equation say 29.

Similarly, for jj is equal to 3 4 up to your total number of branches, ln is total number of branches, right branch currents i 3 i 4 up to iln, in this case it is 7, ln is 7 in this case our case our case it is a node num total node is 8. So, branch number this ln our case it is a l our case it is 7 right therefore, can easily be computed from equation 27, I mean from this equation you can do whatever equation we have made right, from this equation you can calculate for other branches also right.

So, branch currents calculation is shown, that how to do this of course, if initial values of i 3 are known and I showed you how to compute initial values of your what you call that your i right.

(Refer Slide Time: 11:09)



Now what I will do 2 algorithms will explain, this is the first one, now look whatever I have explain that is the algorithm, then I will take lateral branches, but question is

question is that that examples after explaining 2 different methods, then I will take couple of examples for solving here, then we will come to the voltage stability part.

So, algorithm is first in step 1 reads, it is substation voltage, that is V 1, line data and that is r x values, and load data that is pl ql right, assume a flat voltage start that is V i is equal to V 1 is equal to 1 angle 0 say for i is equal to 2 3 nb is the total number of nodes right, this is substation voltage line determines nodes branch everything will come here, in the line data right.

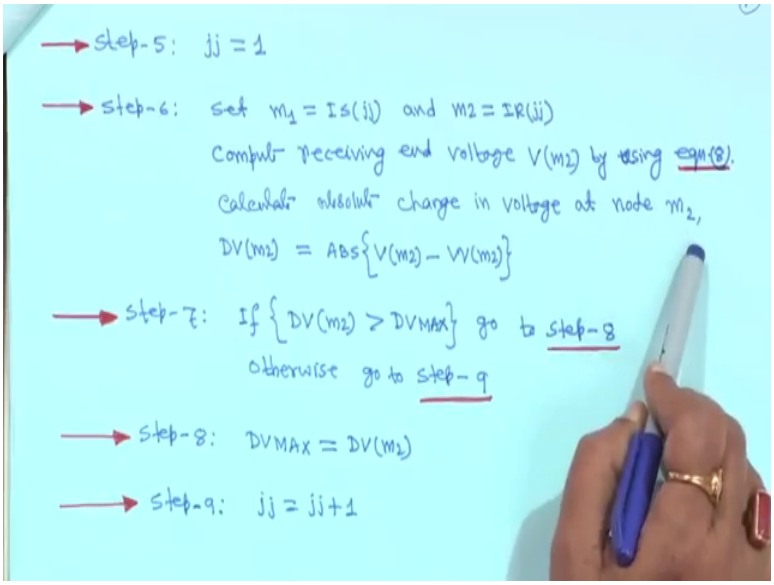
Now, from the matrix you form the matrix e jj K for j j is equal to 1 to ln, and then K is equal to 1 to N jj; that means, this data you please read into the computer from the matrix this after making this table, you please read this data right. So, this 1 actually instead of reading I have made it from the matrix. So, form from the matrix I read it in the computer, 4 jj is equal to 1 to ln, and K is equal to 1 to up to N jj. So, N jj I means read line data means branch number sending end node, the receiving end node, total number of nodes beyond branch j j N j j, all these things you have to read write everything, whatever have been given in the table all this data after that, you read e matrix I have written form the matrix, but read e matrix for this 1, these all these things you have to given as a data right.

Here in the program also you can convert it to per unit system, but here if data we assume in per unit, but when we will take the numericals, we will show you, that how to convert into the per unit values right, now you say sita set iteration count say it is equal to 0, instead of 1, I making say it is equal to iteration 0, then dv max that is voltage difference maximum is 0, calculate load current ip by using equation 26, for p is equal to 2 3 nb. So, let me go to equation 26, this is equal equation 26 right, for p is equal to 2 3 here I am writing 8, because 8 nodes we have taken in general you have nb number of nodes. So, find out that load current ip plp because, pl ql known initial values of V is are known because here it is flat voltage start right. So, that is a really initial values of load current. So, you can compute in per unit.

So, that is why calculate your first ip using equation 26, after that you calculate branch current by using equation 27, then once it is done, then you calculate the branch current whatever your we have shown, that your ijj is equal to sigma right your what you call that I is equal to 1 to N j K is equal to 1 to N jj small i ej j K right. So, equation 27, that

branch current equation you have given, there you use 2 for loop for calculate this branch current directly you are getting it right.

(Refer Slide Time: 14:31)



So, once it is done branch current is done, then this voltage i have shown you how to calculate voltage magnitude, set m 1 is equal I have told you that only 1 for loop is required. So, set m 1 is equal to is jj, put jj is equal to 1 right is jj and m 2 is equal to ir jj right, and calc compute receiving end voltage V m 2 by using equation 8, this is given calculate the absolute change in voltage at node m 2 receiving end voltage, for your what you call your m 2 is equal to ir jj.

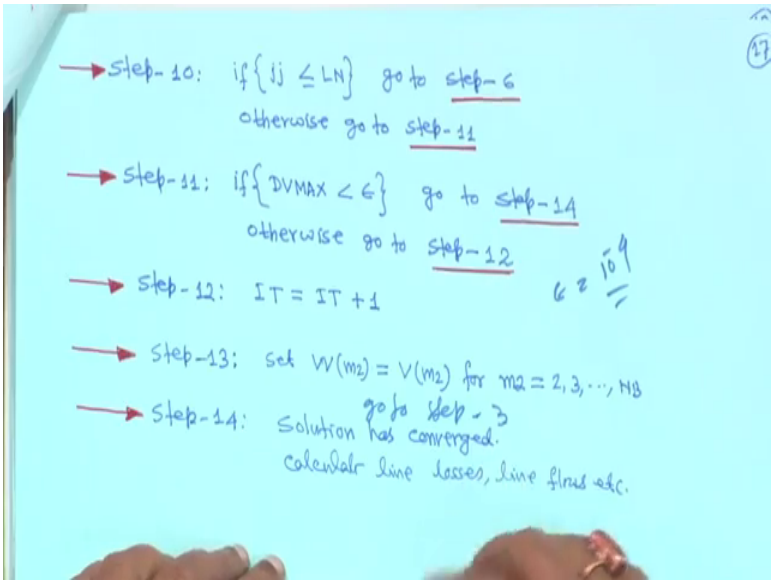
So, Dv max that is Dvm 2 right absolute, vm 2 minus VVm 2 right. So, what will do this VVm 2, actually it is not given here initially. So, initially when you assume all these things, initial values. So, here once you make then here you can I am writing here I for I missed it actually, here you put some VV your I right, you take magnitude because here we are not magnitude mag we are taking absolutely no need, VVi is equal to vi you take right, for i is equal to 2 3 up to N b that also you make it, because these initial values. So, I am taking your vm 2 minus VVm 2, after that this VVm 2 will be replaced by V m 2 right.

So, one this is done now you check, if Dvm 2 greater than Dv max or not because initially we have set some Dv max is 0, if it is if it is your Dv max to get at the e 1 go to step 8, you put Dv max is equal to Dv m 2, otherwise go to step 9, that is increment

branch number jj is equal to jj plus 1 right, they have starting from jj is equal to 1, you increment jj is equal to jj plus 1, right and initially every time we are trying to find out what is the Dv max value, all though initial value of Dv max you can set it to 0 we have set it to 0 right.

And then what you call then increase in your increase jj is equal to jj plus 1, right then if jj as long as jj less than equal to ln the total number of branches, you come to step 6 because step 6 again you have to for jj is equal to 3 it will be computed, conclude step 6 right. So, it is go to a step 6.

(Refer Slide Time: 16:45)



Otherwise go jump to step 11, right in the step 11 because every time going to it is computing Dv max right, same as a gauss seidel method you take a max of voltage difference.

So, here also same thing we are doing right. So, i that there is if Dv max less than epsilon, go to step 14 here solution has converged, otherwise you go to step 12, step 12 iteration count i t is equal to i t plus 1 right, and again set your step 13 you set VVm 2 is equal to vm 2, initially we have assumed this one is this one, but now you have to set VVm 2 is equ for m 2 is equal to 2 3 up to nb number of nodes.

Then your what you call you are then step 12, i 2 is equal to i t plus 1, and if solution has converged is said this one, and here also when you are setting VV is equal to your this

thing VV m 2, then after that immediately will not come I am missed one, it is go to your step you have at from where we were starting your computing this thing step 3 right. So, again you come to your step 3.

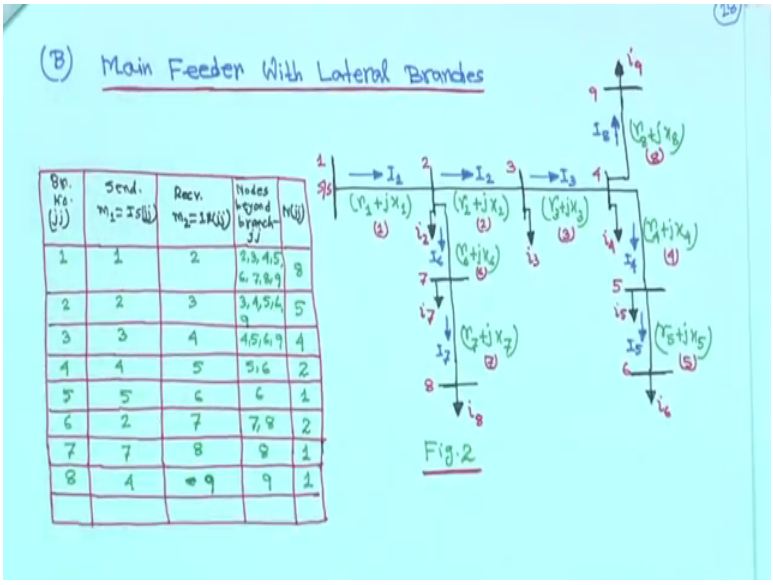
So, this way and the otherwise it will because iteration count is starting from what you call from here, but ultimately you have to again come to step 3, because again initially we will start Dv max is equal to 0, I miss this one, but I will retelling it right. So, step 4 please it is less than epsilon, epsilon will be some value say 10 to the power minus 4, this value set and then solution will converged right.

So, this is actually your what you call algorithm. So, till now look there is no first thing is here there, is no derivative involved as your these things happen for your what you call for newton raphson load flow method right, no derive deriva derivative is there right, and it is straightforward only that you are exploiting the radiality of the network that we are doing it, and the second thing is that if you use for distribution load flow, you have to go for couple newton raphson method for solving such things right.

For distribution system generally decoupled or first decoupled flow, it does not converge actually, it most of the cases it diverges, but if you use couple newton raphson method they need converges right, but you have to news you need to know, that you have to evaluate that pool Jacobean matrix is required, the coupled newton raphson method, but here there is no newton raphson method nothing is there, it is simply basically backward forward type right, and you can easily, easily solve this network just network ah you know exploiting the radials characteristic of the network right. So, things are very simple, nothing is there actually and classroom purpose when I will solve this we will find it is much easier, and hope you have understood up to this, for main feeder case for main feeder case right.

Now, next you would because we have to generalize it. So, that is why main feeder case you have find easy, everything this same algorithm is applicable for the generalized case also. So, for generalized case also algorithm will not be given, these are same algorithm we will do this, right same algorithm, but let us see now that generalized case right.

(Refer Slide Time: 20:17)



Now, the as it is a classroom type of thing so, I cannot take a very large distribution network, but here I have taken a 9-node distribution network right. So, this is a substation right, 2 lateral branches have been taken listen this, whatever way we have explained the thing this numbering of the nodes are arbitrary.

Whatever way whatever way you are number the node, your e matrix automatically will be form from your formation of the node automatically. So, this node there is no systematic way of node numbering, you just what you would put any number the way you want to you put it, right in between 1 to 9 after suppose this is 1,2,3,4, I make it this is 1 9 this may be 2, this may be 5, and this may be your 4, the way I want it does not matter. So, the way you want you can number, it is not a problem, just try to maintain the number should be in between 1 to 9, after that wherever you put those number it does not matter because you have a 9 node right.

So, there is no only thing is that connectivity according to connectivity, you up to form this e matrix e matrix is important right. So now, this is substation this is your 9-node problem. So, this 1,2,3,4,5,6 actually this is actually 1,2,6 actually say if it is called it is a main feeder, we have from to another lateral branch only 2 loads are there in the lateral branches because, this is the classroom exercise I cannot take very big network and cannot give one, then it will be it is it would then it will be very clumsy, and another lateral is there whose node is only, only one branch is there, right and this is instead of 8 node, this is 9 node I have taken such that your understandable easier.

So, this is branch 1 all red mark in the bracket these are branch number 1,2,3,4,5, this is your 5, then branch this is branch 6, this is actually branch 6, I have written here, this is branch 7, and this is branch 8 right, branch sampling also the way you mark the way you give the node, the way will give the branch number automatically we will proceed right, but to avoid the confusion because when you generate the data in computer you will see in serial number 1,2,3,4 like this. So, better you can you better you put that your branch number accordingly right.

So; that means, this is green color these are all impedance, z 1, z 2 that is r 1 plus jx 1 r 2 plus jx 2, these are all impedances everywhere load is given look here, i 2 load is there pl 2 plus jq l 2, but not. So, on here then figure will be very clumsy right, but you from main feeder case we have shown it is, here it is i 3 means pl 3 plus jql 3 load is there, similarly i 4 pl 4 plus jql 4 load is there. So, everywhere for i 9 pl 9 plus jql 9 load is there. So, everywhere load is there right, but not shown, but i just in the main feeder case everything is shown, right and branch according to branch current also suffix i 1, but when you write the your mathematics form then it will be in bracket right.

So now with this you make this table first. So, this is branch number, you have total node 9. So, you have 8 branches 1,2,3,4,5,6,7,8, then sending a node this is in short i have made because space problem here on this page, though these said means sending a node m 1 is equal to is jj receiving a node m 2 is equal to i r jj, nodes beyond branch jj these are the nodes beyond in branch jj and N jj, total number of nodes beyond branches a look how it is, you considered branch 1 this is a branch jj is equal to 1 branch 1 sending end is 1, receiving end is 2, how many nodes are there beyond this branch, 2,3, I mean I am just counting 1,2,3,4,5, this is 6, this is 7, this is 8, beyond this branch 8 nodes are there. So, it is I am putting 8 and what are those nodes 2,3,4,5,6, 2,3,4,5,6,7,8 7,8 and 9, these are the node 2,3,4,5,6,7,8,9, this is the node beyond branch 1 right.

Now, next is nodes beyond branch 2 this node, as soon as you are coming to branch 2 these are actually back, these you need not look back right you have to look the forward side right. So, beyond branch 2 whatever the nodes look, 3,4,5,6 and 9, that is why I have taken lateral branches. So, generalized 3,4,5, beyond this branch these are the node. So, it is 3,4,5,6,9. So, 5 nodes are there that is why N jj that is N 2 is equal to 5 right, next you come to branch 3 branch 3 how many nodes are there, 1,2,3 that is 4,5,6 and 9. So, 4,5,6

and 9, these are the 4 nodes, and total your total node is 4, because 1,2,3 and this is 4. So, this is 4 right.

Similarly, if you come to branch 4; that means, this branch, if you come to this branch right, if you come to this branch, then that total number of beyond this branch is 2 because 5 and 6. So, come to branch 4, the total number here this is 2, and which are those nodes 5 and 6. So, this is 5 and 6 these are the nodes right.

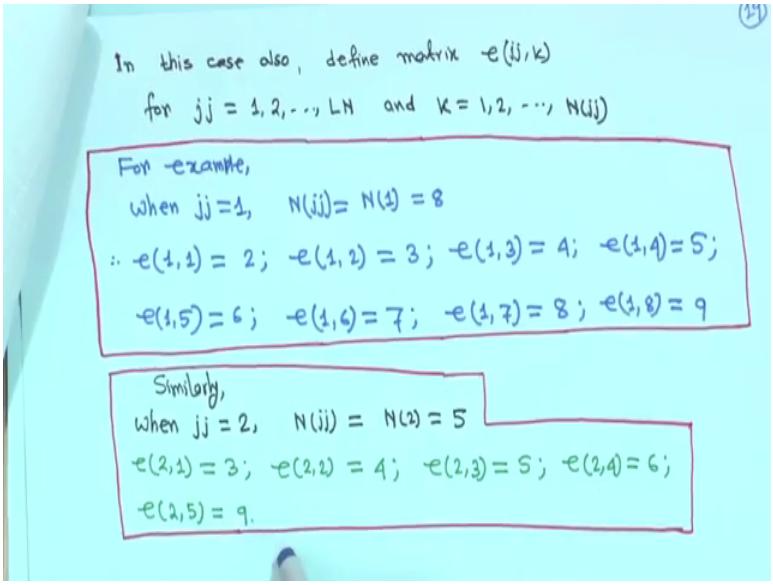
Similarly, if you come to branch 6 right, when you come to branch 6 here, right this is the branch that only beyond this branch beyond this branch only 1 node is there that is 6. So, N j j is equal to 1, this is only one node and which are the node, which is that node 6. So, this is node 6, now you come to branch 6; that means, this this is the branch, beyond this branch how many nodes are there 2. So, this is N 6 is equal to 2, it is 2, and what are those node 7 and 8, this is 7 and 8, now come to brunch 7, this is branch 7, beyond this branch which node is there node 8 is there. So, node 8, and how many only one. So, this is one.

Similarly, you come to branch 8, branch 8 means 4 to 9. So, 4 to 9 this one right, and here it is, your what you call your beyond this branch only one node is there. So, it is only one, and which are that node which is that node it is 9. So, it is 9, now connectivity is look 1 to 2, 2 to 3, 4 to 5, 5 to 6, 1 to 2, 2 to 3, 3 to 4, 4 to 5, 5 to 6 right, then note when you come into branch 6, the sending end node is 2 receiving end node is 7. So, it is 2 to 7 right because it this lateral is emerging from node 2. So, it is from to this branch 7 6 is actually 2 to 7, 6 is 2 to 7, then 7 to 8.

Similarly, this branch eight it is emerging from node 4. So, 4 to 9. So, here sending end is 4 and m 2 9, and if you calculate using the same thing automatically your voltage, and your current same way if you calculate, it will be calculated for only thing is that you have to compute the ejj K matrix. So, this is actually element ejj K matrix right. So, this is actually main feeder with lateral branches for explanation.

So, just if you see for example, we have to our objective is now, everything has been explained before. So, nothing to explain all connectivity everything will match with the previous algorithm, only you have to form this your ejj K matrix and these are the elements for ejj K matrix, these are the element right.

(Refer Slide Time: 27:51)



For example, in this case also define matrix ejj K, right for jj is equal to 1 to ln, and K is equal to 1 to N jj, in this case ln is equal to 8 because 9 nodes are there. So, number of branches is 8, and K is equal to 1 to N jj; that means, for each the 1 jj is equal to 1 to you have to see for example, when jj is equal to 1, N jj is equal to 8 right and; that means, your e 1 1, e 1 2 matrix up to e 1 8 you get; so e 1 1 2, e 1 2 3, e 1 3 4, e 1 4 5, e 1 5 6, e 1 6 7, e 1 8 8, sorry e 1 7 8, and e 1 8 9.

So, look e 1 1 2, e 1 2 3 this data you have to read it is computer, this this data you have to put it into the computer right. So, the e 1 1 2, e 1 2 3, e 1 3 4, e 1 4 5, e 1 5 6, e 1 6 7, e 1 7 8, e 1 8, from the inspection you can form this matrix and feed it in to the computer, similarly when jj is equal to 2 N jj is equal to N 2 is equal to 5 right, look at this when jj is equal to 2 N jj is equal to N 2 is 5 and; that means, your e 2 1 is 3, e 2 2 4, e 2 3 5, e 2 4 6, e 2 5 9, look at that e 2 1 3, e 2 2 is equal to 4, e 2 3 is equal to 5, e 2 4 is equal to 6, e 2 5 is equal to 9, this way just these elements I have given to you, such that you can easily found the matrix, and put in the computer for a day.

Thank you very much we will be back again.