Electrical Distribution System Analysis
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Lecture – 28
Backward/Forward Sweep Load Flow Analysis
Part II

In the last lecture, we have started analysis of distribution system and we have started with load flow studies. Last lecture we have seen, one algorithm which is called as backward forward sweep algorithm which is classical algorithm of load flow studies in distribution system. Initially what I did actually I have introduced to algorithm with simple example, and after that we have seen step by step algorithm of basically backward forward load flow.

Let us see what we have seen so, we have seen that if there is distribution system.

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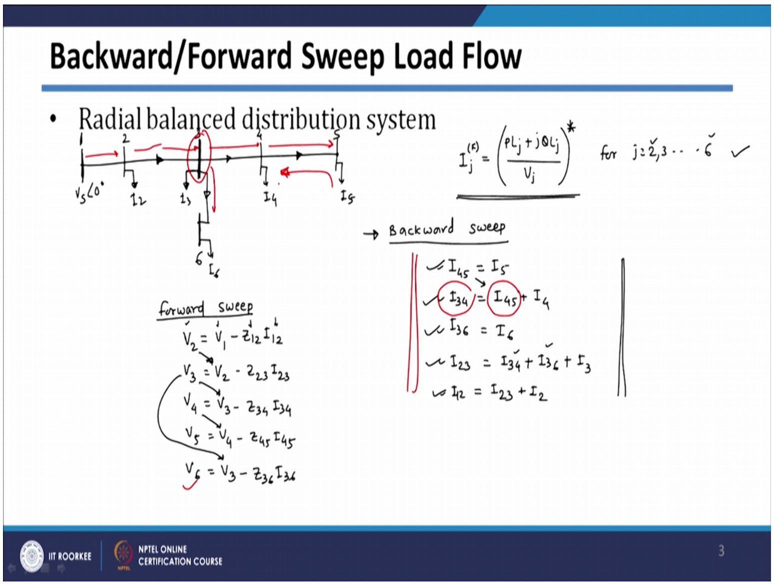

Let us say distribution system is like this, you are having this distribution system here, there are various buses say these are actually there is one branch here, bus number 1 2 3 4 5 and say this is bus number 6. Bus 1 voltage is fixed as a V S angle 0 degree. And, in this case we can write your current equation I j at any kth iteration will be equal to P L j, plus j Q L j divided by V j, which is basically facer. And, then you have to take the complex conjugated bit and then it will be run for j is equal to 2 in this particular case, it will run up to 6. So, using this we can get the currents load currents of each bus starting from bus number 2 ending with 6.

And, then we have seen that in case of backward sweep, we are calculating the branch currents. So, in this case you have already calculated this load currents, which are basically say I 5 I 4 I 6 the load current is here it is say I 3 and here say I 2; So, this all the load currents are calculated in this step. Then, in backward sweep we have can calculate the branch currents. So, we know that we have to start from end nodes and we have to go towards your source node. So, we will start with this end node as well as this end node here so, end node bus number 6.

So, say I 4 5 will be equal to I 5. So, current into this branch will be just I 5 current. So, I 4 5 will be just I 5. Now, current I 3 4 will be equal to this current which is between I 4 5 plus I 4. So, it will be I 4 5 plus I 4 I 4 is already calculated you can use it here. Then, I there 6 current I 3 6 will be equal to I 6 because in this branch only I 6 current will be flowing. And, then we have calculating I 2 3, which is basically current into this branch will be equal to current which is flowing in I 3 4 plus current, which is flowing from I 3 6 plus current at bus 3 which is I 3.

So, here I 3 4 and I 3 6 we already calculated before that and then I 1 2 1 2 will be equal to I 2 3, basically this current which is flowing in this branch plus current load current at bus 2. So, this equations we can have an backward sweep, which will give basically line currents in all the lines. And, then we have seen in forward sweep we need to calculate bus voltages. So, in forward sweep we calculate bus voltages.

So, explicitly if you write this is first voltage V 2 will be equal to bus voltage V 1 which is V S angle 0 degree, which will fixed minus your Z 1 2 into I 1 2, which you have calculated at here. So, V 1 is fixed I 1 2 is also calculated here 1 2 impedance is known. So, we can get voltage V 2, voltage V 3, will be equal to voltage V 2 minus Z 2 3 into I 2 3, I 2 3 is calculated V 2 is calculated before V 3.

So, V 2 I also known then V 4 will be equal to V 3 minus Z 3 4 into I 3 4 I 3 4 is calculated here, and V 3 we have calculated earlier step. Similarly, you get V 5 will may equal to V 4 minus Z 4 5 into I 4 5. And, V 4 is taking from here and I 4 5 already calculated it here and then V 6 will be equal to V 3, because this 6 branch is connected 2 branch bus 3 here 6 bus is connected to bus 3 here.

So, it will be V 3 minus Z 3 6 into I 3 6. So, I 3 6 already known and V 3 V can get it from here, which is calculated before calculating V 6. Because, we are staring with source node, we are starting with source node and then we are going on calculating the voltages till end node. So, voltage when we are calculating voltage of V 6 V 3 will be already calculated. And, then in backward sweep we have seen, we start with end nodes and go towards forward nodes.

So, in that case I 4 will be already calculated before calculating I 3 4 because this branch is actually end branch. So, currents in branch which are connected to end nodes will be calculated first, and then we are going towards source node. So, this was basic philosophy of backward forward sweep algorithm exp detailed algorithm of backward forward sweep load flow, we already seen in the last lecture.

Now, let us see how we can use this algorithm for three phase systems, because we have seen that in many cases your distribution system is unbalanced one, and if you are analyzing unbalance system you have to do load flow analysis with full three phase system. So, you have to considered all the three phases during the analysis. So, let us see or let us considered simple three phase distribution system similar to this.

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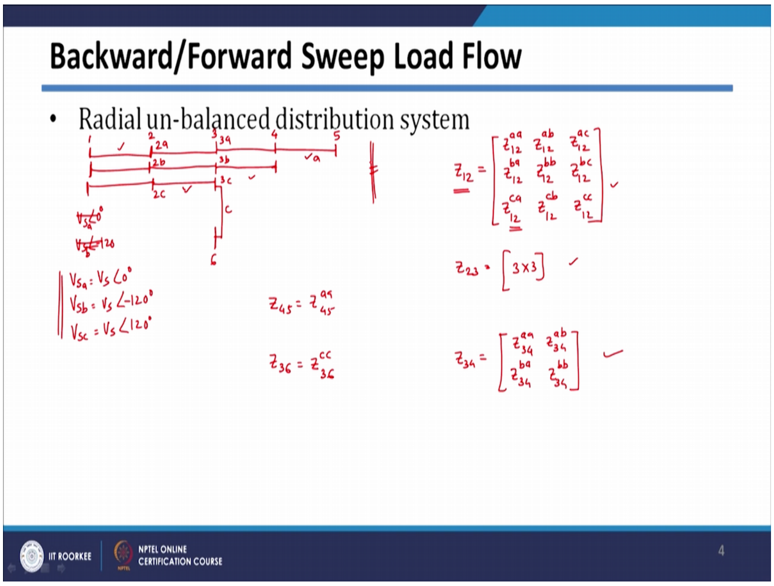

So, you are having see this three phases n and say this is bus number 1, this is bus number 2, and then same three phases are extended till bus number say 3. So, here your bus number 3 and after bus number 3 say only 2 phases are extended, third phase is ending here and they are connected to number node number 4. And stay after this only 1 phase is extended and here your bus number 5 and this phase c will be extended and connected to bus number 6. So, here so, if you see this will be bus which is basically I can call it 2 a, this I can call it 2 b, and this I can call it 2 c. Similarly, this is 3 a, 3 b, and 3 c and this 6 node will be having only 1 phase similarly node 5 will be having 1 phase, and node 4 is having 2 phases.

Now, if you see impedance matrix. So, Z 1 2 impedance matrix will be actually 3 b by 3 c, because all the three phases are there and all the 3 phases are basically mutually coupled with each other. So, it will be having Z aa Z ab Z ac Z ba Z bb Z bc Z ca Z cb and Z cc are the impedances of or impedance matrix of all the 3 phases. Now, since these impedances are between node 1 and 2 I can just write this 1 and 2. So, all the impedances of 1 2 will be like this. So, this is nothing, but Z 1 2 impedance matrix between node 1 and node 2.

Exactly similar way I can write Z 2 3 it will be also similar 3 by 3 size. However, I need to change only this index here index will become 2 3 otherwise it will be same. And, if it is having same structure the same matrix can be used for this section also. However, if you see this section between 3 and 4 so, in this case your Z 3 4 will be of 2 by 2 size. So, it will be Z aa Z ab Z ba Z bb. And since it is between 3 and 4 I can just give index 3 4, everywhere.

So, this will be impedance matrix between 3 and 4 this is how we have to write, then impedance matrix Z 4 5. So, Z 4 5 will be just since I it is having only 1 phase it will be Z aa and I it is a phase. So, Z aa between 4 and 5 and then when I am setting Z matrix of 3 6, it will be again Z; however, this phase is c phase. So, it will be Z cc 3 6. So, we can see that depending upon number of phases present in particular section of the line the impedance matrix will change. So, you need to use the particular impedance matrix for particular section of this one.

Similarly of you see the voltages. So, source voltages will be perfectly balance I can assume and having equal magnitude. So, these will be V S angle 0 degree, which is voltage of a phase V S angel minus 120 degree. So, I can say this is V S a V S b or I can say V S a will be equal to V S angle 0 degree, V S b will be equal to V S angle minus 120 degree, and V S c will be equal to V S angle 120 degree. So, this is this voltages will be perfectly balance and they will not change during the iteration. So, voltages of other buses will change in during the iterations. So, what I will do actually we will try to write explicit step by step algorithm for this particular system.

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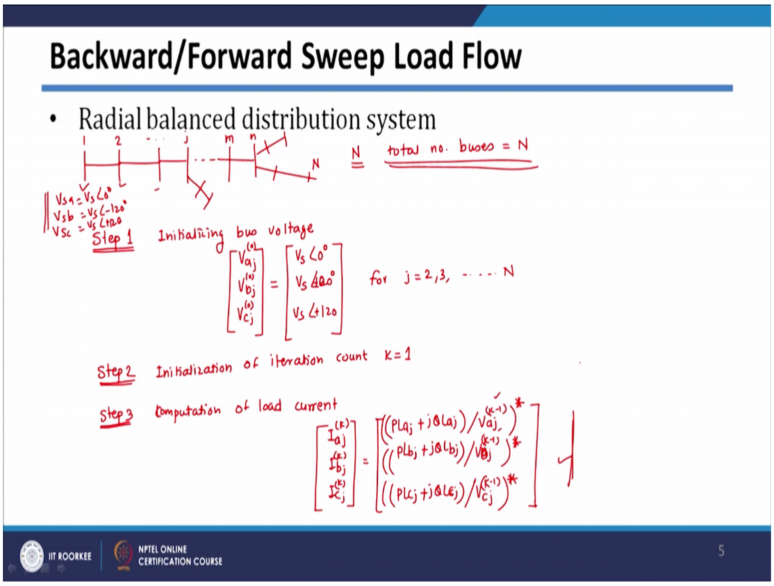

So, that, we will understand, how we can use it for three phase system? So, in this case again I am assuming any three phase generalized system we already seen that how to get the impedance matrix. So, any generalized three phase system similar to earlier system, I can assume that it is having some branches here. And, then some branches are connected here, any generalized system say 1 2 these are the node numbers any zth node, say this is m bus number n and if say there are N number of nodes.

So, total number of nodes are N into the system. So, total numbers of buses are say N. In this case also step 1 is initialization voltage. So, explicitly write the algorithm. So, step 1 will be initializing bus voltages. So, we will initialize the bus voltage.

However, in this case there will be complete matrix of voltages. So, V a j V b j and V c j which are voltages of any zth bus at 0th iteration, because we are initializing it. So, I will just writing 0th iteration will be equal to initially as I told you we are assuming the voltages at this bus which are basically V S angle 0 degree, V S angle minus 120 degree, and V S angle plus 120 degree, which we are initialize initializing for j going from 2 3 up to all the buses that is capital N.

So, all the buses will be initialize to all the 3 all the voltages with initial voltages, which are V S a V S b and V S c, which is equal to V S angle 0 degree V S angle minus 1 0 degree and equal to V S angle plus 120 degree. So, all the buses like 2 3 up to n will be initialize with these voltages at initial bus.

Then, we have seen step 2 step 2 will be initialization of iteration count and we are using k as a nomenclature for this. So, k is equal to 1 is initialization of iteration count and then step 3, we have seen that we need to calculate load currents. So, basically computation of load current will be done in step three. However, in this case there are all the three phase currents. So, depending upon how many number of phases present, how many phases present in a particular section you need to get phase currents.

So, I a j at kth iteration, I b j at kth iteration, and I c j at kth iteration, which are basically three phase load currents, which will be equal to it depends upon loading of this one. So, load P L a j plus j Q L a j load of a phase and zth node, divided by voltage of k minus oneth iteration, and then we are taking complex conjugate of it.

So, this gives me the load current of a phase, similarly load current of b phase will be equal to P L b real part of the load have b phase plus j Q L b j divided by voltage V a j V b j at k minus 1th iteration, and you have to take the complex conjugate of it. Similarly, we can get P L c j plus j Q L c j, which is load at bus number c at jth bus phase number c at jth bus will be equal to v c j at k minus 1th iteration, and you have to take complex conjugate of it is actually k minus 1th iteration. So, after getting currents we go for step 4.

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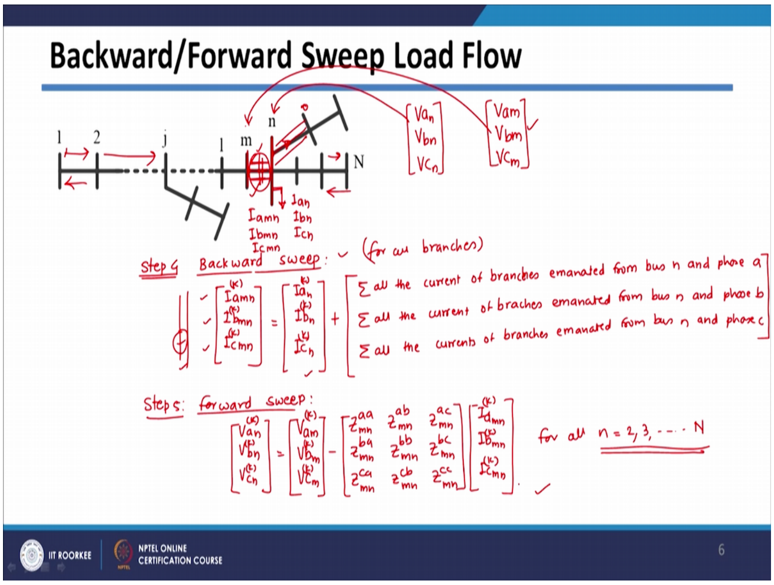

And, step 4 we have seen that it is basically backward sweep and in backward sweep we are calculating line currents. So, line currents now there will be 3 phases. So, there will be 3 line currents here. So, Imn line current in a phase, Imn in b phase, and Imn in c phase. So, we need to calculate all the 3 phases any branch Imnth branch, I can get Imna or I can write instead of this I can just write Iamn, Ibmn, Icmn. So, in this case also Iamn Ibmn and Icmn, which is basically currents flowing in three phases of mn section of the line and it is again at kth iteration. So, I have to write iteration count k here will be equal to.

So, we need to add the phase currents into this one again the phase there are three phase currents. So, Ian is phase current, in a phase Ibn in phase current, in b phase Icn phase current, in c phase at nth bus. So, it will be Ian Ibn and Icn all the 3 currents which already calculated in this kth iteration. So, this currents are already known plus, we have seen that summation, now in this case there will be 3 summation of all the branches, all the currents of branches emanated from bus n and phase a.

Similarly, all the currents of braches emanated from bus n and phase b. So, all the braches which are connected to phase b which are going out of this, because we have seen that in n phase itself there may not be all the branches which are connected to next bus which is connected here say mn o. So, there is possibly that all the 3 braches may not be connected to o bus and then in this case all the currents of branches, emanated from bus n and phase c.

So, this will give you all the three phase currents of all the branches of this particular distribution system. So, once you get the current we should go for step 5, which is forward sweep and we have seen that in forward sweep we are basically calculating the nodal voltages. So, in this case nodal voltages V a n Vbn and Vcn at kth iteration. So, say this is the this node n. So, at this node the voltages a phase voltage will be van b phase voltage will be Vbn and c phase voltage will be Vcn.

They, will be calculated based on voltages of earlier node that is voltage of node m which is basically Vam, Vbm, and Vcm. So, these voltages minus voltages minus voltage drop which is happening in this will give me voltages at m. So, this will be equal to voltages at nth bus will be equal to voltages of mth bus which is Vam, Vbm, and Vcm. At kth iteration, because we have seen that this is forward sweep, we calculate voltages of this bus first and then we will go for this bus. So, this voltages are already known minus.

Now, in this case it will be impedance matrix and if it is all the 3 phases are present into this section, it will be 3 by 3 impedance matrix. So, it will be Z aa Z ab Z ac Z ba Z bb Z bc Z ca Z cb and Z cc and since this section is mn section. So, I can say just write mn everywhere. So, this is nothing, but impedance matrix of this line section here, and then this should be multiplied with your line currents, which are flowing through this line and we have seen that we already calculated this line currents in step number 4. So, this line currents will be Iamn, Ibmn, and Icmn at kth iteration we already calculated.

So, this will give me voltages of nth bus after completion of forward sweep. And, this will be for all n which is starting from 2 3 and up to N and this sweep will be done for all branches. This will done for all the branches and this will be done for all the nodes. So, this is how we get all the nodal voltages.

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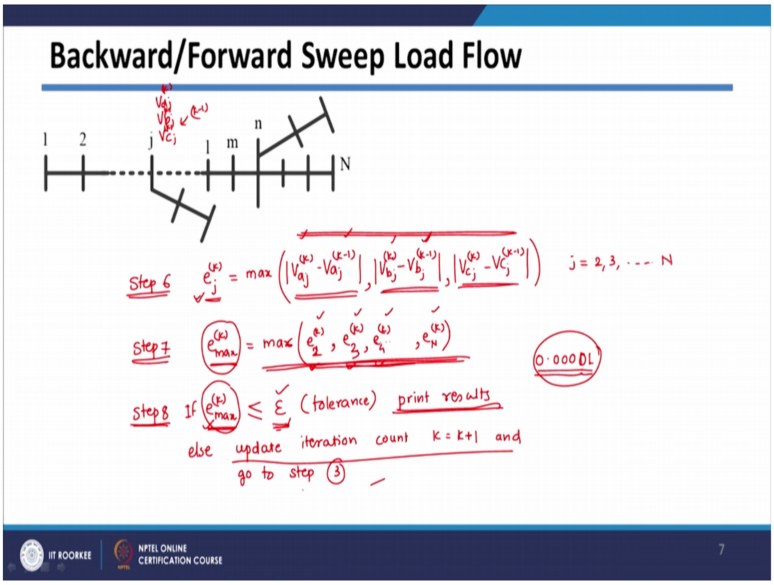

And, then we have seen that step number 6 is to get the errors of the voltages, now here there will be 3 errors. So, error of the voltages of jth bus in kth iteration will be equal to max of. So, first you have to calculate the at jth bus there will be 3 voltages. So, if you are considering say this is your jth bus. So, you will be having Vaj Vbj and Vcj 3 voltages, which are calculated kth iteration as well as k minus oneth iteration this voltages will be available.

So, by taking the difference of particular voltage so, it will be Va j, at kth iteration minus Vaj at k minus 1th iteration, this will be 1 error in error in a phase. Then error in b phase. So, you have to subtract the 2 iteration voltages that is kth iteration voltage of b phase and kth iteration voltage of b k minus 1th iteration voltage of b phase, and then third Vcj at kth iteration minus Vcj at k minus 1th iteration at mode of it you have to take it.

And, maximum of it maximum is becoming in a phase or b phase or c phase will be nothing, but or error in voltages of say jth bus. So, this will learn for j j equal to 2 3 and it will go up to N. So, it will get errors in bus voltages maximum error in bus voltages, at each of the bus. And, then step 7 will be similar to our algorithm. So, e max of kth iteration will be equal to your max of e 1 kth iteration, e 2 kth iteration, up to e N at kth iteration.

So, here all these values e 1 sorry e 2 start from 2 so, e 2 e 3 e 4 at kth iteration. So, this e 2 e there e 4 they have already calculated in step 6 and we are getting the maximum errors, by calculating the max of it. So, these are nothing, but errors of the voltages at particular bus, and getting maximum error will get maximum error bit might be happening at any bus in to the system. And, once you get the maximum error in step 8 you have to compare this maximum error with respect to your tolerance value.

So, e max at your kth iteration will be if it is lesser than your epsilon, which is tolerance, which is given if this condition is getting (Refer Time: 29:43). So, there we have to use if statement here. So, if this is true you have converge then print the results, and as well as store the results. And, else if this condition is not a not satisfied means e max is still more than your tolerance value you have to update, iteration count k is equal to k plus 1 iteration is updated and go to step number 3.

So, if this error is more than your tolerance value you have to go to the step number 3, where by using the voltages of earlier step, you have to get the currents and from the currents load currents, you have to get the branch currents using the backward sweep starting from end node and moving towards the source node, you will get all the branch currents.

And, once you get the all the branch currents, you can use the which is called as forward sweep; So, starting from your source node keep on getting the voltages till your end node by using step number 5. And, once you go get the voltages compare the voltages of this iteration with respect to earlier iteration for all the three phases here and get the maximum deviation at 1 particular phase for that particular bus.

And, then calculate maximum error at all the buses. So, this will give you what is called as a maximum error for all the buses and then compare this maximum error with respect to your tolerance value, which may be 0.0001 for if you are using per unit system. This will be sufficient and then if you are comparing this if the error is lesser than this tolerance value, you can say your converged with algorithm print the result, otherwise again a iteration count and go to the step 3. So, you will keep you will be this loop till your algorithm converges.

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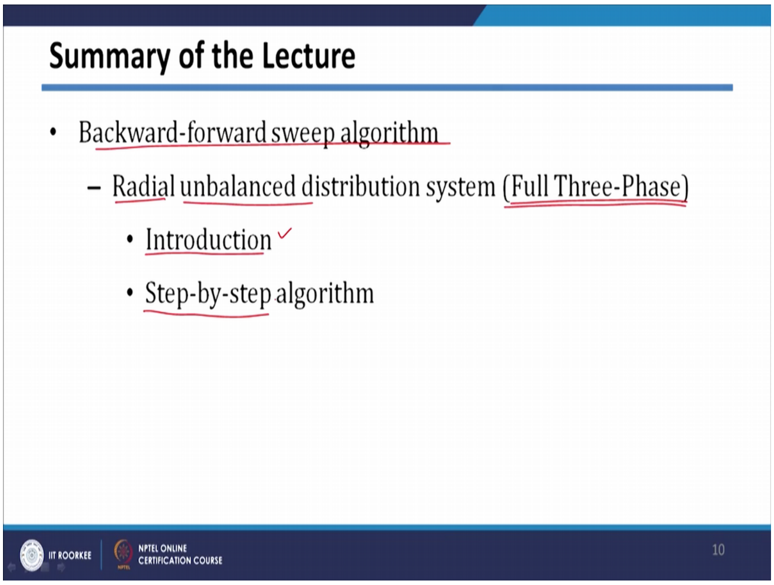

So, in this particular lecture we have seen backward forward sweep algorithm applied for radial system, but unbalanced system. So, we have seen that whenever unbalanced system is there we have to consider all the three phases. So, we have seen how to use this backward sweep forward sweep algorithm for full three phase system, we are all the three phases are considered. Here, I have introduced you concept where we have seen what are the impedance matrices for different sections of the line; and, how they are defined and after defining your impedance matrices we have seen step by step algorithm for 3 phase, backward forward sweep algorithm.

Next time we will see another algorithm, which is based on direct approach in that case we will see how this process of backwards forward sweep is simplified and effectively used.

Thank you very much.