Electrical Distribution System Analysis
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Lecture – 27
Backward/Forward Sweep Load Flow Analysis Part I

In the last lecture, we have completed modeling of distribution system components. And, in this particular lecture we are going to start distribution system analysis. And, initially we will start with load flow analysis and then we will go to the short circuit analysis.

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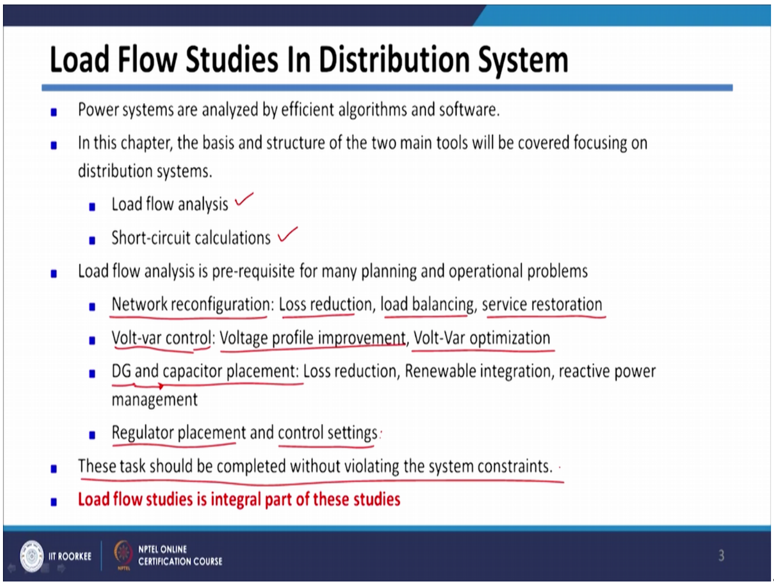

So, these tools are basically load flow analysis and short circuit calculations. So, we have seen load flow analysis and short circuit calculation in our B Tech course.

However, for distribution system the methods or algorithm used for load flow studies as well as short circuit calculation they are different. So, in this particular chapter we will see load flow analysis and short circuit analysis for basically distribution systems.

Now, if you go for load flow studies the load flow study is pre requisite for many planning as well as operational problems. So, these problems like network reconfiguration, need for loss reduction, load balancing, or service restoration. Ah. We need load flow studies before doing it, then for volt var control this is basically required for voltage profile improvement in a distribution system or volt var optimization. In this case also you need load flow study results so, that we can arrive at proper volt var control in a distribution system.

Then, in a planning studies when you are placing DG or capacitor may be it for loss reduction or renewable integration or reactive power management or voltage profile improvement, we need load flow studies results. So, that we proper placement of DG are capacitor will be done.

Then, for placement of regulator or control setting of regulator we need load flow studies, we have seen that in case of placement of regulator or when you are setting when you are doing setting in this line drop compensator circuit, those are basically based on load flow studies. And, we have seen that all these stars should be completed without violating your system constraints.

So, while doing this load flow studies the we can also in cooperator your constraints of the system. So, that constraint's will not get violated. There for your load flow studies will always be integral part of when you your solving this kinds of issue. So, flow studies will be integral part of those studies.

Now, in your our b tech course you might have a studied methods like Newton Raphson or Gauss Seidel.

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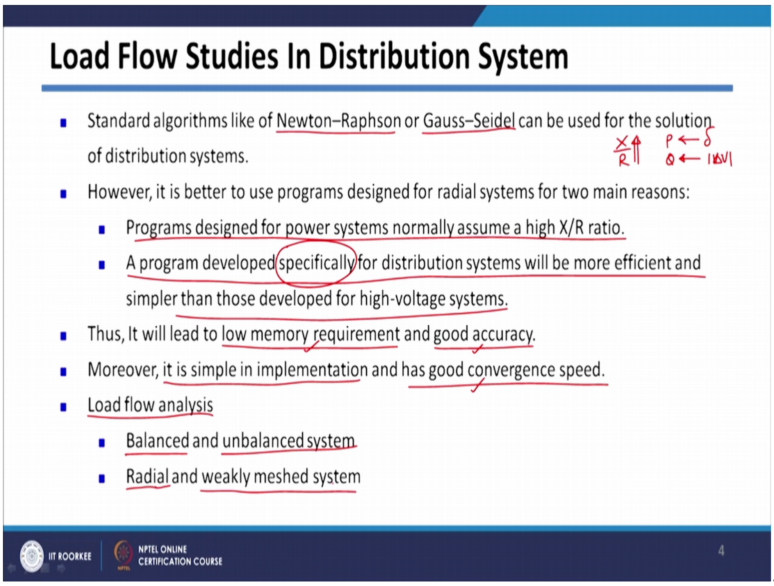

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So, these methods like Newton Raphson or Gauss Seidel we can use it for distribution system also. However, the X by R ratio of distribution system is very poor, and because of this convergence of this methods is very poor means, they will converge very slow.

Because, in transmission system we know that X by R ratio is very high and because of this X by R ratio, which is very high. There will be decoupled effect means your P will be basically depend on angle of the voltage that is delta and Q will be mainly depend upon your voltage difference delta V.

And, because of this decoupling effect your Jacobean metrics of Newton Raphson will be diagonal dominating, and because of this diagonal dominance it will converge fast.

However, in case of distribution system this X bar R ratio is very poor. So, as I discussed program designed for power systems normally as in that X bar R ratio is high. Therefore, program developed specifically for distribution system will be more efficient and simpler than those developed for high voltage.

So, we can developed some different algorithm for distribution system, which will be more efficient as well as they will be specifically for distribution system, thus it will lead to low memory requirement and good accuracy. So, this simple algorithm or specific algorithm for distribution system, they will be lead to low memory requirement and good accuracy.

Moreover, they will be simple in implementation and has good convergence speed. So, as I told you whenever going using Newton Raphson or Gauss Seidel method for distribution system their convergences slow. So, we can develop some other methods, whose imply implementation will be simple and will give good convergence or it will converge fast.

So, load flow studies will be required for studying balanced as well as unbalance system. So, generally we have seen that distribution systems are unbalanced. So, many cases we need to study unbalanced systems. Also, we need we can take the advantage of systems distribution system, which are radial mainly radial as well as weakly meshed. So, will develop the algorithm for radial system or sometimes weakly meshed systems.

Now, last let us start with one of classical algorithm used for distribution system analysis or load flow analysis of distribution system which is called as backward forward sweep load flow algorithm, which is class classical one of for distribution system analysis.

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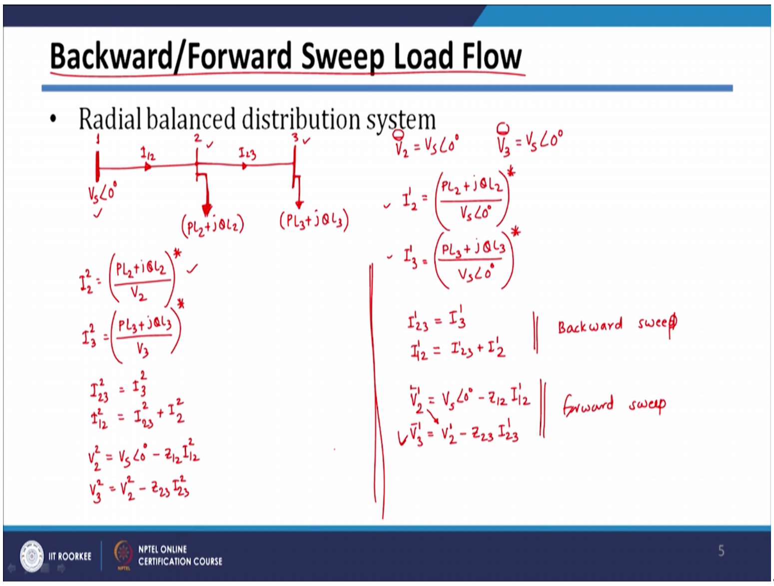

Let see how it works? So, in this case you are having say simple 2 base system; like this then there are 2 loads are connected say this load is PL 2 plus j QL 2 and this loads say PL 3 plus jQ L 3. And, this is bus number 2 bus number 3 and this is your bus number one source bus, the voltage at this bus is given and will remain constant on all iteration. So, we are keeping the bus of this voltage at this bus one will be constant at say V S angle 0 degree.

Now, this backward forward sweep algorithm will work like this initially, we assume that voltages at bus 2 as well as bus 3 which is equal to 2 voltage at source bus. So, V 2 we can say it will be V S angle 0 degree, as well as voltage V 3 will be equal to V S angle 0 degree.

So, this V 3 on putting bar on this it will be actually vector quantity, but for brevity many times I will not write this bar here. So, I will just write to V 2 V 2 will be your complex quantity or vector as well as your V 3 will be your vector.

So, in this case what we can do we can calculate the load currents at each buses. So, load current as bus number 2, which will basically I 2 current will be equal to PL 2 plus j Q L

2 divided by your V S angle 0 degree, because we are assuming voltage at that bus is V S angle 0 degree and we are taking complex conjugate of it. So, that will get current I 2.

Similarly, will calculate current I 3; I 3 will be equal to PL 3 plus j QL 3 divided by VS angle 0 degree because, in this case also at bus 3 you are assuming voltage is VS angle 0 degree so, complex conjugate of it.

So, current I 2 3 will be equal to just load current at bus 3 which is I 3, and then current I 1 2 will be equal to I 2 3 as it is, if you apply case will at this point. So, I 2 3 plus current, which is flowing at this load current flowing at this bus number 2, which is we have calculated which is I 2. So, I 1 2 will be equal to I 2 3 plus I 2.

So, this is called as backward sweep. So, all the line currents we are calculating by going backward from your n nodes, and if you are reaching till your first node or source node.

And, then voltages will be calculated starting from source node. So, I can calculate write the equation for V 2 will be equal to V 1, which is basically V S angle 0 degree minus drop, which is happening across this particular line which is impendency say Z 1 2 and current flowing through this is I 1 2.

Similarly, I can calculate voltage V 3 will be equal to V 2 minus Z 2 3 into I 2 3. And, this is called as forward sweep forward sweep.

And, in this case we have calculating voltages in forward direction starting from your source node and we are reaching to the n node. So, that we can get the voltages at say from V 2 than from V 3 and then you can use this V 3 updated voltage V 3 into when your calculating voltage V 3 here.

Then, now and remember that here these V 3 as well as V 2 they are complex numbers as well as we can say their phrases, for brevity I am not given bar one it.

So, using this I can calculate again current I 2. So, current I 2 will be equal to again loads I am considering constant power loads. So, if they loads are not constant power loads or if they are mixed load, this load also need to be updated in each iteration.

However, in this case since I am considering constant power load the const loads will remain constant. So, it will be PL 2 plus j QL 2 divided by your new voltage, which you have got is V 2 and in you have to take star of it.

So, V 2 will be having some angle that I have not written it here, and then similarly I can get I 3, which will be equal to PL 3 plus j Q L 3 divided by your V 3 star.

Now, to differentiate between these I 2 and I 3, I can say this these are I 2 and I 3 at first iteration, this I 2 3 and I 1 to at first iteration and these voltages, which you have got is at the end of first iteration.

Now, here we have started second iteration. So, at the second iteration this is say current has second iteration, this is current at second iteration. And, then I 2 3 at second iteration will be equal to again I 3 at second iteration.

So, this first I 3 at second iteration and then I 1 2 at second iteration will be equal to I 2 3 at second iteration plus I 2 at second iteration, which you have got it here, and then again voltages will be updated. So, V 2 at second iteration will be equal to VS this voltage we are keeping constant so, it will not never change.

So, V S angle 0 degree minus Z 1 2 into I 1 2 at second iteration this was this first iteration. So, I just I have to write first iteration here and this V S it we also at first iteration and then V 3 at second iteration will be equal to V 2 at second iteration minus Z 2 3 and 2 I 2 3 at second iteration. And, we have to keep it repeating this pattern till we converge so, how to check the convergence.

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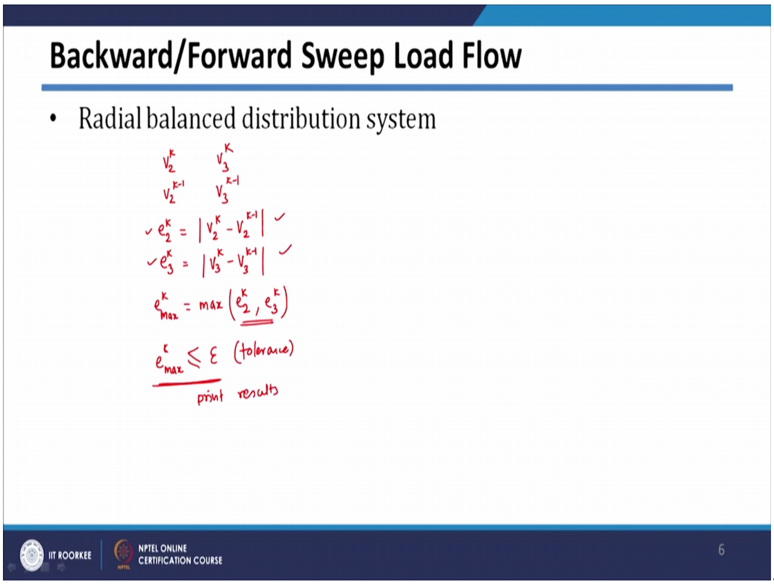

Let us see. So, we have got values of V 2 at say kth iteration and then we have got V 3 at kth iteration, by doing many iterations. And, we know the values of V 2 at k minus 1th iteration also and V 3 at k minus 1 iteration also.

Then, error of voltages at node 2 at k th iteration will be equal to mode of V 2 which you have got at k th iteration, minus V 2 which we have got at k minus 1 iteration. And, then error in 3 voltage at node 3 will be at k th iteration will be equal to V 3 at k th iteration minus V 3 at k minus 1th iteration and it is mode.

And, then you have seen. So, in k th iteration where getting this 2 errors here then to get maximum error. So, maximum error at k th iteration I can say a max, which will be equal to maximum of e 2 k. And, e 3 k means we have to get the maximum value of errors you have to from all the errors.

So, in this case there are 2 buses. So, you have to get the maximum value from these 2 buses which is e max. Now, then you can compare this e max with your threshold value if this e max is less than or equal to your tolerance limit which said epsilon. So, whatever tolerance limit we you said, if it is less than this then we can actually print your results.

Now, let us see the steps in this particular algorithm that is backward forward sweep load flow algorithm.

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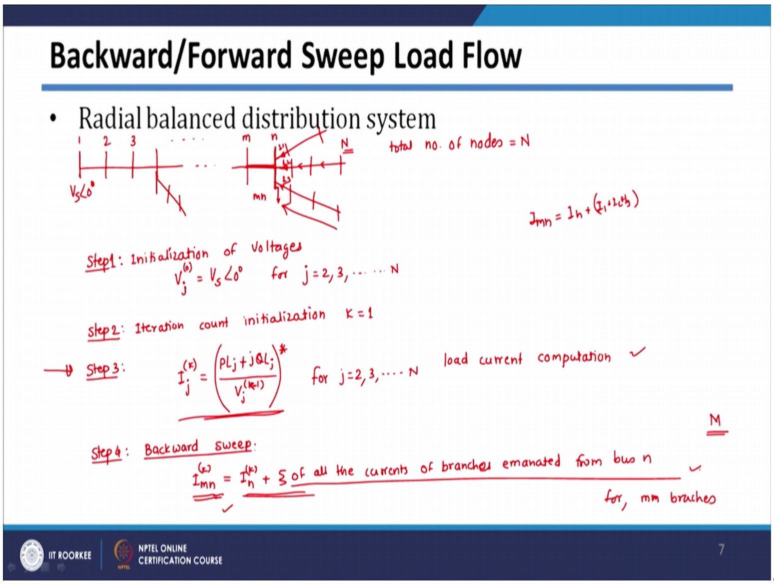

So, for any general type of distribution system, say your distribution system is something like this you are having some buses. And, then some are they have some branches say here also there are some branches.

Let us this is first node second node third node, and then there are many number of node say this node, node is m this node is n and say there are N number of nodes into the system. So, total number of nodes say equal to N.

Now, let us see is the steps. So, voltage at the first is I am assuming it is V S angle 0 degree as per our philosophy algorithm and which will never change in during the iteration it will remain constant. So, step one is initialization of voltages.

So, in this case will initializes voltages of all the buses. So, I can say V j at zeroth iteration will be equal to V S angle 0 degree, and this will be defined for all j is starting from 2 3 and which will go to up to N.

So, basically we are assigning all the nodes which are j which is changing from 2 2 N, we are assuming the voltages should be V S angle 0 degree that is your step 1. So, this is your step first then step 2 initial initialize your iteration count.

So, iteration count initialization. So, here I am taking K is equal to o1ne. So, it is first iteration then step 3, step 3 we have seen we have to calculate your load currents. So, load current equation we have seen I j load current at any Z th bus at say K th iteration.

Now, in this case since if it is iteration number 1 it will k k will be equal to 1 will be equal to P L j, which is basically real part of the load and then j QL j imaginary part sorry imaginary part of the load at k th bus, divided by V j voltage at Z th bus, but that is calculated at k minus 1, because we do not know that voltage here. So, that is calculated at k minus 1 iteration so, earlier iteration.

So, in this case when you are calculating for say k is equal to 1. So, this first iteration and then you have to use the voltage is which are basically at k is equal to 0 that is V j 0, which is we already initialized and then you have to take the complex conjugate of it. And, this we have to do it for all the j ranging from 2 3 up to N.

So, load currents at each bus will be calculated by this equation which is basically step 3. So, step 3 is basically load current calculation, and then your step 4 is basically you have seen it is backward sweep, where we are calculating the branch current.

So, when I am calculation say I mn, which is basically branch current which is flowing between branch connected between bus m and n, will be equal to at kth iteration, will be equal to I n which is basically load current at mth dash, which is calculated at kth iteration we already calculated it in step 2 plus summation of so, this summation of all the currents of branches emanated from bus N.

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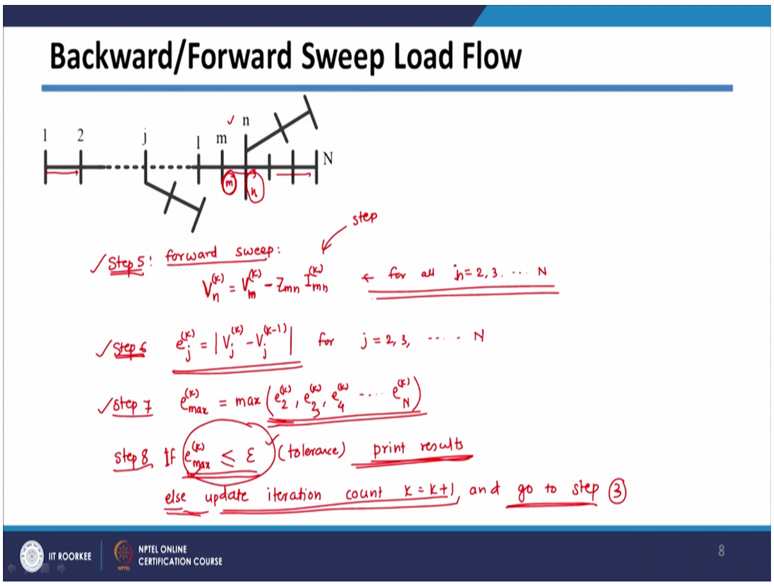

Then, is step 5 we have seen it is forward sweep and in forward sweep we are calculating voltages at each bus. So, voltage any nth bus voltage at any n th bus at k th iteration will be equal to. So, when I am calculating voltage at n th bus voltage if m th bus m th bus will already calculated. So, which will be known because we are actually starting from source node and we are going towards leap nodes or n nodes.

So, before going to the nth node we already calculated the voltage of mth node. So, voltage then voltage of mth node which is already known minus impedance of this branch say Z m and current flowing through this branch is I mn, this you have at kth iteration which we already calculated in step 4.

So, this will be available from step 4 and this V if voltage of bus m, we already calculated in same step, but before calculating voltage at n th node.

So, this how we can get the voltages at each bus using your forward sweep and then in step 6 we are calculating error. So, error at any jth bus. So, this will be again repeated for all j, which is going from or all ns which are going from 2 3 up to N.

So, we basically using this we are calculating voltages of each bus and then ej error in voltages of jth bus, in kth iteration will be equal to mode of V j bus voltage of jth bus at k th iteration minus voltage of same bus at earlier iteration k minus oneth iteration, and we are taking the mode of it.

So, here also this will be repeated for your j going from 2 3 up to N. And so, after getting errors of voltages in each of the bus you can get the maximum error. So, in step 7 will get maximum error. So, e max of your kth iteration will be equal to maximum of all the errors.

So, here we are getting all the errors like we are getting error in 2 of k th iteration, error at bus 3 at kth iteration, error at bus fourth at kth iteration, we have to error at nth bus and kth iteration and when we get maximum error.

So, these are the error nothing, but the error at each bus and when we get maximum error in step 8, we compare that maximum error with respect to your tolerance value which you have selected. So, this if this e max at kth iteration will be less than or equal to epsilon, which is basically tolerance value, which is selected if this condition we getting satisfied.

So, I can write if statement here if this condition is getting satisfied your converge with result. So, print results which are correct else if this condition is not getting satisfied update the iteration count update iteration counts. So, we can make k is equal to k plus 1.

So, now, you have got next index iteration and then you have to go to and go to step 3. So, step 3 we have seen step 3 is here. So, again will calculate using the voltages at k minus oneth iteration earlier iteration will calculate your currents, at each bus load current at each bus. And, then we will calculate branch currents by going backward towards the source node will calculate currents in each branch by adding this one. So, this will be run for all mn branches in the system.

And, then we have seen we have to use forward sweep to get the voltages. So, will go to step 5 to get the voltages and then get the error in each bus voltage maximum error from all the errors in all the buses. And, this maximum value will be become compare with tolerance value, if it is lesser than tolerance value, you have to print the result if error is more than tolerance value; you have to still keep iterating. So, you have to iterate the update your iteration count to k is equal to k plus 1 and you have to go step 3. So, you will be in this loop till this condition get satisfied.

So, this is your backward forward sweep algorithm of load flow. In next class we will see one example of this and then we will go for 3 phase backward forward load flow algorithms.

Thank you.