Electrical Distribution System Analysis
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Lecture – 32
Direct Approach Based Load Flow Analysis: Weakly Meshed System

Dear students, we are studying direct approach based load flow analysis and till now whatever distribution load flow analysis method, we have seen we have seen their applicable only for radial distribution systems. So, whether it is backward forward based algorithm or direct approach based algorithm; we have used in for radial distribution system.

However as I told in the last class there are some cases where distribution system is operated in weakly meshed mode, in that case whatever algorithm we have studied, they are not applicable basically this are direct approach based method we should be suitably modified, so that we can use it for Weakly Meshed System.

So, in this particular lecture we will see how we can use this direct approach based method for weakly meshed distribution system, because we can modified this BIBC matrix and BCBV matrix such that it can be use for weakly meshed system.

Now, let us see how we can use this method for weakly meshed system, so in case of weakly meshed system let us consider simple system which you have already consider.

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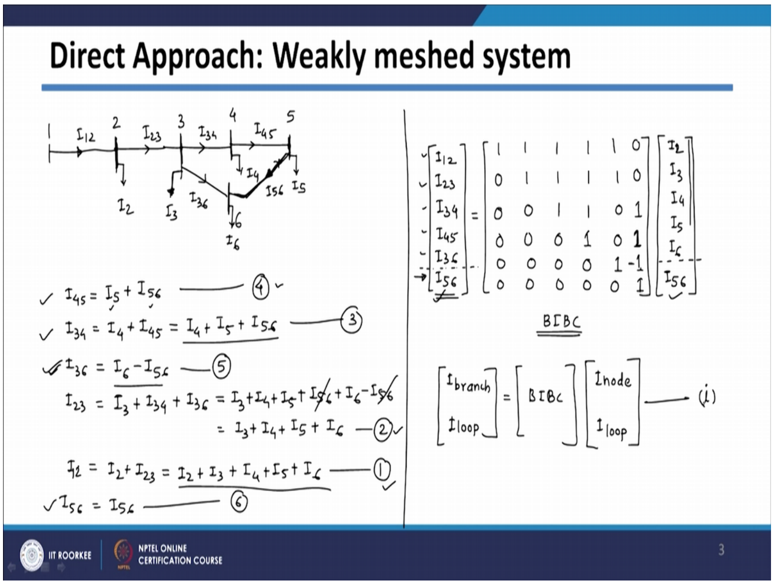

So, let say your having this branch 1, branch 2 and then your branch 3, so this is known number 1, 2, 3, 4 and let us say one more means 5 and we have to consider this system where there is one more node which say node number 6 here.

Ah then this current we called as I 1 2 this current I 2 3 this is I 3 4 this is I 4 5, I 3 6 and at each node there is load current I 5, I 4 here will by I 6 here I 3 and then say your I 2 and we have seen how to solve load flow problem for this 1.

Now, consider your having weakly meshed system, let us consider 1 weakly mesh system where let us say this and this node is connected such that there is 1 loop which is getting formed here and when you connected this node 5 and node 6. So, in this particular branch there will be current which say I 5 6 is flowing in given show on direction.

So, here if you write your KCL equations let us say if your applying KCL at node number 5, then I can write your I 4 5 will be equal to your current I 5 plus I 5 6. So, when I applying at node 5 when applying KCL at node number 4, so it will be I 3 4 current which is approaching towards node will be equal to your current I 4 plus I 4 5 and I 4 5 already got it here which is basically I 5.

So, I 4 5 is actually I 5 plus I 5 6 and then let us apply KCL at node number will first apply to the say loads node number 6. So, it will be I 3 6 which will be equal to I 6 and since direction of this current which is I 5 6 which is minus. So, it will be I 5 6 here minus I 5 6.

Then apply at node 3, so I 2 3 will be equal to I 3 which is node current load current at node number 3 plus I 3 4 which is going out plus I 3 6 which is also going out. So, if you add them it will be I 3 I 3 6 you already got it here, so it will be I 3 4 first I will write.

So, I 3 4 is plus I 4 plus I 5 plus I 5 6 and here it is plus I 6 and minus I 5 6. So, this will get cancelled out what will remain is I 3 plus I 4 plus I 5 plus your I 6. Similarly, in I 1 2 we can get the case will at node number 2, so I 1 2 will be equal to I 2 plus your I 2 3 which will be equal to your I 2 plus I 3 plus I 4 plus I 5 plus I 6 all the currents are coming.

Now, you have got here various equations let say this is equation number 1, this is equation number 2, this is equation number 3 this is 4 and this is say 5, now one more equation I am adding and in that equation I am saying current I 5 6 is actually equal to current I 5 6 and this I am saying equation number 6.

Now, if you write this equations in 2 matrix from, on left hand side matrix you will be having this currents basically all the branch currents. So, from 1 equation number 1 we are on the left hand side I 1 2, equation number 2 we are having I 2 3 equation number 3 we are having I 3 4 equation 4 I 4 5 equation 5 I 3 6.

And equation number 6 we are having I 5 6; which is equal to some matrix say here and the currents which are involved here are basically I 1 sorry I 2, I 3, I 4, I 5, I 6 and one more currents which is having is I 5 6 and after knowing this equation I can easily write the matrix which is, so from equation number 1 we can see we are having all the currents except I 5 6.

So, here I have there will be 1 entry everywhere except I 5 6 because in equation number 1 we are not having I 5 6 current; equation number 2 we are not having I 2 current and I 5 6. So, there will get 0 otherwise all the currents are present in equation number 2 and this is also 0 and if you see equation number 3 which is basically this here I 2 I 3 are not there and so you are having I 2 is not there I 3 is not there I 5 is there I 4 is there I 5 is there and I 5 6 is there.

So, here we are having 0 and then here we are having 1, I 6 is not there in that equation. So, if you see equation number 4 here I 4 5 is having only 2 terms which I 5 and I 5 6, so here I will get this I 5 related term. So, all this other terms are 0 and here also it is 0 and then here we are getting 1 and then if you see this equation number 5, so I 3 6 which is equal to I 6.

So, here 0 0 0 0 you are getting 1 here and here we are getting multiplied by minus 1 and last equation that is equation number 6 we are getting all the entries 0 except I 5 6, so you are getting 1 here.

So, on the last column we are getting 4 entries which are 1 and again I am calling this matrix as BIBC matrix which basically convert so bus injection to branch current matrix. Now if you observe here this particular current which is represent basically loop current which, otherwise if this loop current is not there actual system is radial one.

So, if you remove this band system becomes radial that is why this radial branch which is basically making loop I can consider I loop. So, these are actually branch currents and this extra branch which is added basically making loop and calling it has I loop. So, basically I can write this I branch current and then I loop current.

So, I loop current is only this I 5 6, if there are 2 loops there will be 2 entries in I loop; if there are N we can say L loops there will be L entries in I loop and this then there is BIBC matrix and here these currents are basically nodal load currents. So, I can say I node and then there is 1 entry which is similar to your left hand side, which is again I am calling at is I loop, so we have got this equation say equation I here which will be using it later. So, we have got BIBC matrix for weakly meshed system.

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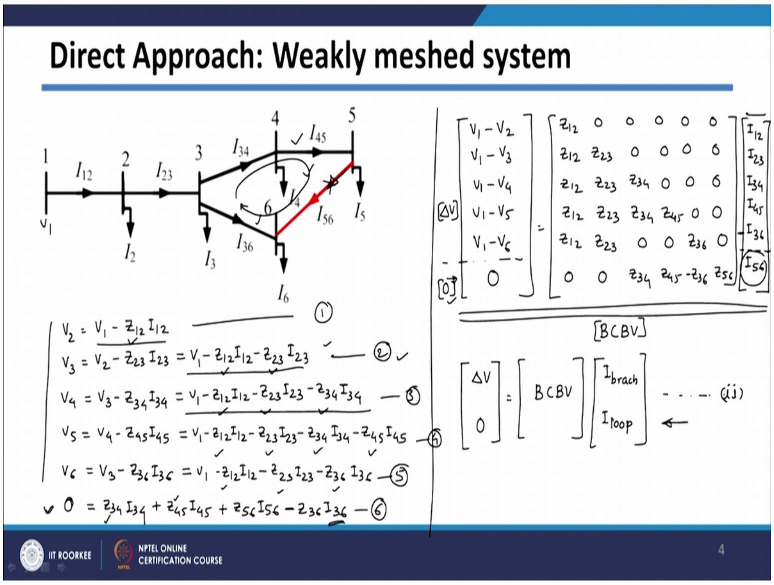

Let us see how we can get BCBV matrix for weakly meshed system. So, to get the BCBV matrix we need to write the KVL equations of the voltage nodes. So, we know that V 2 will be equal to V 1 minus Z 1 2 into I 1 2, basically this node voltage V 3 will be equal to V 2 minus Z 2 3 into I2 3.

So, V 2 already calculated so same thing I can write it will be equal to V 1 minus Z 1 to into I 1 2 minus Z 2 3 into I 2 3 similarly your V 4 will be equal to V 3 minus Z 3 4 into I 3 4. So, it will be V 3 we already got it here, so it will be V 1 minus Z 1 2 I 1 2 minus Z 2 3 I 2 3 minus minus Z 3 4 into I 3 4 and then V5 will be equal to V 4 minus Z 4 5 into I4 5.

So, V 4 we already got it here, so it will be V 1 minus Z 1 2 I 1 2 minus Z 2 3 I 2 3 minus Z 3 4; I 3 4 minus Z 4 5; I 4 5 Then only node 6 is remaining so V 6 will be equal to, now this V 6 which is connected to node number 3 because we are considering this is radial branch this are the loop branch, so we will consider only radial branches.

So, here it is connected to node number 3, so it will be V 3 minus Z 3 6 into I 3 6; V 3 we have got it here which is V 1 minus Z 1 2 into I 1 2 minus Z 2 3 into I 2 3 minus Z 3 6 into I 3 6 and then one more equation I am writing considering this loop here.

So, if you consider this loop starting from say 3 4, so we know that if you apply KVL for this particular loop; voltage total voltage of the loop will be equal to 0, in that case this drop which is basically Z 3 4 into I 3 4, then this drop will be plus if you see the current direction, Z 4 5 into I 4 5, then this drop by considering this loop branch here which is again plus because, your in same direction of loop.

So, it will be Z 5 6 into I 5 6 and then last is this branch, however we can see that the current direction is in opposite, so here we need put minus sign Z 3 6 into I 3 6. So, basically we applied KVL for this loop and let us say this is your equation number 1, equation number 2, equation number 3, equation number 4 5 and 6 and if you put them into matrix format, we have seen that the matrix is something like this. Here we know that this is nothing but V 1 minus V 2 V 1 minus. So, V 1 actually voltage at this node V 1 minus V 3, V 1 minus V 4, V 1 minus V 5, V 1 minus V 6 and here we are getting 0 for the last equation.

So, there are actually voltages in first 5 equation and last equation there is no term which is related to voltage, so that is why we put 0 here and right hand side we are considering this impedance multiplied by current. So, this currents are I 1 2, I 2 3, I 3 4, I 4 5, I 3 6 and I 5 6. So, if you see equation number 1 there is only 1 Z 1 2 which is getting multiplied by I 1 2, so here only Z 1 2 is present which is getting multiplied by I 1 2 so all other entries are actually 0. Equation number 2, if you see there are Z 1 to multiplied by 1 2 and Z 2 3, so here where I Z 1 2 and Z 2 3 other entries are 0. Equation number 3 where in 3 entries those are Z 1 2, Z 2 3 and Z 3 4 and all other entries are 0, equation number 4 Z 1 2, Z 2 3, Z 3 4 and Z 4 5.

So, Z 1 2, Z 2 3, Z 3 4 and Z 4 5 other entries are 0 and here where I am Z 1 to Z 2 3 and directly Z 3 6. So, Z 1 2, Z 2 3 and this is 0 0 and here where having Z 3 6 and 0 and last equation if you see we are having Z 3 4, Z 4 5. So, here Z 1 2 this is not there Z 3 4 we are having, Z 4 5 we are having and Z 5 6 we are having, so here there is Z 5 6 is coming and I 3 6 is getting multiplied with respect to minus Z 3 6.

So, if you write this equation into matrix form we are getting this equation here and this we call at BCBV matrix basically branch current to bus voltages. However, it is not exactly the voltage here, so we can write this collectively here. So, up to this term I am calling delta V which are voltage difference and this I am calling matrix of 0. So, depending upon number of loops in your system the size will be decided.

So, there are N number of loop there will be N number of rows of 0 voltage into your matrix system. So, here I can just write this it will be delta V and then 0 will be equal to your this BCBV matrix multiplied by again.

If you see up to this up to I 3 6 from I 1 to we are having I branch because, these branches are basically radial branches and then I 5 6 which is basically making loop. So, that current I am writing has a loop current, so depending of 1 number of loop forming branches this loop current entries will be decided. So, I divided this into 2, so let say this is equation number double I. So, equation number is 1 and 2 I can just take on this slide.

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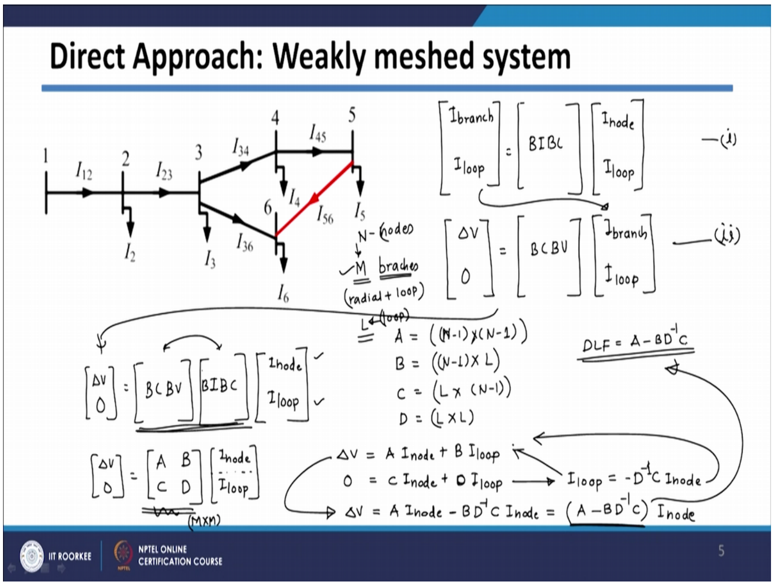

So, first equation which we have got is I branch equal and then I loop which is equal to your BIBC matrix. And this was equal to your current I node and then this again it was I loop and then this was your for equation number 1 we had got and then if you had got delta V 0 which is equal to your BCBV matrix and this is getting multiplied by I branch and I loop here, this is your equation number 2 and what I can do actually I can just put this equation into this here.

So, it will basically become your delta V 0 will be equal to BCBV matrix multiplied by your BIBC matrix multiplied by your I node minus this I am sorry I loop here. So, now we can see that in this case this I node currents are actually known because, they we can calculate them from the loads which are connected at each node.

However, this I loop currents are unknown so we need to eliminate them, so to do that let see this multiplication if you do that is BCBV multiplied by BIBC, so it will be delta V 0 and let say this matrix is having 4 terms A, B, C and D after making the multiplication multiplied by I node and I loop.

Now, this size of this matrix will be M by N, if there are M number of branches if there are N number branches in the system; size of this matrix will be M by N number of branches consisting loop branches also excluding radial branches plus plus loop branches. If you consider both if there are NM number of branches means size of this will be M by N, out of this your size of A matrix will be N minus N minus 1 by N minus 1 where we know that N is actually 3 number of nodes in the system.

So, N minus 1 by N minus 1 which will be size of A matrix, size of B matrix will be there will be N minus 1 rows and there will be L number of loops say L number of loops are there, then size will be L columns will be there in B matrix in C matrix there will be L rows multiplied by your N minus 1 columns and D matrix will be L by L.

Where L is actually loop forming branches and capital M is I am considering total branches at including radial plus loop. Now if you see this equation here and as I told you this loop currents are unknown and we want to eliminate them, what we can do this equation I can write into 2 equations.

So, delta V will be equal to A into your I node plus B into I loop and second equation 0 will be equal to C into I node plus your D matrix into I loop this is your D matrix. And from this equation I can just write your I loop will be equal to minus D inverse into C into I node and this equation I can put into this equation means instead of I loop I can it replace it by minus D inverse C.

So, I can write this equation delta V, so delta V now will be equal to A into your I node plus or here that will be minus because, that minus sign is coming from this equation here. So, it will be minus B into D inverse into C I node. So, this I can write by taking I node common out, so A minus B into D inverse of C into your I node.

So, now we have got this matrix here which will become your new DLF distribution load flow matrix similar to your radial system. So, for weakly system weakly meshed system your DLF matrix will be equal to A minus B into D inverse C and your algorithm will remain same exactly same as we are using radial system and you what you have to do whenever there are weakly meshed system, you have to get the DLF matrix using this particular equation here and once you get the DLF matrix for weakly meshed system, exactly same algorithm which you developed for radial system can be used.

Now, to understand this process let us take one example or before going to the example let us say how we can calculate this modified BIBC and modified BCBV matrix matrices directly ok.

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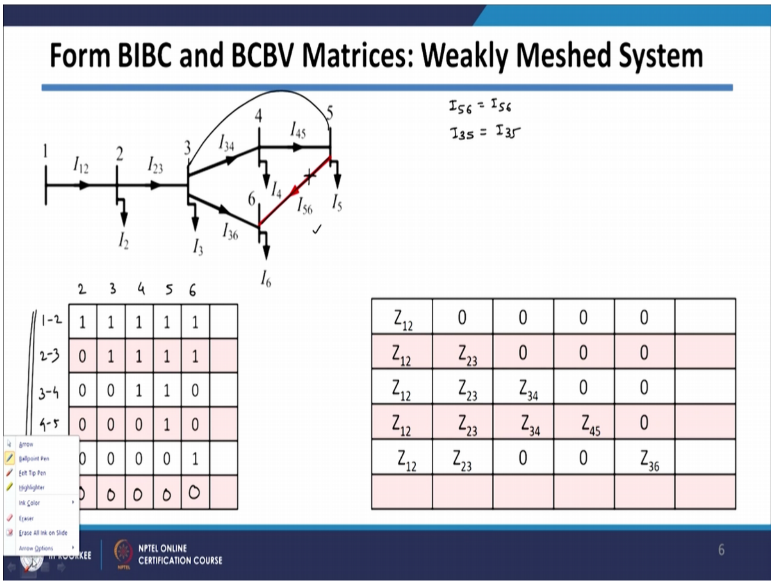

So, let us see consider this example again and when this system was radial we already considered it and when this branch was not there and when we are got your BIBC matrix earlier that BIBC matrix was what whatever I shown it here and we are got this matrix here.

So, these are basically we seen that we give node number here 2 3 4 5 6 and here we give your branch numbers that is 1 to 2 2 to 3 3 to 4 4 to 5 and 3 to 6 these are basically radial branch number. So, we already seen that how to get this particular BIBC matrix and we already seen the algorithm and this example also you have seen we have seen.

Now let s see when we are added this branch here and which is basically making it weakly meshed system and this branch is basically 5 6 branch and we have seen that earlier when we have written, so this 5 6 branch I am writing it here and as I told you 6th equation which you added earlier is involving only loop branch current means, I just I have written sixth equation when we are found BIBC I had written I 5 6 is equal to I 5 6.

So, if they are many number of loops say one more loop add between say 3 and 5, same one more equation which you will adding if there is I 3 5 is equal to I 3 5.

So, here all these entries will basically will be 0 only, so in earlier equation there is no term which is related to I 5 6. So, I will just erase this, now when I am adding the branch which is basically I 5 6 this 1 what we need to do we have to subtract your column 6 from column 5.

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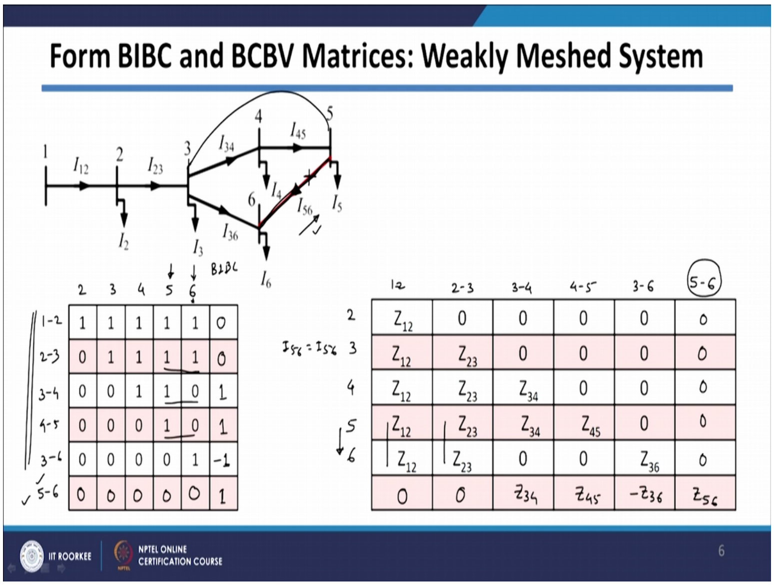

If you are considering direction of this current in this branch is from 5 to 6. So, subtract 6 from 5 if you are considering in opposite direction subtract 5 from 6 ok.

So, in this case we are considering current is starting from 5 and then ending with 6, so we need to subtract this column 6 from 5. So, in this case this 1 minus 1 it will be 0 here also 1 minus 1 it will be 0 here it is 1 minus 0.

So, it should be 1 here and 1 minus 0 it should be 1 here and here 0 minus 1. So, it will be minus 1 here and as I told you we are considering this equation that is I 5 6 is equal to I 5 6 that is why we will get 1 here.

So, you can see that once you form your radial BIBC matrix, you can immediately convert into weakly mashed BIBC matrix, just by knowing which branches are making loops. So, if you know that you can easily find your BIBC matrix here by using the algorithm which I just explained it here.

So, as I told you whenever we are considering branch from 5 to 6 subtract 6 from pip node. In BCBV also we can use same philosophy ah, so we have seen that here we give node numbers so 3 4 5 and then 6 and here we give branch numbers. So, it is 1 to 2 2 to 3 3 to 4 4 to 5 and 3 to 6 and this corresponding to 5 to 6 and we have seen when we have wrote the equations for forming the BCBV matrix in this.

So, in first 5 equations we are not getting any term related to I 5 6, so here in any of the equation we have not getting any term which is related to 5 6. So, basically in first equations we are not getting any terms which will 5 6, so so we need to put 0 there. So, we need to add column 1 column which is basically 0 0 0 at 5 6 line and then similar since I am adding branch form 5 to 6 direction of current is from 5 to 6, then you need to subtract sixth row from 5 th row.

So, in this case it will be Z 1 to minus Z 1 2 it will be 0, Z 2 3 minus Z 2 3 0 it will be Z 3 4 minus 0. So, Z 3 4 Z 4 5 minus 0 Z 4 5 0 minus Z 3 6 it will be minus Z 3 6 and here as I told you and second step you need to replace this entry by impedance of Z 5 6, so here we need to put impedance of Z 5 6.

So, you can see that by using this logic here you can add many more branches in to your system, which makes your system weakly meshed. So, we have got this BIBC and BCBV matrix and we have seen the algorithm also how we can modify your radial BIBC and radial BCBV matrixes. So, that we can get it for weakly meshed system depending upon which lines are making loops.

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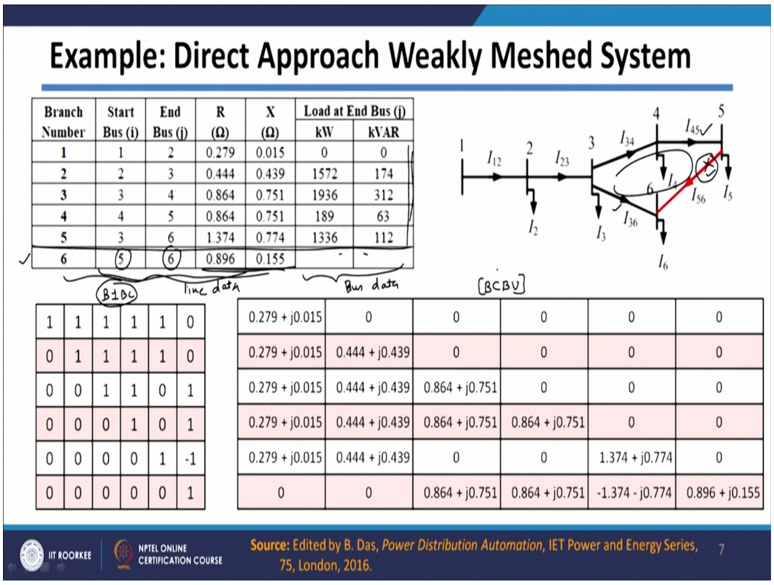

Let us take one example which illustrate this process here we already seen it just I will show you how we process it here. So, as I told you in the same example ah, so we are used data till this point added one more line which is from 5 to 6 having impedance given in this column and then loads at each node already considered so there will not be entries here.

So, this is your line data of weakly meshed system and this is your note data or bus data of weakly meshed system and using these columns we form your BIBC and BCBV matrixes. As I told you first right open the loop forming branches you can open any branch if this loop is getting formed here, you can open this branch or this branch or this branch any branch can be opened and that will be considered as I loop branch and first find BIBC in BCBV matrices for radial system and then modify these matrices including each of the loop forming branch.

So, if you do that you will get BIBC matrix we have seen already how we got it and then BCBV matrix also you have scene which you have got here I just put the impedance actually impedance values, so this is your BCBV matrix and then we have seen we multiply them.

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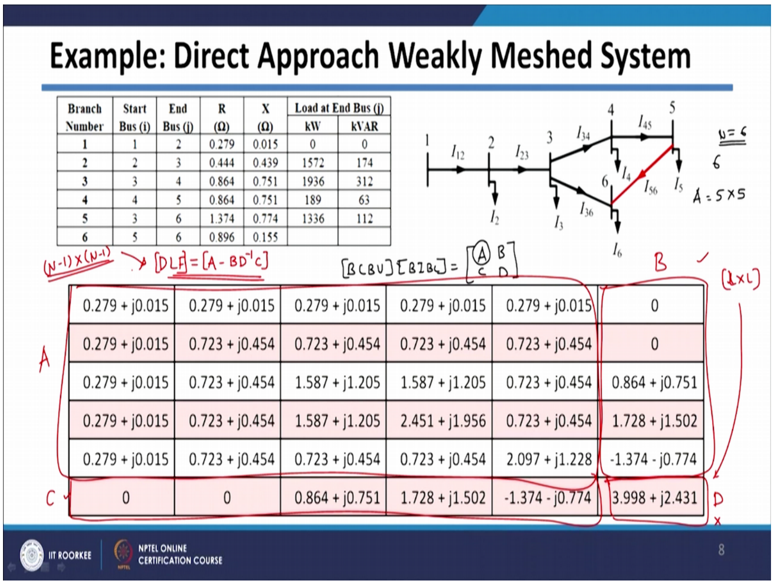

So, BCBV multiply by your BIBC matrix and that we have seen that we get that A B C D matrix which explained in weakly meshed algorithm system. Where A we have seen N minus 1 by N minus 1 here the number of nodes are 6, so size of a will be actually 5 by 5 N minus 1 by N minus this 1 because, your N is actually equal to 6 total number of nodes are 6.

So, here so this will form your A matrix, this will form your B matrix this will form your C matrix and this will form your D matrix. So, if there are actually number of loops are more, then there will be more number of rows in C matrix similarly there will be more number of columns in B matrix and D will be depending upon number of loop multiplied by number of loops. So, it will be L by L size in since in this case only 1 loop forming we are considering the size of DVS 1 by 1 and then we have seen that the distribution load flow matrix DLF, we have got which is equal to A minus your B into D inverse into C and if you do that this operation we have seen that this size of this DLS matrix is basically N minus 1 multiplied by N minus 1. So, it will be N minus 1 by N minus 1 size of this DLF matrix.

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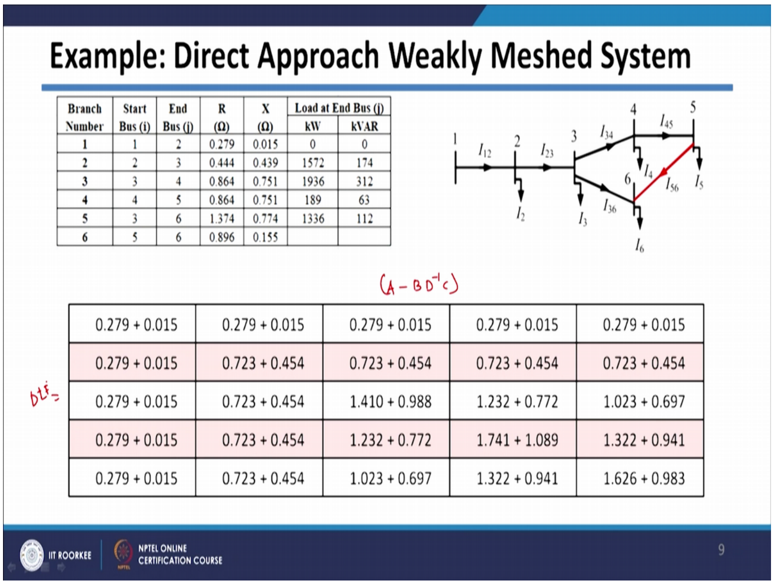

So, from this if we get this DLF matrix by doing A minus B into D inverse C, you are you have got this DLF matrix for that same system and once you get the DLX matrix your algorithm will be same exactly same algorithm you can use.

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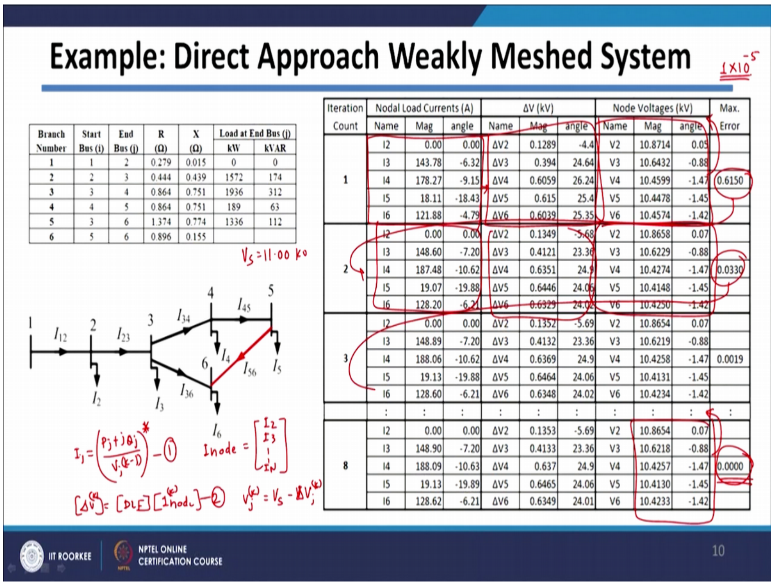

That is basically first calculate your nodal current using this equation divided by vj which is calculated at early iteration take star of it. So, it is equation number 1 equation number 2.

So, it will give you I node matrix which is basically I 2 I 3 up to in and then we get delta V which is basically DLF matrix which you have formed in last slide multiplied by your I node matrix and this is your equation number 2 and the third equation is Vj at Kth iteration will be equal to Vs minus delta V j at any Kth iteration.

So, here we are getting at kth iteration using nodes I node current at k th iteration and then as I explained in case of direct approach based method ah, the process will get repeated that is first gate nodal values of current. In first iteration we calculated this nodal value, nodal load currents by using voltage which is equal to 11 KV at each of the node.

So, Vs is eleven Kv then using equation number 2 gate delta V then using equation number 3 update the voltages, then compare with voltages earlier iteration get the error go to next station again calculate current delta V update the voltages get the error and keep on repeating.

Till we actually converts to result where error between voltages of this iteration and already earlier iteration are negligibly small or you can say below the tolerance value. In this case we have considered tolerance values is 1 into 10 raise minus 5. If you are keeping lower tolerance value it will take more iteration if you are keeping less tolerance value it will converge in few iterations.

So, here for this particular tolerance value the algorithm has converged in 8 iteration. So, in today's lecture we have seen how we can get or how we can consider weakly meshed system to solve the load flow problem, because till now before this lecture whatever systems we have considered where radial and in this case first we have seen how we can consider this loop forming branches and how to get BIBC and BCBV matrix.

And then we have seen if you are ready the BIBC and BCBV matrix for a radial system, how we can modify these BIBC and BCBV matrices to include loop forming branches. So, that modification or simple algorithm I explained you and once you get this modified BIBC and BCBV matrix, you can get modified distribution load flow matrix by dividing the multiplication of BCBV and BIBC into 4 parts and once you get that DLF matrix your algorithm will be same as earlier which is used for radial distribution system.

So, here we complete the direct approach based method and I was considered one example also which illustrate, how we can use this direct approach based method for a weakly meshed system. So, next time we will see one more algorithm which is based on implicit Z bus matrix.

Thank you.