Electrical Distribution System Analysis
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Lecture - 36
Direct Approach for Short-Circuit Analysis: Introduction and LG Fault

Dear students, we are learning short circuit analysis of distribution system. In the last class, we have seen one of the phase variable method where we have seen that we can get fault current for various faults in the distribution system by constructing a Thevenin's equivalent circuit till the short circuit point. However, if the network is very large size means there are more number of buses in your distribution system application of this Thevenin's equivalent circuit base method will become very difficult. Because it is getting this Thevenin's equivalent circuit itself will be tedious task.

In that case this direct approach base short circuit analysis method will be handy. So, in today's class, we will see direct approach based short circuit analysis. So, this direct approach based analysis we have seen in case of load flow method. So, a direct approach we are used for load flow calculations.

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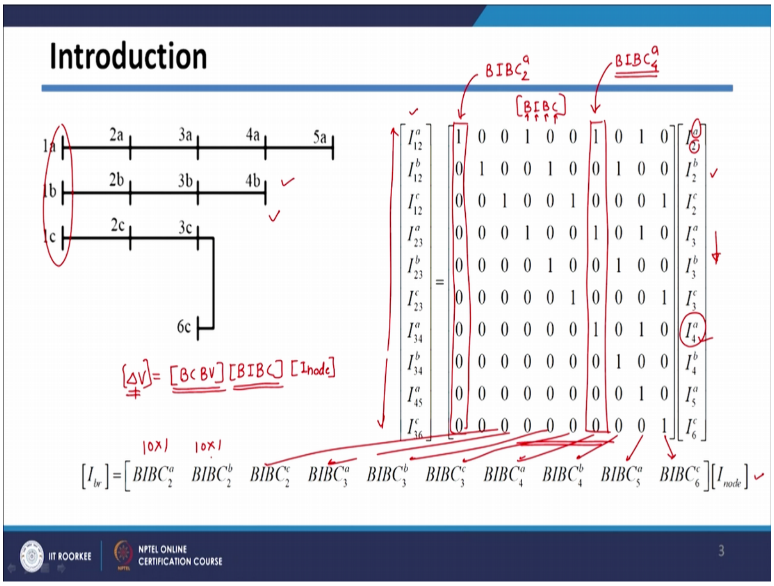

And we have seen that in load flow calculation, we have seen this equation delta V is actually equal to your matrix B C B V multiplied by B I B C into your nodal current, so I node. So, these particular equations we have solved to get the load flow problem solved.

So, in this case, voltage difference between actual bus voltage to the source bus is given by this delta V matrix. And in that case we have got these two matrices which are B C B V and B I B C. And these matrices are something like this we have seen that this B I B C matrix which basically look like this. For this particular network, if you get B I B C matrix we already, seen how to construct this B I B C matrix when we studied the load flow analysis.

So, B I B C basically it is bus injunction to branch current matrix. So, it will it will convert your load voltage load currents to branch current. So, these are basically branch current in the all the three phase branches of this particular system. And these are nothing, but load currents at each of the nodes. So, these node currents will be converted into branch current using these B I B C matrix. We have seen how to construct that B I B C matrix.

Now, for short circuit analysis, I am just modifying this B I B C matrix not exactly modifying only defining in different way, so that each of this column will be defined separately. So, say this is the first column which is actually corresponding to your node number 2 and phase a, so that is why I am calling this column as B I B C since it is corresponding to node 2 and phase a. So, it will be called as B I B C 2 which is subscript; and a is super superscript.

Exactly similar way if you say if you considering this particular column here so this particular column will get multiply to this particular current. So, this will be called as this column of B I B C matrix will be B I B C and it is corresponding to fourth node. So, this fourth will come here. And then which is again corresponding to phase a. So, phase a will come here. So, this column I will call it as a B I B C subscript 4 and superscript a.

Like this if you write for all the columns you will get matrix which is something like this. So, this column is corresponding to this. So, various columns are corresponding to various columns of this particular matrix; and then we can write it like this. So, these are basically columns which are basically number of unknown nodes first node is actually known node. So, I am just we are not considering that remaining unknown nodes. So, in this case, they are 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, so there are 10 nodes. So, this size of this will be 10 by 1 seen this column. So, all this B I B C matrixes matrices will be actually 10 by 1 size. So, B I B C we are dividing in terms of columns.

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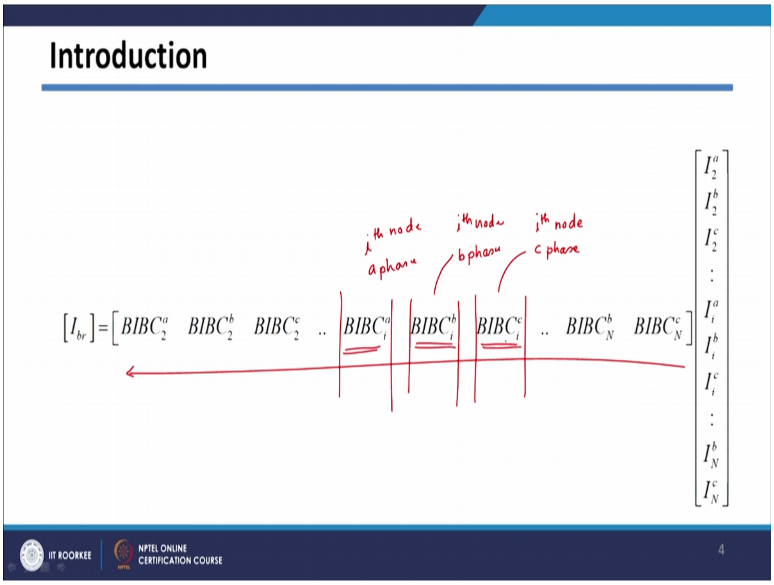

So, in generalized way, if you divide general B I B C matrix, it will look like this which are having many number of nodes here. So, corresponding any i-th node the matrix column matrix of B I B C will be called as this one. So, this is corresponding to i-th node and a phase; this is corresponding to i-th node, and b phase; and this column corresponding to again i-th node and c phase. So, this actually nomenclature is given, so that we can add it with a particular column for the short circuit analysis purpose.

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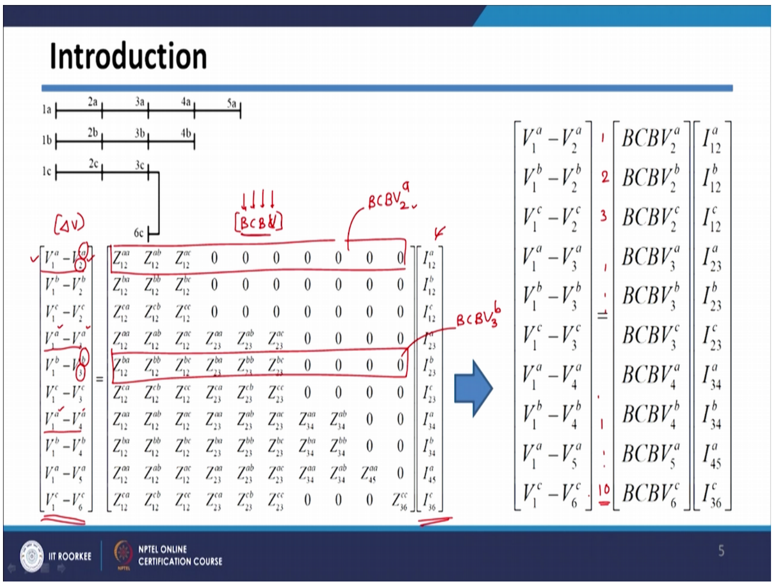

Similar way, we have this B C B V matrix. And we also seen this B C B V matrix to in your load flow calculation. So, structure of B C B V matrix will be something like this. We also we are seen how to assemble this matrix. And here this is basically delta V which gives difference between first node to the corresponding node. So, this is this gives difference of first node to second node; this gives from first node to third node of a phase. This gives from first node to fourth node of a phase like this.

And these are basically branch current, so B C B V this is V B C B V matrix basically convert your branch currents to bus voltages. So, this matrix is nothing but branch current to bus voltage matrix. So, these are the branch currents, these are the branch currents and these are the bus voltage differences. In case of B C B V, I am dividing this matrix as the row. So, this particular row, if I consider of this B C B V matrix, I am calling this row, since it is corresponding to node 2 and a phase, I am calling this row as B C B V 2 a, so this actually corresponding to node 2 a phase.

Exactly this way if you consider this particular row, here it will be called as this row will be called as B C B V; and it is corresponding to node 3 and b phase, so it will be 3 and b. Like this if you write for all the rows of B C B V matrix, they will basically look like this. So, this is corresponding first row second row, this third row like this it will be corresponding. Since, there are ten nodes unknown nodes in this particular system; we will be having ten rows in B C B V matrices. So, B C B V we are dividing into rows and we are giving correct corresponding names to B C B V rows. And B I B C we have seen we have converted into columns.

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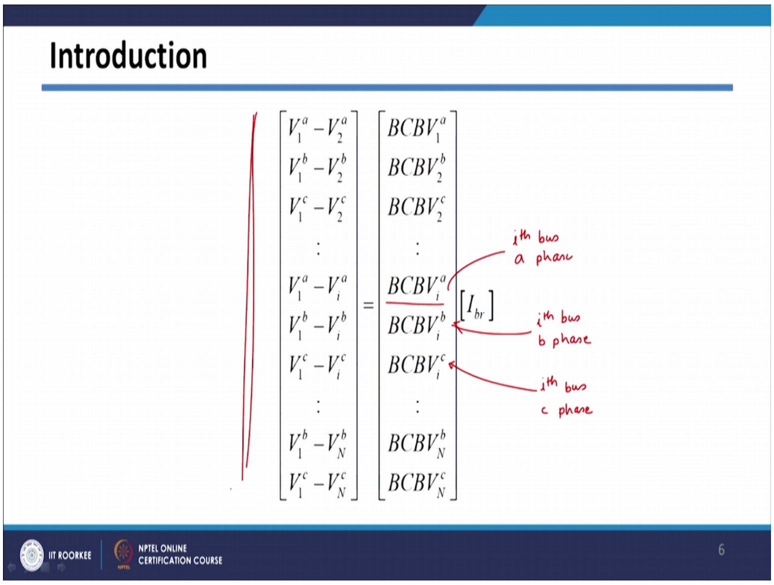

So, so B C B V in generalized way if you write, it will be like this. So, this is corresponding to your, i-th bus and a phase; this is the row corresponding to again i-th bus and b phase. And this any general row i-th row will be actually i-th bus is corresponding to c phase. So, it is generalize way of writing your B C B V matrix will be in terms of your row.

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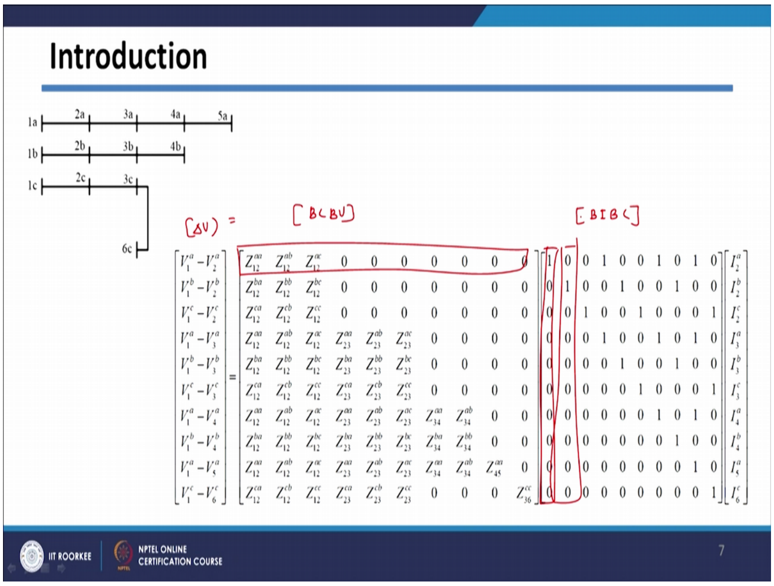

So, if you write your B I B C matrix and B C B V matrix we have seen that this is nothing but your delta V which is equal to B C B V into B I B C. And we have seen that we have converted this B C B V into various rows; and this B I B C, we have converted into various columns.

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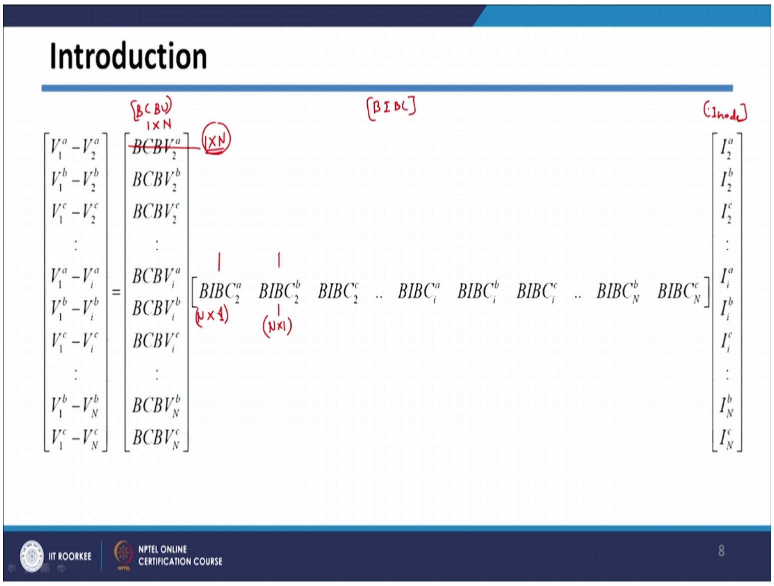

And if you do that, we are got this structure. So, B C B V in terms of this rows, so row size of the row will be actually if there are n number of known nodes it so size of this will be 1 by N, N unknown nodes; and this will be N, N by 1. So, each of this component column of B I B C will be N by 1 size. And each of this row of B C B V matrix will be 1 by N size.

So, there will be one row and N columns into this matrix. And this is your B I B C as I told you and this is your I node. So, in short circuit analysis, we are going to use this nomenclature of B C B V and B I B C matrices; and we are going to use it for corresponding fault analysis.

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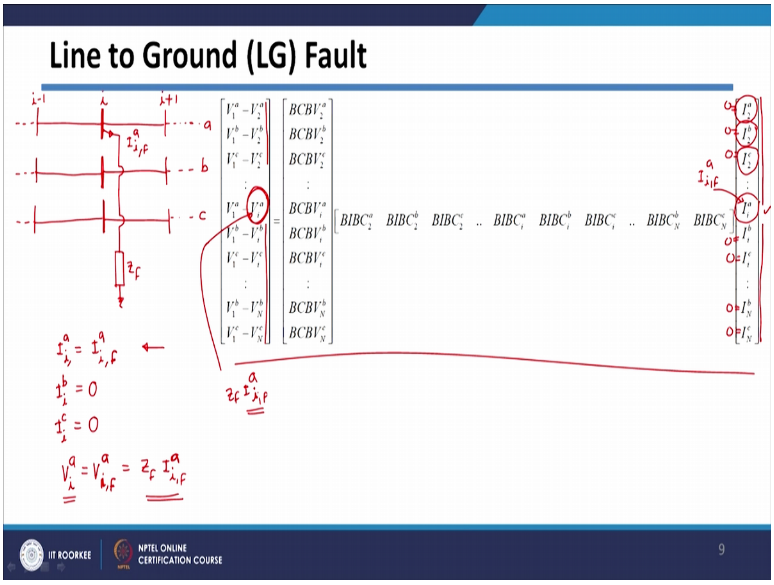

Now, let us starts with common fault which is most occur in our distribution system that is line to ground fault where one line get short circuited. So, let us say your generalized system is something like this, where this is say i-th node. And this is just node before i, this is just node before vector i. So, this is will be say i minus 1. This is i-th node and this is say i plus 1th node. And this is part of large system. So, just I have shown only three buses, there may be very large number of buses in the system. Now, I need to show b phase also. So, this is your b phase. And this is your say c phase. And these are also part of very large system. So, I show dot here.

And so this is your a phase, b phase and c phase. And let us say this line to ground fault is occurring on a phase. So, if the line to ground fault if it is occurring on a phase, this will be represented by this section. And this fault impedance is say z f. And the fault current which is flowing towards fault is say I, post fault f. So, this is nothing but your current I load current in bus I of a phase will be after fault it will be so this comma f represent post fault quantity. So, post fault current of a phase of i-th bus will be given like see this one.

Now, this fault current is very large as compared to your load currents. So, load currents will be negligible as compared to fault currents. In that case, since all other nodes like this node of b phase or node of c phase they will be serving load currents which are basically negligible. So, we can say that I b phase current will be almost equal to 0 as compared to a fault current. Similarly, I can say c phase current of i-th bus will be also equal to 0. Also all other currents means load currents at I minus oneth bus or any other bus of all the three phases they will be equal to 0 because they are also negligible as compared to your short circuit current in phase a.

Therefore I can write the voltage at this particular bus i-th bus of a phase so that voltage I can write V i a which is then post fault, it will be I am writing it as a voltage of i-th bus and ath phase and F I am writing for post fault. So, if you observe this post fault voltage here, this current is flowing like this because of that the voltage at this point because of this fault impedance will be equal to your z f multiplied by fault current which is i-th ith bus fault current in phase a.

So, this will be your voltage post fault voltage at bus I a phase. So, basically we have this B I B C normal B I B C and B C B V matrix generalized way. And if you see which entries of this system will change, so here as I told you all other currents are becoming zero except the current of phase a because they will be negligible. So, only this quantity will be nonzero. So, this quantity will be just fault current in a phase, all other quantities will be equal to zero in this particular matrix of right hand side, all the currents will be equal to zero. And on this voltage side if you see, this particular voltage post this voltage will change and this post fault this voltage will become equal to this voltage here.

So, this voltage I can replace it by zf multiplied by i i F. So, it is actually i-th phase current i-th bus current in phase a, where the fault is basically occurred. So, what I am going to do is I am going to replace all these currents by zero except this current all other current will be equal to zero. And then there will be post fault voltages at all the buses. And we know this voltage which will be equal to z f multiplied by fault current in a phase.

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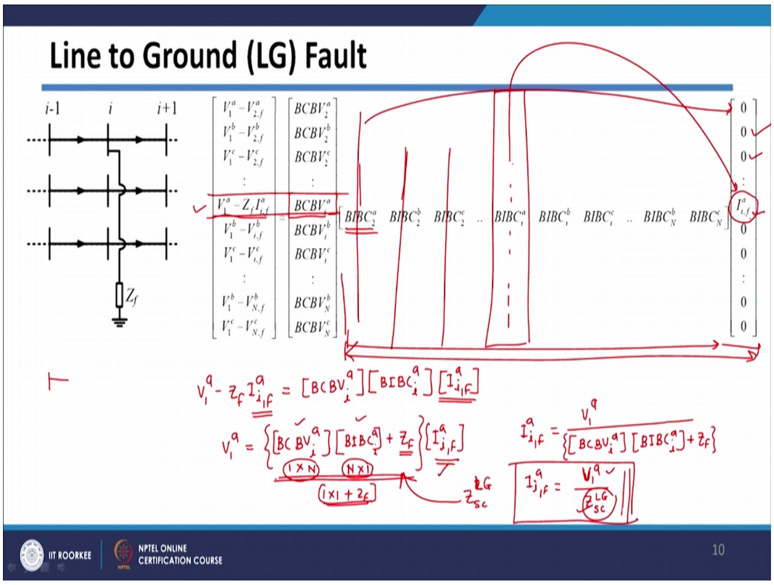

So, if you do this after replacing this voltage here, I got this term is replaced. And as I told you I am replacing all current to zero except this current here; all current will be all the currents will be negligible. Now, if you see this matrix here, and if you see this row which is basically this row, if you write the equation for this row, it will be just I am taking this equation which is corresponding to this row here. What will happen is it will be v 1 a minus z f into fault current in a phase which would be equal to it will get multiplied by this row of B C B V matrix.

So, B C B V of i-th bus and a-th phase. And if you observe this part here from here to here of this matrix part, if you see this whole column means this B I B C 2 a will get multiplied to 0; this column will get multiplied to this 0; this column will get multiplied to zero means most of the column almost all column except the column which is corresponding to this one which is basically this column except this column multiplication of all the columns with respect to the current matrix will be 0.

So, only this column multiplied by this entry because this entry will basically only multiply this column. So, only multiplication of this column multiplied by this fault current will be nonzero other automatically will be 0. So, in this column, I can easily write from the part which is from here to here I can just write BI BC i a multiplied by your fault current in a phase. So, this is the, I have done as I told you since all these columns are getting multiplied to 0 entries.

Now, if you see this equation is in terms of fault current. So, here we are getting this fault current; here also we are getting this fault current here. If you can simplify it, so let us say you can say v one a will be equal to your BC BV i a this one row B I B C i a this is one column plus z f I can take this I fault current of i-th phases i-th bus and ath phase common out this will be equal to it is basically only one entry. So, we do not have to write matrix also here.

And as I told you we are basically interested in getting the values of fault current. So, values of fault current will be since it is only one entry, I can just write of a phase will be equal to we have to take inverse of this again this will be only one entry because as I told you this will be 1 by n matrix and this will be n by 1 matrix.

So, if you multiply 1 by n to n by 1, you will get actually 1 by 1 entry plus this z f also single term which is fault impedance. So, this will be just one complex entry complex number here. So, it will be just I can say v 1 a phase divided by your this matrix which is B C B V i a and B I B C i a plus your zf. And this I can say V 1 a of divided by z sc in case of LG fault. So, basically this Z sc in LG fault is given by basically this term here. So, this term basically I can call into this particular bracket, I can say z short circuit impedance in case of LG fault.

So, if you divide this with respect to V 1 a, V 1 a is known because this actually as I told you V 1 a is actually voltages at the first or source bus where as I told you voltages of the source bus are known. So, this is known and this we are calculating just based on B C B V and B I B C matrices. And as we have seen earlier this B I B C and B C B V matrices are just based on the line impedances and your topology of your network, we can get these B I B C B C B V matrices. And they are not they are generally available with us and a fault impedance value is also available and from this I can get this fault current for a phase. So, this is your fault current equation which you have got.

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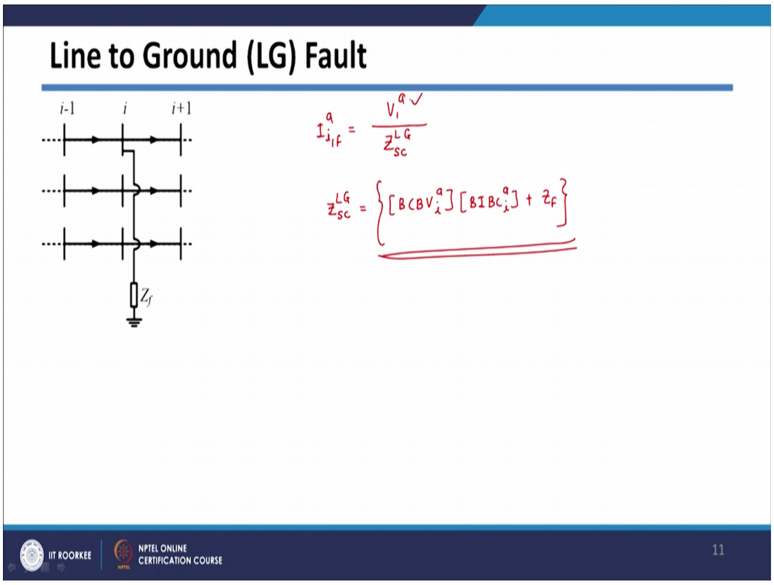

So, basically what we got in this case the fault current equation V 1 a divided by your z short circuit in case of LG fault. And this z short circuit in case of LG fault, we have got this matrix here plus your z f. And we can easily get this matrix, this is known, so we can calculate your fault current. During the short circuit calculation we are also interested in calculating post fault voltages. So, let us see how we can calculate this post fault voltages.

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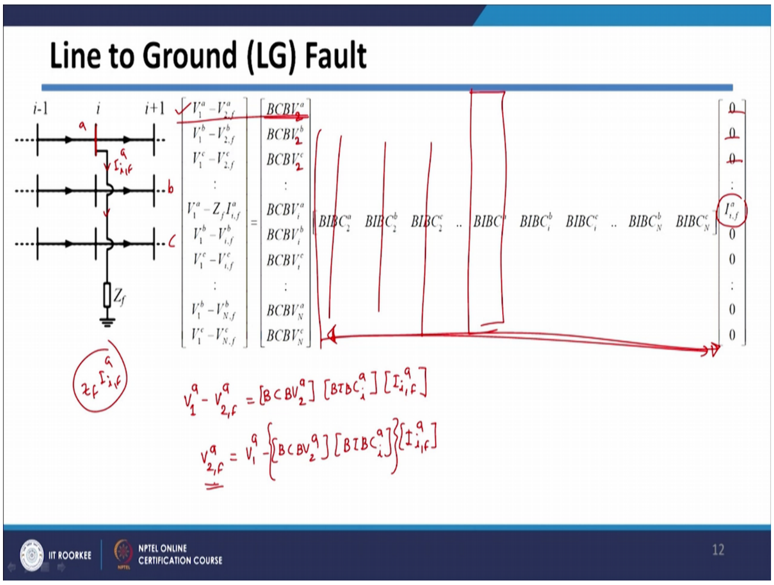

Again I am taking that same equation which you have got so only in that B I B C and B C B V matrix, we want just change this quantity here. As I told you here the voltage will become Z f multiplied by current which is flowing through this one is fault current in a phase. So, it will be fault current in a phase; so voltage of this i-th bus of ath phase, so this is are a, b, c phases. So, it will be given by Z f multiplied by the fault current in a phase of i-th bus.

And here as I told you only one entry will be existing because all the other currents will be negligible as compared to these fault currents. So, all the load currents I have considered 0 that I already explained you. So, if you observe this equation here, so if you want to calculate any post fault voltages, so say you want to calculate post fault voltages of this particular bus means bus 2 and a phase. So, I can easily write from this particular row equation it will be V 1 a minus V 2 F a which is actually post fault voltage of bus 2 and a phase which will be equal to. So, this particular row B C B V it should be actually 2, 2, 2 here. So, it is 2 B C B V 2 and a phase.

And here as I told you we already simplified this part of the matrix. And as I told you of all these all other column they are getting multiplied with respect to 0. So, they are not contributing anything. So, immediately we can write this total part as just multiplication of column which is corresponding to this I F. So, basically corresponding to if you are having this column here which is B I B C i a multiplied by your F.

And we can easily write now. So, V post fault voltage of bus 2 a phase will be equal to V 1 a minus your this part here that is B C B V of 2 a; and B I B C i a into your fault current which we already calculated. So, this fault current is known only one quantity. And then we can get the post fault voltage of the bus 2. We can also write this equation in terms of all the three phase quantities. So, if you are taking all the three phase quantities together say you want to calculate of this particular bus all the three phase voltages.

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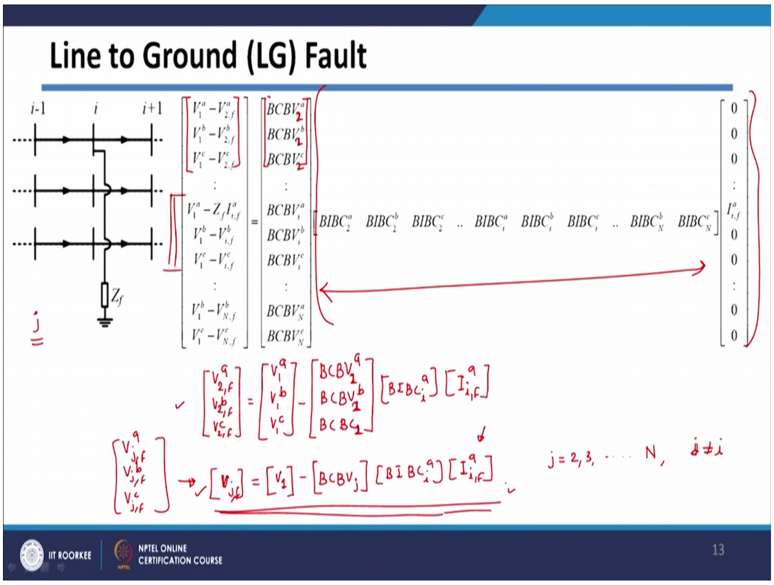

So, I can just write it like this. So, similar to earlier slide I can just directly write it. So, V 2 F a phase V 2 F of b phase V 2 F of c phase post fault voltages of all the three buses will be equal to V 1, V 1 b, V 1 c minus and I need to take all the three rows now BC BV 1 a, B C B V 1 b, B C B V 1 sorry here they are this is two actually. So, this is 2 corresponding to second row because first row is a known row. So, first node is known node. So, we are not considering that. And it will get multiplied and as you know the simplification of this part of the matrix we also seen that it is just B I B C i a multiplied by f a.

And this is for say second node, we can generalize way we can write it like this. So, for all the three phases collectively, I can write for any j-th bus any j-th bus, I can write V j this consists of all the three phases means it will be this matrix will be basically V j F a phase V j F or b phase V j F of c phase post fault voltages of j-th bus of all the three phases. So, instead of writing a, b, c, I am just writing this as a whole three phase voltages. Here also instead of writing a, b, c, I am just writing three phase voltages. So, it is a just I need to write as it as V 1 minus this will be again instead of writing all the three phase rows I can say BC BVof any j-th phase j-th of bus for all the phases. And here this will remain same B I B C i a and it will be I i F.

So, for any general bus I can calculate post fault voltages. So, this is I just write post fault j comma f. So, any post fault post fault voltages of j-th bus, we will be calculated using this equation. And this fault current is already calculated, so we can get the voltage post fault voltages. And here we can vary this j from 2, 3 up to n, n unknown buses. And then only thing is you should know this j should not be equal to your i-th bus because i-th bus you are not this equations you are not considering all other buses except I bus you can get the all other bus voltages for all the three phases using these equations.

So, in today's lecture, we are started with direct approach based short circuit analysis. In that case we have made use of the direct approach based analysis which you have studied in load flow analysis where we have studied this B I B C and B C B V matrices. And in this particular short circuit analysis, we try to make use of those matrices by dividing these matrices in terms of rows and columns. And we have also studied one fault that is line to ground fault which is mostly occur in our distribution system.

In the next class, we will see few more faults which can be studied using this direct approach based method.

Thank you.