Basic Electrical Circuits
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Lecture - 37
Number of Independent KVL Equations
and Branch Relationship

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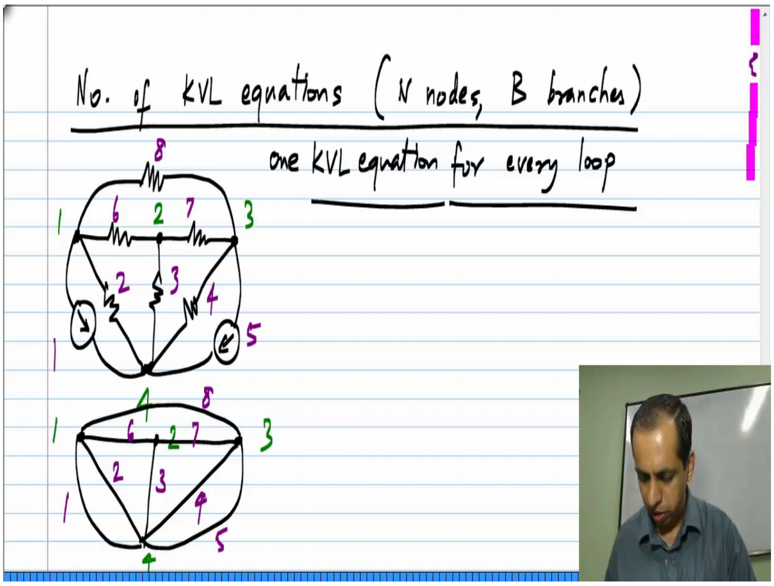

We have determined the number of KCL equations. Now similarly we have to determine the number of KVL equations that we can write for a circuit with N nodes and B branches. Now this is slightly more complicated then counting the number of Kirchhoff's current law equations, but of course, still can be done. I still considered the same circuit 1, 2, 3, 4 nodes and 1, 2, 3, 4, 5, 6, 7, 8 branches. So, now how do we count the number of KVL equation; first of all we write KVL equation around loops. So, there is one KVL equation for every loop, and we have to find the number of independent loops. By independent loops I mean for instance these branches 1 and 2 form a loop; branches 1, 6, 3 form a loop; branches 2, 6, 3 also form a loop.

There are three loops, but it terms of there are only a independent loops, so we can take either this loop and that loop or any two of them; only two of them will be independent. So, how do we form independent loops; to discuss this efficiently without rewriting the circuit every time, I will introduce the concept of the graph of a circuit. The graph of a circuit is nothing, but basically the same topology the same nods and branches, but we are not worried about what the branches contain, what elements there are. So, these are used for discussing general properties of circuits. So, we do not worry about what the elements there are, we simple denote each of them by a line. So, the graph of this would be the same number of nodes. We have the four nodes and eight branches. Graphs are widely use for analyzing general properties of networks, and there is a lot of theory behind it, but for us basically it is simple depiction of the circuit, so that is we are going to use that far. And our goal right now is to find the number of independent loops in this graph.

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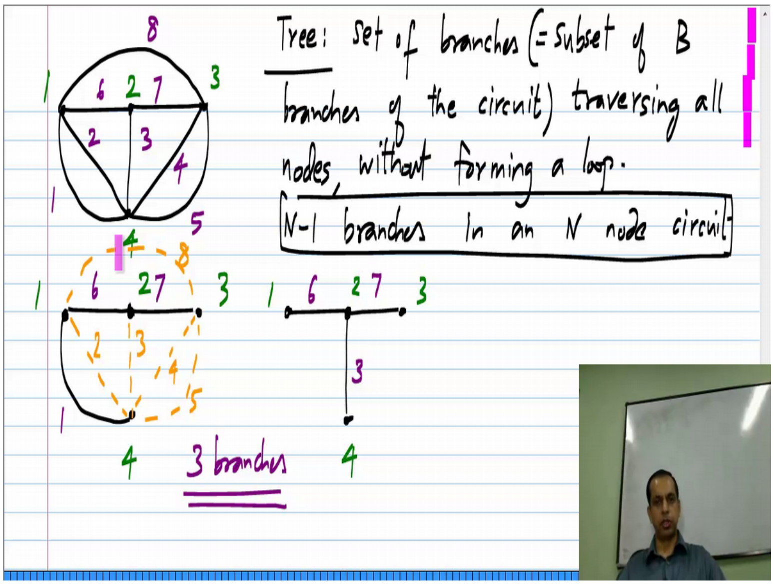

To do that let me redraw the graph over here. So to count the number of independent loops what we do is first form what is known as a tree. Now what is that tree, tree is a set of branches, which is basically a subset of all the branches; subset of B branches of the circuit which traverse all the nodes. So, all nodes should have at least one branch connected to it, but without forming a loop. So, this should be clear, if I show an example, they can be many trees, there are many, many possibilities, but you can start from any of them. So, let me show you one example of a tree. So, these are the four nodes and I will take branches 1, 6 and 7. So, 1, 6, 7, so clearly all four nodes at least one branch and there is no loop form yet of course, this is not only trees that possibly there are so many others, you can just take this graph and then form them yourself. I will show you just one other example.

Again so I can take these branches, these three branches and every branch 6, 7 and 3; again we have a tree and all nodes are connected to at least one branch, but there is no loop, so this is also a tree. And you can for many others. Now one thing a notice is that both of these trees that they have 3 branches and you can check and make any number of trees, you can from the circuit and you will find the all of them will have 3 branches is this the coincidence of course not, we have n nodes, you start from one node you go to the next one, you order the nodes any which way you want I have in this case shown 1, 2 3 4, but you could also have done 1, 2, 3, 4 etcetera, you take any ordering of the nodes many of connect branches from node 1 to node 2; node 2 to node 3 and so on.

So, clearly in going from node 1 to node N by connecting a branch between every successive pair of nodes, you will have N minus 1 branches. So, if you have N nodes the tree for the circuits will contain N minus 1 branches. So, there will be N minus 1 branches in an N node circuit. So, remember we are starting off with the circuit with B branches, and out of that we will take it N minus 1 branches to form the tree. So now what next, so it is must be pretty obvious what is coming next now; if I have a tree what do have, I have branches connecting every node of the circuit and there is no loop yet. Now if I had of any more branches that is for instance here I have taken branches 1, 6 and 7. So, what I have a left out are I will show them with dash lines, I have left out 2, 3, 4, 5 and 8. It is pretty obvious that to a tree if you had any of the remaining branches you will form a loop. So, if I add branch 2, there will be a loop here; if I add branch 3, there will be loop over there; and if I add branch 8 there will be loop form by branches 6, 7 and 8. So, once you have a tree, you add any branch to it you will form a loop. So, now, it is here very easy to count the number of loops.

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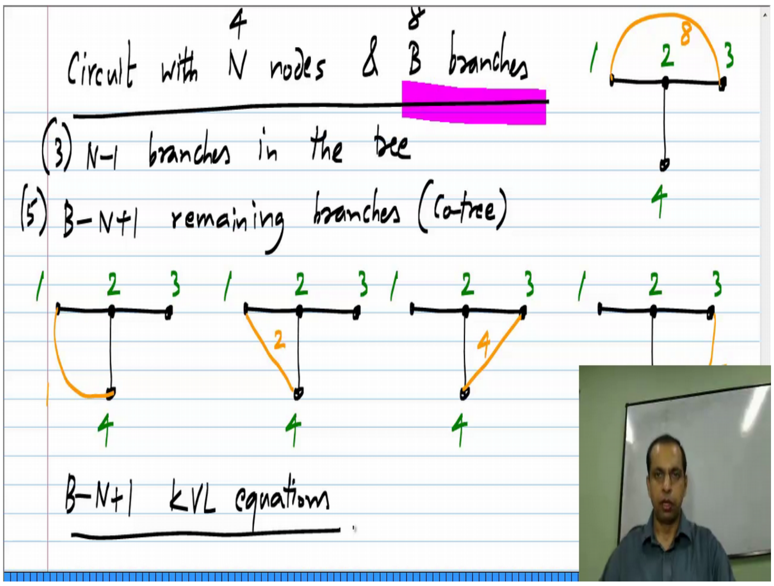

We have a circuit with N nodes and B branches and circuit with N nodes will have N minus 1 branches in the tree. Now out of B branches, if you take out N minus 1, we will have B minus N plus 1 remaining branches, which is also called the co tree. Now introducing each of these B minus N plus 1 branches to the tree will form a new loop. So, what you do is you first form a tree and then you take this branches one by one, and add them that is you take one of this branches you form one loop, and remove that you take another branch, you form another loop and so on. So, in our particular example, we will start with let say this particular tree. So, we had let me put this down, we had four nodes and eight branches. So, we 3 branches in the tree and then 5 remaining branches, so we will have 5 independent loops that is we have B minus 1 independent loops and consequently B minus 1 independent Kirchhoff voltage law equations. So, just to illustrate this, I will show the loops. So to this, I add branch number 1 by form a loop, branch number 2 I form another loop, branch number 4, I form another loop, branch number 5 another loop, and branch number 8 another loop. So, there are 5 loops and I can have B minus N plus 1 Kirchhoff voltage law equations. So, in an N nodes circuits, we have N minus 1 KCL equations and N node B branch circuit we have B minus N plus 1 KVL equations.

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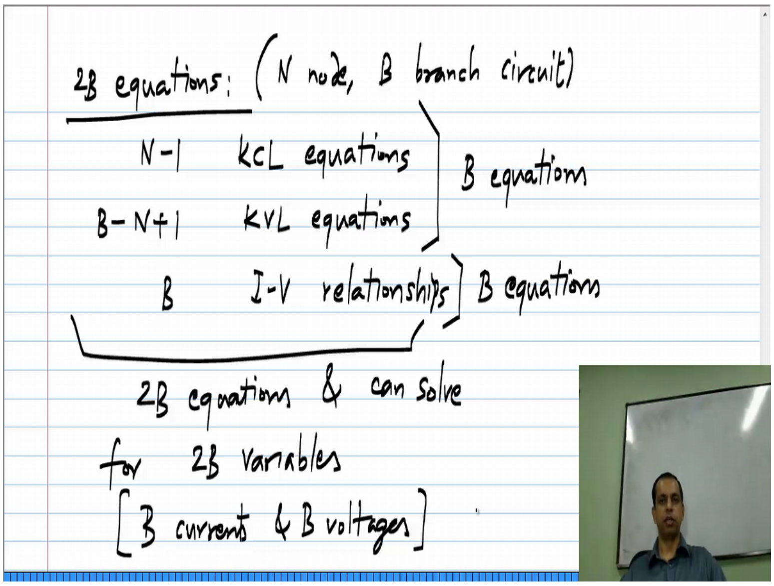

So, earlier we said that we have to solve for 2 B variables. Now let us see how we get the 2 B equations, where do we get them from first of all we have N minus 1 KCL equations. So, this is for an N node, B branch circuit. So, N minus 1 KCL equations, B minus N plus 1 KVL equations, and these two together will give us B equations. And also we have B branches, so each branch will have its current voltage relationship. So, we have B I-V relationships which give you B more equations. So, together we have 2 B equations; and by solving these, we can solve for 2 B variables. And what are the 2B variables, B currents and B voltages in each of the B branches.

So this is we setup the equations and so all for every variable in the circuit. Now what we will do is we will look at few methods of circuit analysis, now of course, it is not always that you use the systematic way of writing down all the equations and solving for every variables. We will also look at some ad hoc methods that we use and then will go on to systematic methods which you have to use when you have some more complicated circuits especially circuits with multiple sources. It turns out that when you have single source there are many simplifying techniques that you can use, but when you have multiple sources, you have to be a little more systematic.