Introduction to Electronic Circuits.
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Lecture-3.
KCL, KVL & Network Analysis.

Professor: As i told you last time, we will 1st talk about circuit laws and then we will see how these are useful in network analysis.

Student: Excuse me.

Professor: Yes.

Student: In the last lecture you talked given an example about the fuse.

Professor: Yes.

Student: How does that… What is the reasoning behind the resistance (())(2:16).

Professor: The resistance goes to infinity when the fuse melts. The heat generated is so high that the wire melts.

Student: What (())(2:30), that law will not be applicable?

Professor: Which law? Till the point of melting, yes. The heat generated is so high that it melts and therefore causes a discontinuity, the resistance becomes infinite.

Student: Discontinuity is there in the resistance?

Professor: Yes, when it becomes discontinuous then the power generated is 0.

Student: Only after it melts the resistance will become infinite, it does not become infinite (()) (2:58).

Professor: At the point, at the point of melting, we are talking about 0 - and 0+. And this relationship is only a model, it is not the actual situation, it is a model. But this is the way to see how the fuse melts. After the fuse melts the resistance becomes infinite, all right. And it gives the current at which it melts. Okay. Any other questions on the previous lecture? All right. i had explain to you the difference between a circuit and a network. A network may or may not contain a circuit, a network is a broader term than a circuit. Network may contain more than one circuit, it may also contain elements which are not parts of any closed path for any circuit.

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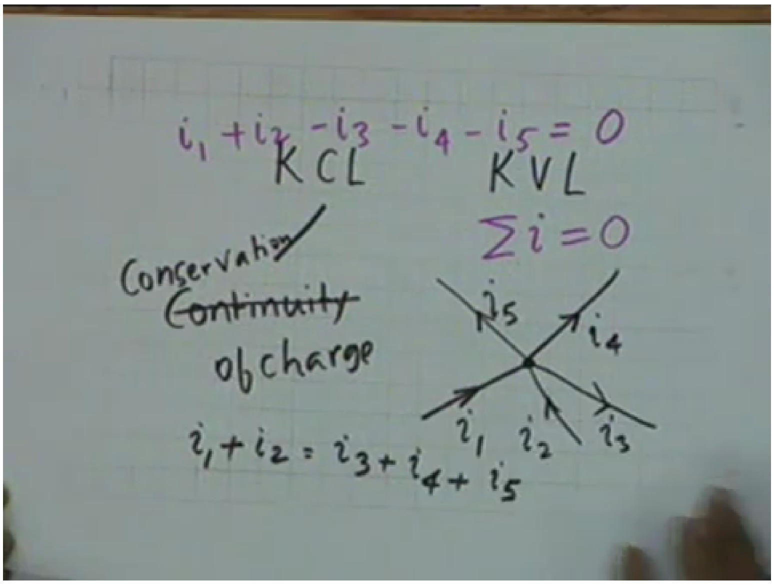

The basic tools for network analysis are due to Kirchoff, Kirchoff's current law and Kirchoff's voltage law and as you know already Kirchoff's current law is an expression for continuity of charge, continuity of charge. That is in a dynamic situation, charge cannot accumulate at any point in the network and this is expressed in terms of Kirchoff's current law. That is if we have a node, any point in the network where 2 or more branches meet is called a node.

if we have a number of branches like this meeting at this point, through some currents arrive at the node, through others the current leaves the node and let say these currents are i1, i2, i3, i4 and i5, very low KCL means that the total current entering, i1 plus i2, total current entering must be equal to the total current leaving, that is i3 plus i4 plus i5. So that over any period, any interval, the total charge that arrives at the junction leaves the junction. And this is an expression for the continuity of charge.

KvL, Kirchoff's voltage law on the other hand is an expression for continuity of energy or conservation of energy. Continuity of charge is a correct expression but continuity of energy is not a grammatically sweet expression. it is better to say conservation or you use both, for both you use conservation of charge and conservation of energy. KCL is an expression for conservation of charge, KvL is an expression for conservation of energy. Sometimes KCL is stated in terms of algebraic sum which means that each current shall then be given at polarity, it is either positive or negative.

Now any current that enters the node can be called positive, although there is nothing sacred about it, it can also be called negative. But you must be consistent, namely the current arriving at the node is considered positive, that the current leaving the node must be considered negative or vice versa. So that this relation, this relation that I wrote here could also be written like this, i1 plus i2, both are positive, i3 leaves and therefore i3 is to get a negative sign, similarly i4, similarly i5. And this gives you the algebraic sum and therefore this is equal to 0.

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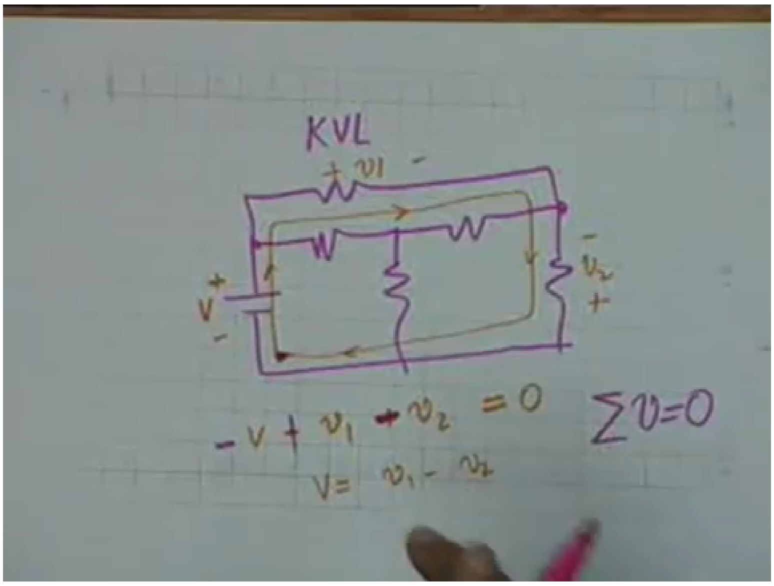

Symbolically sometimes you shall simply write Sigma Y is equal to 0. Sigma i meaning the algebraic sum of the currents at a particular node and this is an expression of KCL. KVL on the other hand relates to a closed path, a closed path. For example you have let say a battery, resistance, another resistance, another resistance here, perhaps a 4th resistance and perhaps another resistance. This is a network, all right, which contains a number of circuits one, this is one of the circuits, this is another circuit, this is another circuit. There are other closed paths, for example, for example this is a closed path, all right, there are number of circuits here, a combination of them makeshift into a network, all right.

in this network if you take any closed path, for example the closed path that i have shown with arrows you, if you take any closed path, then KVL states that the algebraic sum of the potential differences or algebraic sum of the voltage drops is equal to 0. Now let us say this battery is plus - in this direction and let say this is v1, v2 with these polarities. All right. And then when you go round this loop, when you go round this closed path, I have to fix a direction, do I go clockwise or anticlockwise. Let us say we go anticlockwise and - to plus, that is from smaller potential to larger potential, let us consider that as positive arbitrarily, we can also do it the other way round.

Let us consider that as positive, then v shall be considered positive. Whereas v1, this voltage drop, it goes from plus to -, so it should be considered as -, v- v1. Then when I come here, the 3rd element here, the 3rd resistance from - to plus, so this shall be considered positive and this sum shall be equal to 0, all right, which can also be written as capital V equal to v1 - v2 or any other way that you like. Or we could even have like this, - v plus v1 - v2 where we consider positive or negative, that is higher potential to lower potential, that is a positive potential drop for positive voltage, that is you change the convention.

Whatever be the convention, so long as you are consistent, there shall be no mistake, all right. So it is a convention if you add up this convention, then the voltage drop v if you go in this direction, the negative, this is positive and this is negative, okay. in other words sometimes we simply says Sigma v equal to 0. Now what is, where is the conservation of energy implied here? Conservation of energy is applied in the sense that you know the definition of potential as a point is the amount of work done in carrying a unit positive charge from infinity to that point, all right.

Now if you carry a unit positive charge along this loop, then you start from some point and you come back to the same point. So the total energy consumed must be equal to 0, all right, because it comes to the same point. And if you take unit positive charge through a potential difference of v, obviously the work done is v. And is you take it in the direction of potential drop, work done is positive, if you take it in the opposite direction, work done is negative. And that unit positive charge or any positive charge, any charge Q, that cancels out from both sides and therefore you are left with only voltages or potential differences.

And this basically is KVL. Did you know of this interpretation earlier?

Student: Yes.

Professor: Conservation of energy, all right. So KCL and KVL are nothing unique in electrical engineering or in network theory, they are expressions for familiar, familiar conservation laws that hold, conservation of charge and conservation of energy. Now let us see how we can use them in analysis of a circuit. We shall go through a series of examples, series of examples and illustrate how KCL and KVL are useful in solving quite complicated circuits.

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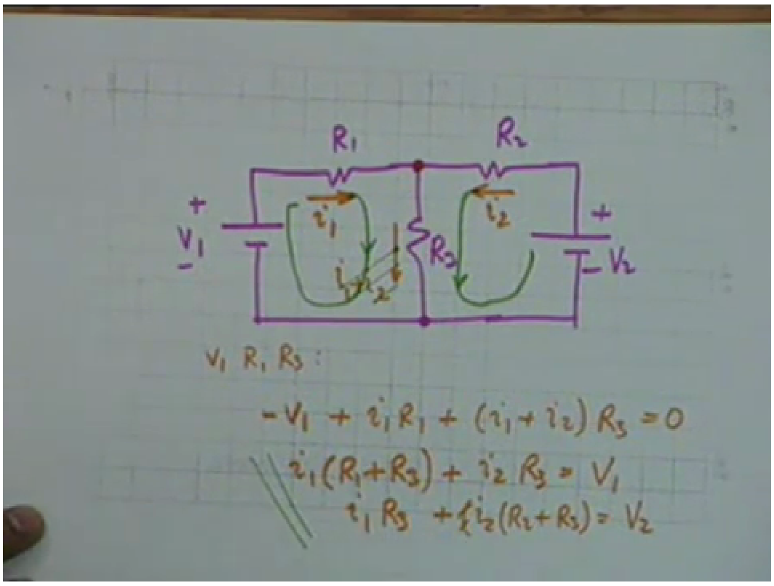

1[st] let us take a very simple circuit. Let say we have a battery v1, resistance R1, another resistance let us say R3 and a 3[rd] resistance R2 and let say we have another battery v2, a very simple electrical circuit. in this discussion and a few more, we shall confine ourselves to resistive networks alone, that is we shall not admit inductances and capacitances yet. When we admit, we shall have to change a little bit, not much and you shall say later, but it is more, it is convenient to consider the rest of circuits and constant voltage for constant voltage sources, that is batteries for constant voltage source or ideal voltage source and ideal current generators, which deliver constant currents, currents which remain constant with respect to time.

With respect to time the voltage is constant, this voltage is constant, if you use a current generator, we will assume that the current is constant, all right. That is we are considering DC sources, direct current sources, either a battery or current source. We will also consider only linear elements, no linear elements we will bring in later. All right. With these 2 hypothesis, with these 2 presumptions, we want to find out everything about this circuit, that is all the currents and all the voltages. There are several methods for solving this and i will illustrate this one by one.

One of them is that you arbitrarily assign 2 currents, let us say i1 and i2 coming out from 2 sources. Then obviously by KCL, this current must be equal to i1 plus i2, all right. Because this is a node at which 2 currents i1 and i2 enter, so the currently being must be equal to i1 plus i2. Now there are 2 unknowns i1 and i2, and therefore it suffices to write 2 equations and solve for them. And these 2 equations are provided by KVL. That is what you do is, take, take this circuit 1st, this loop, v1, R1, R3, then in this loop if you consider - to plus or plus to - as positive, then you start with - v1 plus i1 R1, this is the potential drop across R1 plus i1 plus i2 times R3, this should be equal to 0, all right.

This is the application of KVL along this loop v1, R1, R3, is that okay? Which I can write in a slightly different manner, i can write i1, by simplifying i can write i1 R1 plus R3 plus i2 R3 is equal to v1, all right. The 2nd loop now, let us take this loop, that is v2 R2 R3 in an exactly similar manner you can see that the equation that we shall arrive at is i1 R3 plus i, I am sorry i2 times R2 plus R3 shall be equal to v2. Alright. Now these are the 2 equations which now we shall have to solve. Let me point out right at this point that instead of formulating arbitrarily 2 currents like this, we could have formulated a loop current.

For example we could think instead of specifying a current here, I am taking a detour now to illustrate what is known as loop analysis. instead of, instead of applying KCL to start with, we could assume that i1 is the current in this loop, okay, and we could assume that i2 is the current in this loop, all right. Then, obviously the current, the total current in R3 shall be equal to i1 plus i2, so this is another way of looking at it. it is the same thing, it is another way of looking at it, that you formulate instead of branch currents.

You see what I did was I formulated the current in the branch R1, I had formulated a current in the branch R2 and I found out by KCL the current in the previous method, whereas instead of that, one could also do like this, one could formulate able to loop currents like this, one is i1 and the other is i2. One might ask your which direction clockwise or anticlockwise? This is absolutely arbitrary, there is no set rules, nothing sacred about it. You may set out to loop currents in any direction. if finally let say i2 comes out as a negative quantity then you know that the actual direction of i2 shall be in the other direction, that is all.

So as far as setting of loop currents is concerned, there is no sacred rule, you could go all clockwise, you could go all anticlockwise, you could go some clockwise and some anticlockwise, there is absolutely no problem. Now you see that these equations, these equations are the same if we write on the loop basis. We say i1 for example gets dropped in

R1 and R3. So i1 R1 plus R3, then across R3 i2 also drops, so plus i2 R3 and this is equal to v1. Alright. So loop analysis and branch current formulation give the, gives exactly the same results. is this point clear? We might in some instances formulate loop currents rather than going through branch currents.

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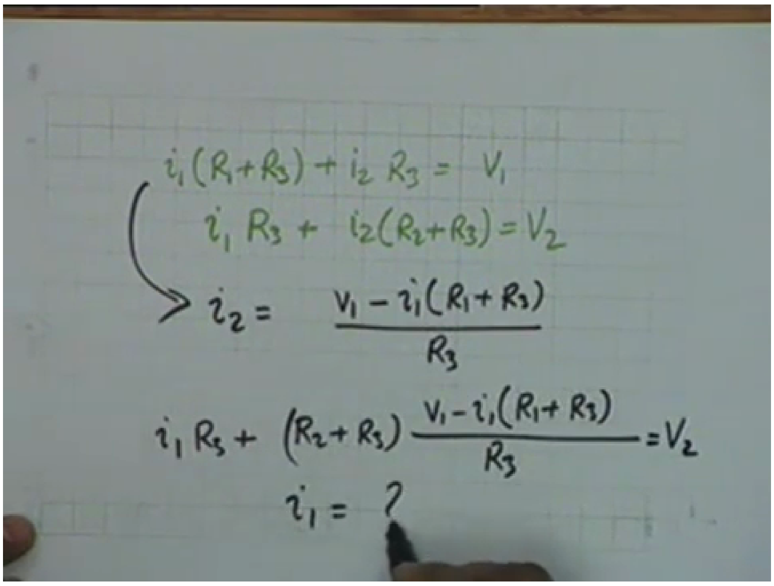

Alright, so our equations are, the 2 equations i1 R1 plus R3 plus i2 R3 is equal to v1 and i1 R3 plus i2 R2 + R3 is equal to v2. One of the simpleminded way of solving this would be to eliminate one of the variables. There are 2 variables i1 and i2, so you eliminate one of them. For example from the 1st one you would write i2, i2 is equal to v1 - i1 R1 plus R3 divided by 3, all right. From the 1st equation you could find out i2 add equal to v1 - this quantity, the whole thing divided by R3. And substitute this in the 2nd equation, that is you could write i1 R3 plus R2 plus R3 multiplied by i2 and instead of i2 you could write this whole expression v1 - i1 R1 plus R3 divided by R3 and this whole thing is equal to v2.

Now in this equation only i1 is the unknown and therefore you can solve for i1. And once you solve for i1, you can find out i2, this is the method of elimination. However, if you have more than 2 loops, let us say you have 50 loops, a power system network in which there are 50 domestic consumptions and therefore there are 50 loops, then the method of elimination becomes extremely troublesome and tedious. And therefore you need an alternative and a simpler method and this simpler method is offered by this so-called method of matrix equation solution, okay, matrices.

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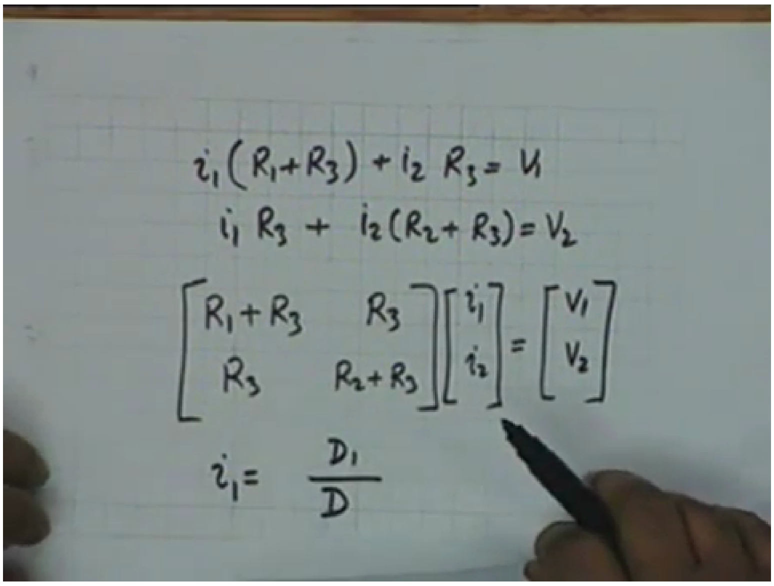

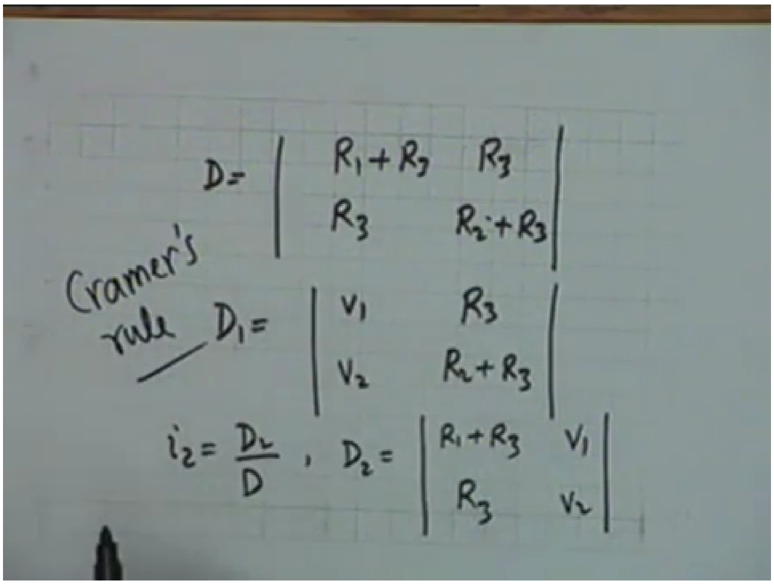

Are you acquainted with determinants and matrices, fine, that is wonderful, then we can go smoothly. Let me write down these equations i1 R3 plus i2 R2 plus R3 is equal to v2, all right. So in matrices, we write these equations in the form of a single matrix equation, that is we write R1 plus R3, 1st the coefficient matrix, R3, then R3, then R2 plus R3, this matrix multiplied by i1 i2 vector, 1 row, I am sorry one column matrix, this is equal to another column matrix namely v1 v2. And it becomes very simple to solve for i1 or i2. For example, i1 shall be equal to D1 divided by D, where D stands for the determinant of the coefficient matrix, that is D is given by R1 plus R3, R3, R3, R2 plus R3, this is the determinant of coefficient matrix.

And you know how to evaluate determinants, all right. This determinant is a 2 by 2, so product of these 2 - product of the, product of 2 R3s and D1 is the same determinant but with the 1st row replaced by the right-hand matrix, that is v1, v2, R3, R2 plus R3. Now similarly you could find i2 as D2 by D square and D2 is the same determinant but with the 2nd column replaced by the right-hand side, that is R1 plus R3, R3, v1, v2. This method is completely general, it is trivial in the case of a 2 by 2 matrix or a 2 loop network. But in the case of a general N loop network, for N is greater than 2, it is a mechanisation of solving a set of linear equations which we get by loop analysis or branch current analysis of a network.

This solution is associated with the name of a gentleman by the name Cramer. So we have applied Cramer's rule. Difficulties arise however if we have instead of only voltage sources, let us consider difficult situations. if we had a combination of voltage and current sources, let us see what happens.

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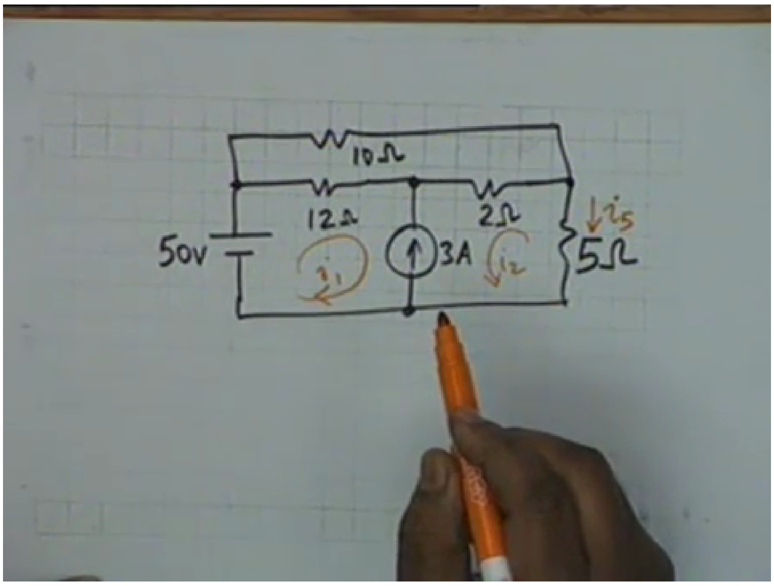

Let say we have a battery of 50 volts, 12 ohm resistance, then a current generator 3 ampere and there are 2 ohms resistance, 5 ohms resistance and to make things complicated we have another bridging resistance here which is 10 ohms. Have you been able to draw? And you want to find out let say this current, let us call this i5, that is the current in the 5 ohms resistance or any arbitrary current, that does not matter, we solve the network completely.

What is the, the problem here is the branch current formulation works perfectly all right, you can, you can formulate currents in the 2 branches, currents here, this current is a constant current source, so this is known, 3 ampere. But if you wish to formulate loop currents, then there is a problem, because this is a current generator…

Student: The middle one is the current generator?

Professor: Unfortunately, yes. Well that is a practical situation, there could be mixture of voltage generators and current generators were you have to be a little careful. For example you can say, you can see that there are, you can formulate 3 loop equations, well you could do that, except that when you formulate a loop like this and you loop currents let us say i1, obviously and a loop current here i2, all right. Obviously i1 plus i2 shall be equal to 3 ampere, -3 ampere, quite so. However do you know the voltage difference across this, you do not.

You do not know the voltage across the 3 ampere source because a current generator can deliver a constant current irrespective of the drop across this. And the drop across this cannot be determined by simply looking at the generator. And therefore you cannot write a loop equations, you cannot write a KVL around this loop is this, if the problem clear? You cannot write a KVL around this loop and therefore the better strategy is that you do not formulate loops.

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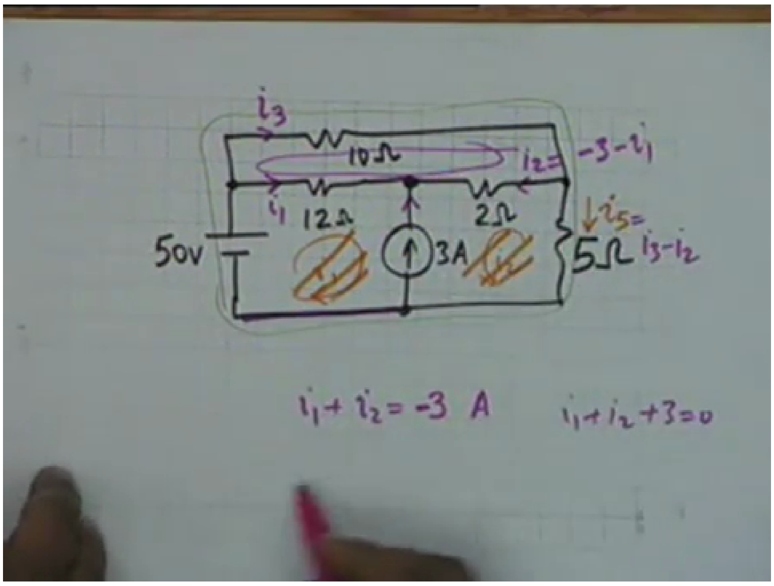

What you do is you formulate branch currents, then you will see how simple the problem becomes. Let us say this is i1 and let say this is i2, then you know that i1 +i2 must be equal to 3 ampere is, is not that right?

Student: -3 amperes.

Professor: -3 amperes, all right, i1 plus i shall be equal to -3 amperes, all right. And if this current is let say i3, you have to formulate a current here, that this current is i3, then obviously by 5 is known in terms of these 3 currents. What is i5? i3 - i2. And you also know i2, i2 is not unknown because i2 plus i1 is -3, so i2 must be equal to -3 - i1, all right. And therefore how many currents are unknown? Only 2 and it suffices to write 2 loop equations now, carefully avoiding the current generator. The current generator must not be inside the loop. So what is the choice?

Student: The bigger group.

Professor: The bigger loop when you can go like this, this is one loop and the other one is the upper loop, okay? 2 loops which do not contain the current generator, that is enough because there are only able to unknown currents. Now why is it -3, because that 2 currents i1 and i2 come here and 3 also comes here, so i1 plus i2 +3 equal to 0 and therefore i1 plus i2 is -3. Alright. Once you are able to do that, then you can solve the circuit, all right. Shall I leave the algebra to you? Okay.

Student: Sir these 3 circuits (())(29:48), it generates a current of 3 amperes but not necessarily current is in this part when making the 2 junctions, which, between which the current source lies, it is not necessary that the current in this portion is also 3 amperes.

Professor: This portion?

Student: No, the other portion in which the current source is…

Professor: You mean this node?

Student: No, the below one.

Professor: No, i do not understand.

Student: (())(30:21).

Professor: What you mean is this current, in this part or this part? Here? Oh it has to be 3 amperes.

Student: You said that there might be a potential drop across this (())(30:38).

Professor: There would be a potential… This when I draw a line like this, it is a 0 resistance line and therefore the potential drop, just a minute, in a line like this is 0. The drop occurs across the 3 ampere current source, what is inside the current source we do not know, it might contain transistors, it might contain resistance and so on and so forth, it may be an electromechanical generator. Across the terminals of the generator, there is a voltage drop, the voltage drop does not occur here, it does not occur here. Whenever i draw a line simply like this, this is 0 resistance line, all right.

So the voltage drop from here to here is the same as the voltage from here to here, agreed, which is a device and what we have shown is a symbol, is this point clear?

Student: There is no effect of the currents coming from the adjacent brands?

Professor: There is effect, i1 and i2, these 2 come here, 3 amperes also comes in and therefore the sum of the 3 must be equal to 0, that is what I wrote here. Okay. So you can say 3 ampere comes here and divides into 2 currents - i1 and - i2, all right, there are many ways of looking at it. The figure has become a bit complicated, so let us draw a fresh figure and loop at the circuit again.

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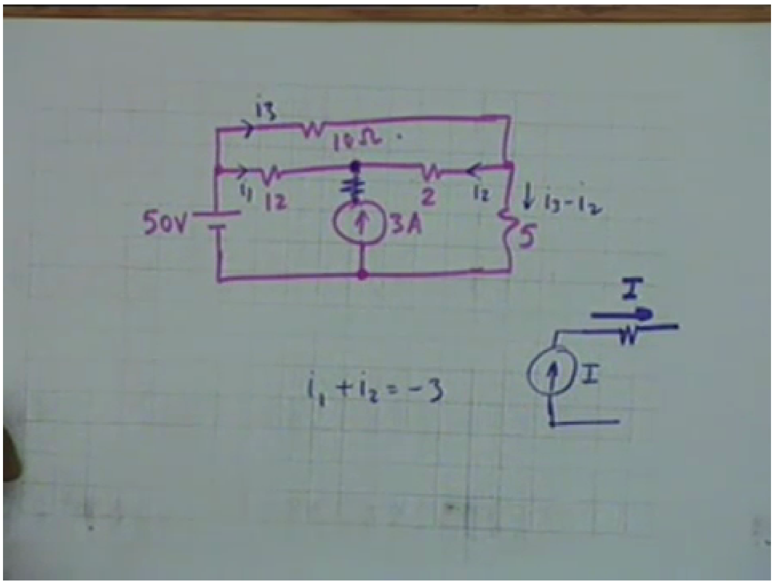

What I had is 50 volts, then 12 ohms, at 3 amperes, 2 ohms, 5 ohms, I am not writing ohms, it is understood that the values are in ohms and 10 ohms, okay. Now, what I was saying is that you should not write, you should not formulate loops indiscriminately because if a loop contains a current generator then you are sunk because you do not know the voltage drop across the current generator. So you cannot write a KVL equations, you cannot write a KVL equation for a loop which contains a current generator. And therefore I said the better strategy is to formulate branch currents, all right.

And this is what we did, what would it was be formulated a current of i1 here, correct of i2 here, then this, then i1 plus i2 should be equal to - 3, all right, then we formulate another current i3 here and so, so this current shall be equal to i3 - i2. And I said that since i2 can be expressed in terms of i1, therefore we have to solve for only 2 currents, namely i1 and i3. And once you solve for them, which will again get a 2 by 2 matrix equation. Yes.

Student: We considered a resistance in the R in which this generator is, current generator is there, so what we will take the value of current generator?

Professor: If there is a resistance here, that is a very interesting question, if there is a resistance here, all right, then will the KCL equation be disturbed? No, a current generator by definition delivers a current capital I, irrespective of what is connected to it. if there is a series resistance it does not matter, the current is still high, whatever be the resistance, so long as it is not, it is not, there is a degenerate case, infinite. if R is infinite than the current generator is disconnected and therefore no current can flow.

So if there is a resistance in series, then there is no change in the KCL equation at this node, all right. Even then you cannot write a KVL equation because you can find this drop but you do not know what the drop across the current generator is, all right. Any other question? Okay, I wish to take this same example to illustrate another method of solving the same network and this method, I wish to introduce like this.

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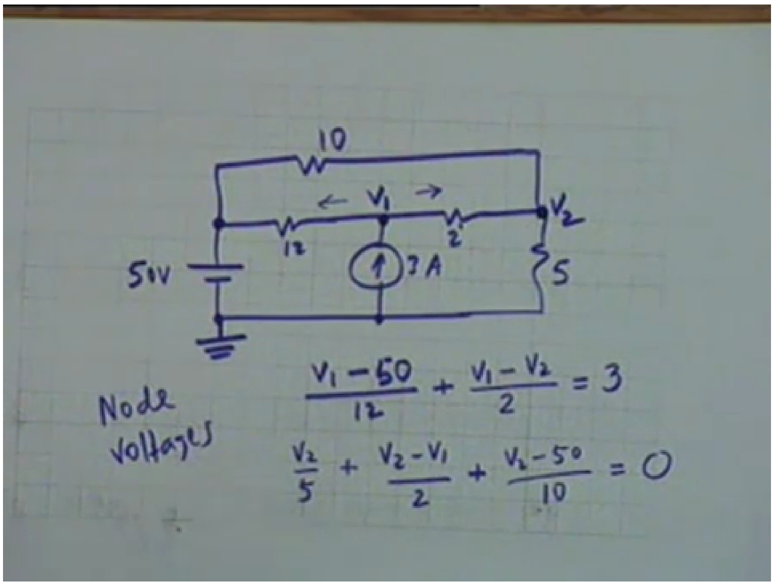

I will draw the network again, 50 volts, 12 ohms, 3 amperes, 2 ohms, 5 ohms and 10 ohms. in this circuit we argue, we argue that if we know, we were trying to solve the circuit for the currents, all right. We wanted to find all the currents, suppose instead of currents we find voltage is, voltages at each of the nodes, the voltage here is obviously 50, we know this because it is connected. And this is a common point, this is a 0 potential point, we could consider as grounded or 0 potential, all right. So this node voltage is 50, this node voltage we do not know, it is a current generator we do not know what this voltage is, we also do not know this node voltage, another note, all right.

These are 1, 2, 3, 4 nodes of which 2 of them are known, this node is 0 voltage, this node is 50 volts, this node we do not know, let us call it v1, this node sweet and not know let us call it v2. if I know v1 and v2, obviously everything else is the circuit shall be known. For example the current in 12 ohms shall be 50 - v1 divided by 12 for the current in 5 ohms is simply v2 divided by 5. So all currents shall be known if you know all the voltages and this is called the node voltage method of solution, node voltage. instead of loop currents or branch currents, we solve for node voltages.

And we apply basically KCL here, we do not apply KVL because we are not going around in loop, all right, we apply KCL. Now to be able to supply KCL and we are solving only for v1 and v2, so you need to write only simple to node equations. At this node the currents that are leaving this node are v1 -50, v1 -50 divided by 12, all right, this is a current that leaves in this direction plus the currents that leaves in this direction is v1 - v2 divided by 2, all right and the current that comes to the node is equal to 3. is that okay, this is the expression for KCL, all right. The current leaving in this direction, current living in this direction should be equal to the sum of these 2 currents should be equal to the current coming.

I could have written this -3 equal to 0 but I have written it 3, which A5, well let us go to the other equation. The other equation will be at note 2, we do. And we see the currents that are leaving this junction are firstly v2 by 5, then plus v2 - v1 divided by 2, this is the current that leaves v2 and goes towards v1, all right, v2 - v1 divided by 2, then plus, there is only another current which is v2 - 50 divided by 10, this should be equal to 0, there is no current generator here, all right. And therefore if we clear this of fractions, we shall get 2 equations in v1 and v2 which we can now solve for.

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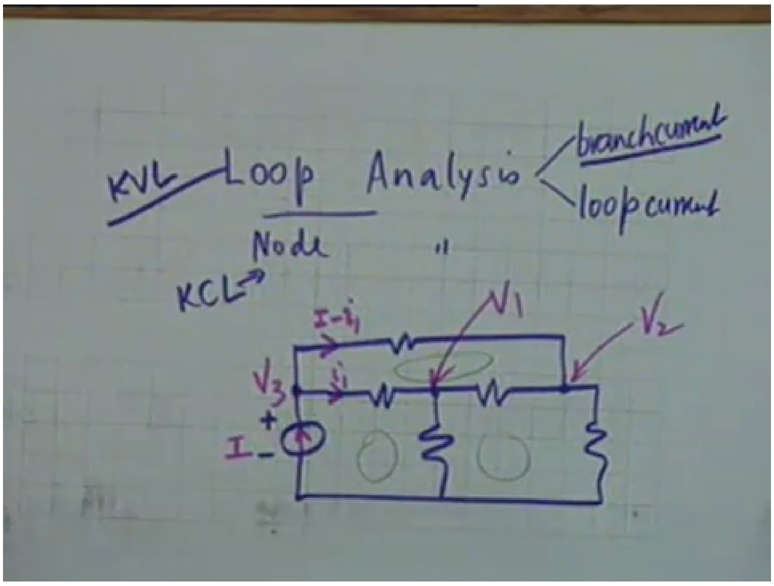

Do you want me to carry out this algebra or you can skip it? I want to know the answer though next time, okay. You solve these 2 problems and let me have the answer next time. We have therefore learnt of 3 different methods, actually 2, 2 methods for solving networks. One is the loop analysis and the other is the node analysis. in loop analysis we encounter situations where a loop equation cannot be written if there is a current generator in the loop and therefore what we did was in those situations we formulated branch currents. if there are no current generators in loops we could formulate loop currents, so there are 2 methods one is branch current and the loop currents.

The branch current method always works, the loop current method may not work if there is a current generator, all right. One has to take stock of the situation and decide the strategy. it is exactly like when you are at a crossing, at a complicated crossing when you are driving, then you have to take an instant decision which way you will turn, all right. in node analysis, instead of concentrating on currents, we concentrate on node voltages, all right. And we write basically KCL equations. in loop analysis we take help of KVL equations, that is the determining equations for currents in loop analysis are KVL equations, the determining equations in node analysis are KCL equations.

in loop analysis we solve for currents, in node analysis we solve for voltages. Either method is okay for a given situation and as you shall see later on, one of them shall be preferable in a given situation. in a given situation you might have to work less with node analysis rather than loop analysis, all right, is this point here? in one of the methods, yes…

in node analysis how do we know which terminal is to be grounded (())(42:15).

Usually wherever the source is, one of the terminals of the source is assumed to be grounded. it really does not matter because you are taking, you are talking of potential differences and therefore any point can be taken as a reference. Let me illustrate, let me give you an illustration. Suppose this you have a network like this, the same network but not with a current source, let us say another resistance like this. And then you have a source here, you have a source here plus -, well it could be current source or what they source, that is i have not shown anything, i have not shown it as a battery for a current source, it could be, it could be any source.

it means that if it is a current source and the current goes in this direction, if the wood they source then this is positive polarity this is negative polarity, any direction it does not matter. You have another resistance here and you have a resistance here, all right. Now can you tell me by looking at the circuit which method you shall follow, loop analysis on node analysis?

Student: Loop.

Professor: Loop, if you follow loop analysis, then the answer is incorrect. if you follow loop analysis, if you formulate 3 loops, you shall have to write 3 equations. On the other hand if you take node analysis, then all that you have to do is to find these 2 node voltages, v1 and v2. And therefore one shall consist of a 3 by 3 matrix, determinant of 3 by 3 and the other shall consist of 2 by 2, obviously node analysis shall be preferable in this context. And this decision you have to make.

Student: Excuse me sir.

Professor: Yes.

Student: If this is a current source…

Professor: If this is a current source…

Student: What will be the potential at the positive terminal of the current source?

Professor: Yes, okay, you got me. i was expecting this question earlier. if this is a current source, obviously this loop equation cannot be written. So what you do if this is a current source?

Student: Convert it into voltage source.

Professor: Then convert it into a voltage source, no, there is nothing in series with this. So all that you know is no you cannot formulate, you cannot formulate loop equations, this loop equation can be written. And therefore what you do is, if this is a current source, now we are going to different situation, all right, if this is a current source i, then you formulate to branch currents, let us say i1 and this shall therefore be high - i1. All right. Similarly i1 comes here, breaks up into 2 portions, okay, similarly Y - i1 comes here, combined with this current and low through this, so you write all the branch currents, then you will to write only loop equations. is that point clear? Yah…

Student: If we follow like node analysis (())(45:26).

Professor: If we follow node analysis, okay, if there is a current source and this is the node, then obviously, then you have to write 3 node equations, yes. You have to find out v3 also and in that situation if you have a current source here instead of a voltage source, which method shall you prefer, obviously loop analysis. This problem clearly illustrates that depending on the source, this is why I did not specify the source to start with. Depending on the source and the architecture of the network, one of the 2 methods shall be preferable, either the loop analysis or node analysis.

But you have to exercise a little bit your grey cells to be able to come to the decision as to which method you shall follow. if you follow a wrong method, you will spend more time, you will get the correct results in the end they will spend more time. And for an electrical engineer, for an engineer, who has taken 110M from SAT R, this should not happen, all right. You should be able to decide right away which method you shall follow. Spend 2 minutes on this, then you will save 20, okay. it is worth spending this time. All right, we shall work out a very large number of problems on loop analysis and node analysis. in fact throughout the course we shall be solving loops and notes only, whether it is an electronic circuit or a passive circuit, this is what we shall do.

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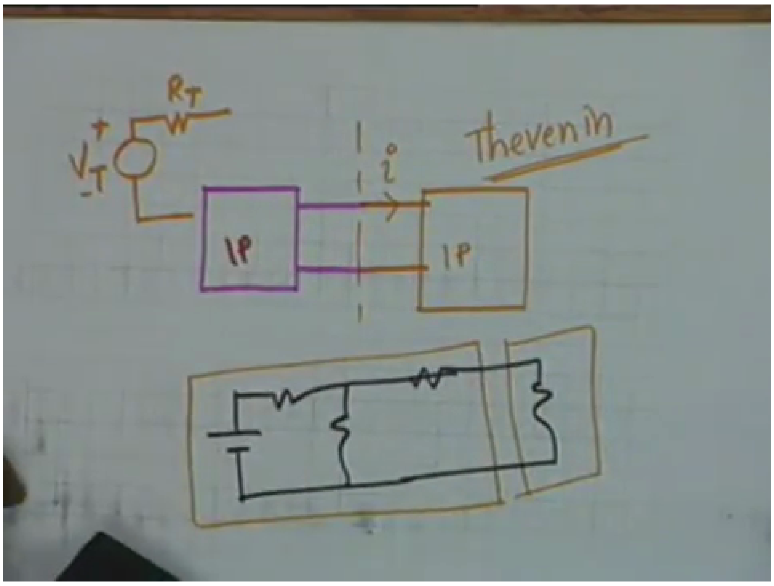

Now we go back to the question of ports, I introduced the concept of ports yesterday. And I said that if I have a network which has 2 terminals only, then yes it is a 1 port and therefore all you can do is you can connect to this either voltage source or a current source or any other general network, okay, any other one port. You can also connect other, not this is the most general connection, this is the one port and this is the one port, let me use this colour, all right, 2 one ports can be connected to each other. Now it may turn out that each of these one ports may contain a source, all right, one or more sources.

And under that condition one can say that this one port is driving the other one port, you can consider like that. Or you can say, there is nothing sacred about the left one driving the right, you may say the right one is driving the left, all right. in such situations, in such situations, one of them is considered as the load and the other is considered as the driver, there is nothing sacred, you could consider this as a driver and this is the load, provided this contains an active element, patriotic originator or a combination. But suppose i have let say the same network that i have drawn, okay, if this is my 1st one port and this is my 2nd one port, obviously the left one is the driver, the right one is the load, all right.

Now whatever be the, whatever be the composition of the 2 one ports, it turns out that in so far as this current is concerned i, all right, in so far as this current is concerned, the one port to the left can be replaced by an equivalent circuit. The one port to the left can be replaced by an equivalent circuit and this circuit consists of a voltage generator VT in series with a resistance RT. you understand what I mean? it turns out that the one port which you consider as the driver can be thrown out and replaced by this simple series connection of a voltage source in series with the resistance RT. in other words i shall be the same whether you connect this one port, actual one port or its equivalent circuit.

And it is in that sense that this is an equivalent circuit, all right. And this concept was 1st given by a gentleman by name Thevenin and this is called Thevenin's theorem. Let me state this formally, Thevenin's theorem states that, insofar as the load current is concerned, one of them can be considered as load, the other can be considered as the driver and Thevenin says insofar as the load current is concerned, an arbitrary 2 port can be replaced by an equivalent voltage source in series with an equivalent resistance. The subscript T should be clear, T stands for Thevenin. The question is what is vT and what is RT?

Student: An arbitrary 2 port?

Professor: It is not a 2 port, it is a 1 port, an arbitrary connection of a one port to another one port. In so far as the load current is concerned, the one port can be replaced by an equivalent voltage source in series with an equivalent resistance. The values of VT and RT, it is already 3:56, we shall consider on Friday.