Network Analysis
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Lecture 53
Norton's Theorem

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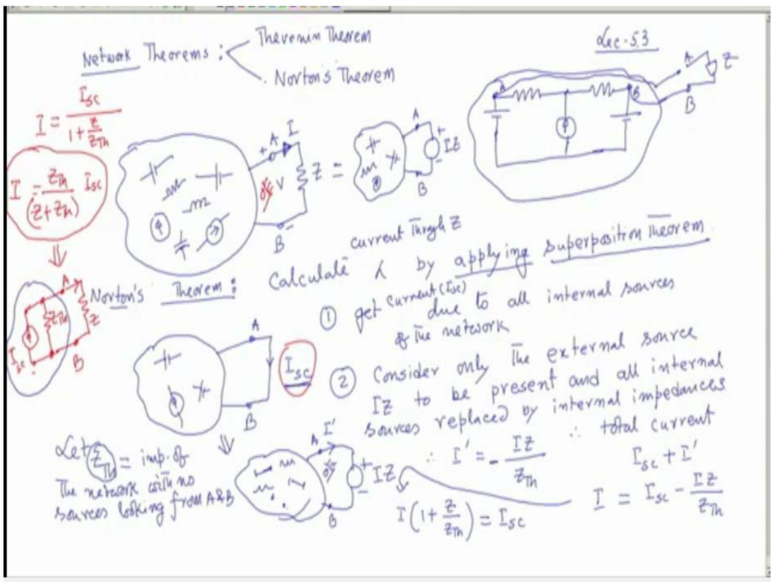

So we were discussing about the network theorems, very important for this course, because a network after all can be analyzed by applying KVL, KCL that is the fundamental, but then there are some theorems, which if judiciously applied network can be solved without much trouble that is efficient method of solving networks, that is why we study various network theorems. I told you one of them was superposition theorem, when more than one sources are present.

Consider one source at a time, find out the current in a particular branch and then superposed those currents to get the actual current, when all the sources will be present, by sources I mean both voltage and current sources and when I say, the sources are replaced by their internal impendences, I mean that if it is the voltage source without any internal resistance, it should be shorted.

If it is the current source; ideal current source, it should be open circuited, we learned that. Then I told you another interesting observation about network that given a network. For example, here last time we did, I just point out, so that you understand it.

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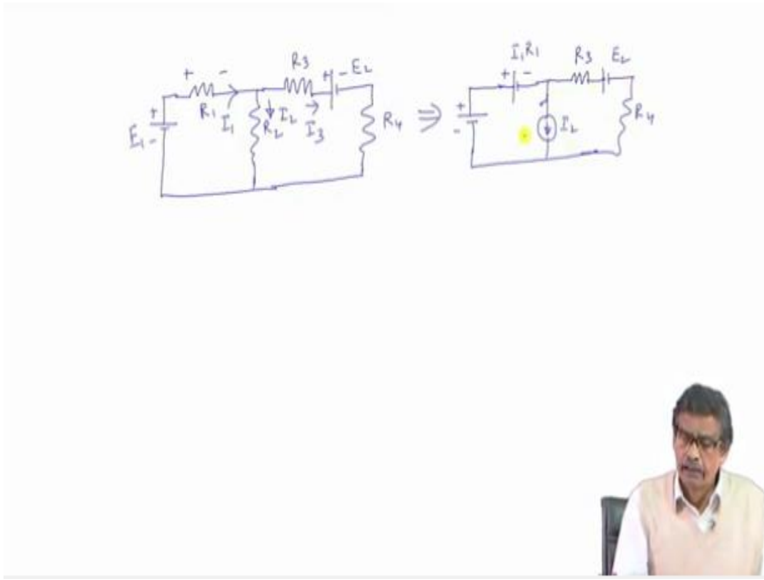

That given a network, there will be several branches present in the network. For example, this network, this is the original network, this one. Now, and suppose, I1, I2, I3 are the current and all, the actual currents in this networks, this branch can be replaced by a current source, another; this is not identical networks, but so, far as this network and this network is concerned when this r2 is replaced by a current source I2.

They are equivalent in the sense that all the branch currents and node voltages will remain same. This is called substitution theorem and we applied these to find out to solve this kind of problem that when there is a network, for example, this network.

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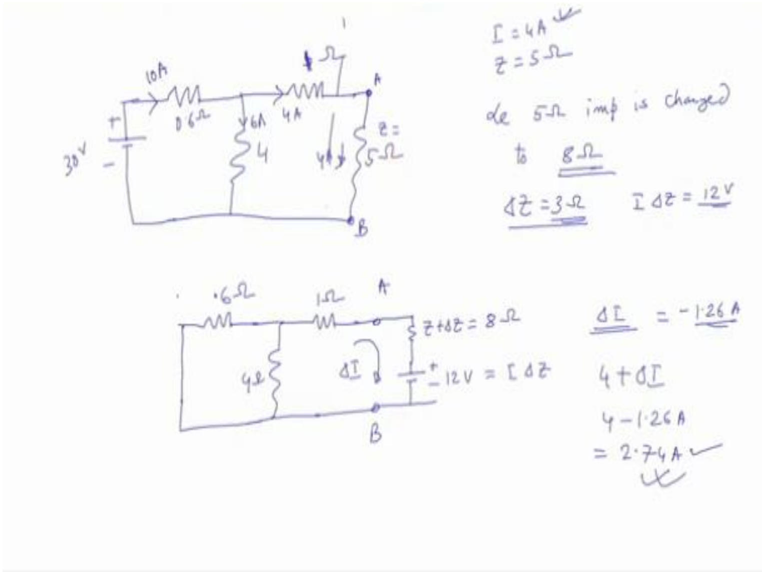

Last time we solved it, if you have solved this network by some means if you know this current, then I say only this impedance I changed to some other value, say 8 ohm, then should I once again resolve this whole network with all the sources present, the answer is no. What you have to do then is that you show the actual impedance now, that is 5 + 3 ohm delta z is 8 ohm and here in this branch, you bring in one voltage, which is equal to I.

The earlier current flowing into the change in impedance that is delta z3 that is 12 volt and all other sources replaced by their internal impedances, which was a single battery here, so I shorted it and you calculate this current, you will get delta I, then to this I, original current if you add delta I, you will get the current in the circuit, when this 5 ohm has changed to 8 ohm. Anyway you practice lot of them.

Now network under this one; network theorems, we will take one most important theorems, network theorems. Under this, 2 theorems are very important; one is Thevenin's theorem and the other is Thevenins and superposition theorem can be easily converted from one to another, but anyway these 2 theorems; not superposition; Thevenin's and Norton's theorem. These are often used in finding out currents in a particular branch of a circuit.

So what do we do is this, suppose, you have a network, where there are several sources; both voltage and current sources, number of them are there, apart from that there may be impedances;

R, L, C. Mind you, this is a symbolic diagram. All these things are interconnected, okay in a particular fashion as it happens in any network, all the sources and all the circuit elements are interconnected.

Now, I come to two nodes, where I will connect some impedance here. Let this impedance be called z is the impedance. For example, this network would be a network like this and these are the two points, this is this part, inside part and these two points could be; this is A, this is B, okay, are you getting, this is A and this is B. So inside this interconnection, I have not shown. Generally, it can be in various ways connected.

So an example is this one, this is the network and these are the points A and B, where I will connect an impedance z, this could be R, L, C, etc., okay and suppose, you connect this impedance, I am interested to know this current I, okay and these voltage across the load is suppose V. So I can solve the network by applying nodal method or Mesh analysis, whatever it is I can solve it and get the currents.

Now, what I will do is this. Suppose, I say that this impedance Iz is there, I would like to calculate; first I will talk about Thevenin's theorem. I will say that calculate VAB by applying superposition theorem. Why superposition theorem, because there are so many sources are there and this network also can be drawn like this, internal things I am not drawing, these things are there, A and B, here this one by substitution theorem, I can say, here is a voltage source Iz.

These two networks will be no different. So what I am planning to do is this that there are several sources inside the network, several elements, current sources, what not and across AV, this z is connected, current is I. Therefore, this branch can be replaced by a voltage source plus minus Iz and it is not going to alter any branch currents of this network here, same currents will be flowing here, that is what we have established earlier.

Anyway, so I will calculate VAB by applying superposition theorem. So the thing is, if you want to apply superposition theorem to calculate VAB, I will calculate it in this way. I will consider all the sources present in the inside the network that is this thing, I will calculate VAB when all the internal sources are present, applying superposition theorem, step 1, get VAB due to all internal sources of the network.

So all sources are present and here is, this should be then replaced by a short circuit, is it not? This is short circuited this source and all these sources are present and I will get this current, whatever it is. So VAB will then be 0 as it appears, if you replace this by a short circuit, VAB will be 0 and then what you do? If you do to it like this, okay, maybe it will turn out to be a Norton's theorem, let us see.

So let us write it down as Norton's theorem. First we are doing Norton's theorem. So I calculate this current, when all the internal sources are present and this is shortened. This source is not present and let this current be called Isc, I will get this current, then I will say, then I will write here, calculate I. This I should also change, calculate current through z by applying superposition theorem. So get I, get current which is Isc due to all internal sources of the network.

That I will get, short circuited what is the current? Then what you do is that consider only the external source Iz to be present and all internal sources replaced by internal impedances, means what? This is the network, the same network after this step 2, I am doing. Here, this source I should short battery, this current source open circuited, this is what I will do and here I will say, I have connected only these voltage source. What is its value? I into z, this I will do.

Now in this network if you apply, so what will be the current in this network, this current I want to calculate, is it not? To apply superposition Isc I have calculated. So I will calculate current because of this in this direction, I dash say, so I dash will be equal to; here there is no sources, so between these two points, what will remain; some impedance you will get across AB. Let that impedance, that is looking into the network that impedance I am telling.

It is z Thevenin's is the impedance of the network with no sources looking from point AB; from A and B. That is this way if you look, what is the equivalent, because there are impedances here, connected in a fashion. So find out the equivalent resistance, that impedance I am calling z

Thevenin’s. So what will be the current, this I dash will be then Iz divided by z Thevenin’s, which has negative sign, because current flows this way.

So I have calculated this current I dash, it will be this. Therefore, total current when all the sources are present, total current. When all the sources are present means, this Iz is present and all these internal sources are present, what will be the current; the theorem says that it should be Isc plus I dash and that is equal to Isc is Isc and Is is this z by z Thevenin’s, is it not? But this must be equal to I, because that is the situation we started, everything is present.

These are present, this is present, that must be I. Therefore, from these I can say that I into 1 plus z by z Thevenin’s, bring this to this side is equal to Isc or I will say that here write with this red colour. Therefore, I will be equal to I from this equation, if you bring this to this side, it will be Isc divided by 1 plus z by z Thevenin’s, from this to that I am writing into Isc, which is equal to z Thevenin’s by z plus z Thevenin’s into Isc. This is the thing I equal to.

Therefore, it looks like across AB, what is it? This is the two impedances connected in parallel, current flowing through it, it means that across AB, as if there is a current source Isc and in parallel there is a z Thevenin’s and let me write AB here; A and B, and here is your z. This equation fits into this current Isc, so what is the current here? It will be this total current into other impedance divided by some of the impedances.

Therefore, conclusion is any network across which an impedance is connected z, I want to find out the load current. I can do by other method that is different issue. Now, I am telling that behind point A and B into this network, if you look at it can be modeled as a current source Isc, in parallel with an impedance z Thevenin’s. Now, what is this Isc, how do I get? To get Isc, what you have to do is this, you find out the short circuit current, okay.

And solve that network to get Isc with all sources present that is what, this is Isc and how to find out z Thevenin’s? All internal sources, replace it by open circuit that is battery replaced by short circuit, current source replaced by open circuit and find out the equivalent impedance looking from A and B into the network. The moment you get that, then you say, however complex this network is, if it is linear networks because we have taken help of superposition theorem.

With the understanding the network is linear, then only I can apply superposition. Therefore, all these complicated things of this network will be replaced by a current source in parallel with an impedance. To summarize, let me draw some circuit and try to find out Norton's theorem.

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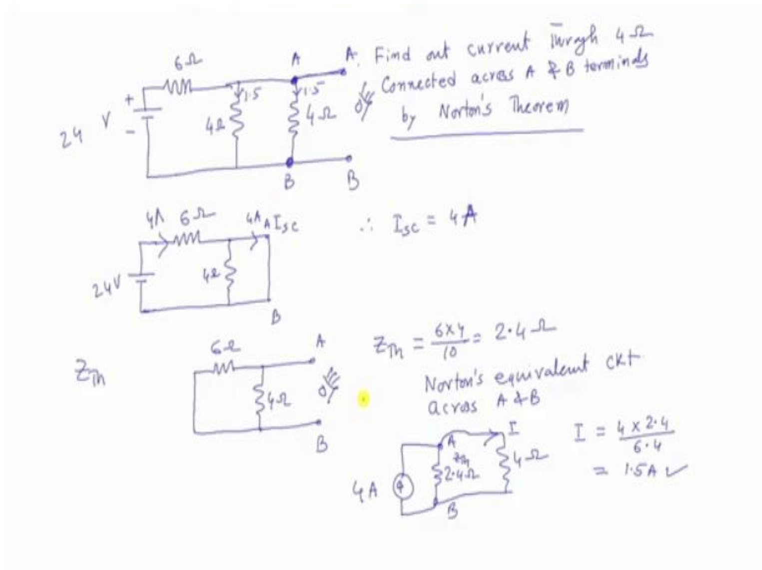

For example, you have a network, I will take simple network also, very simple networks for example, this network. Let us do this simple network, okay, this is suppose, 10 volt, this network has got a voltage source alone and this is 6 ohm and this is 4 ohm and this is also 4 ohm, this is suppose point A and B, find out current through 4 ohm connected across A and B terminals, that is this resistance I want to know, what is the current, okay.

This problem is so simple. Let this voltage be 16 volt or 24 volt, it will be better, 24 volt. So this circuit can be easily solved 4, 4, 2 ohm, 2 + 6, 8 ohm, 24 by 8, 3 ohm will be here, then 1.5 and 1.5 will be here that is known, but I want to solve it by applying Thevenin's theorem. So what you have to do is this, first step is, find out open circuit, I want to apply what is called Norton's theorem, find out current through 4 ohm resistance by Norton's theorem.

So, what is the first step? First step is, you find out the short circuit current. So what you have to do? 6 ohm is there, 4 ohm is there, this 4 ohm is there, then across AB, you have to put a short circuit, is it not? So remove this 4 ohm resistance and put a short circuit and you have to calculate this current, this is Isc, A and B and what will be the value of this current, very simple here the equivalent resistance is 0, so 24 by 6; 4 ampere will flow.

And this 4 ampere will flow all through these, 4 ampere, is it not? Therefore, I will say short circuit current is 4 ampere. It can be easily calculated, then find out z Thevenin's. So to find out z Thevenin's, what you have to do is this 6 ohm, this is 4 ohm, all internal sources should be replaced by short circuit. So 24 volt goes there, this is A and B with 4 ohm removed, this load impedance removed, you find out z Thevenin's, which in this case is 6 into 4 by 10 that is 2.4 ohm.

Then, I say behind this point A and B, Norton's equivalent across A and B will be AB is there. There will be a current source, what will be the value of this current source? 4 ampere and in parallel with this z Thevenin's 2.4 ohm, it is there and then here this 4 ohm, this is 4 ampere. So what will be the current; this current; I, how much it will be? I will be equal to 4 ampere into 2.4 divided by 6.4. It is coming same, how much?

Earlier original current was 1.5, so 1.5 ampere and this is true because here in the original circuit you see by other method; 4, 4, 2, 2 + 6, 8, 3 ampere. Then this circuit solution is already known 1.5, 1.5. So this is how you will apply Norton's theorem. Only thing is that sometimes these points are shown like this A and B and they say that across AB, I am going to connect some impedance, find out the Norton's equivalent of this network, are you getting me?

Then okay, short circuit current you find out, then retain this 4 ohm while calculating z Thevenin's, does it make any sense to you? I can ask you that from this network 2 terminals come out, these 2 networks. Here I will connect some impedance z, then what will be the Norton's equivalence network looking from these AB, then do not remove this 4 ohm, consider it to be internal to the network, then short it, get the short circuit current.

And while finding out the z Thevenin's, find out the z Thevenin's retaining this 4 ohm as well. I think you have understood the point what I meant to say. So this is how Norton's theorem can be applied to. So it is a very interesting statement, because networks may be very complicated across a pair of points, any 2 points you take tapping from the network, the theorem tells that behind all these things, you can always think there is a current source in parallel with some impedance, which happens to be z Thevenin's, we call it z Thevenin's and then your AB terminals.

So complexity of the left and side goes. Therefore, it will be very useful, if you are interested to find out current in a particular branch. For example, if I say apply Thevenin's theorem to find out currents here, here, here in all these impedances. Then each time we have to find out Thevenin's equivalent across those 2 points, that is not a very good idea. So when you are interested to find out current in a particular branch and perhaps the impedance of that branch I will be changing, then it can be applied in this nice way, is that clear.

Therefore, this is the Norton's theorem and in the next class, I will talk about the Thevenin's theorem. Solve many problems, any network you sketch, you draw, put some values, you have calculator, calculate it and satisfy yourself. That is the best way of learning Norton's theorem at least given a particular network. Thank you.