Network Analysis
Prof. Tapas Kumar Bhattacharya
Department of Electrical Engineering
Indian Institute of Technology – Kharagpur

Lecture – 52
Network Theorem-II

Welcome to 52 lecture on Network Analysis. So in my last class, I told you about some very interesting observations in the form of substitution theorem. Now, today let us do some application of that.

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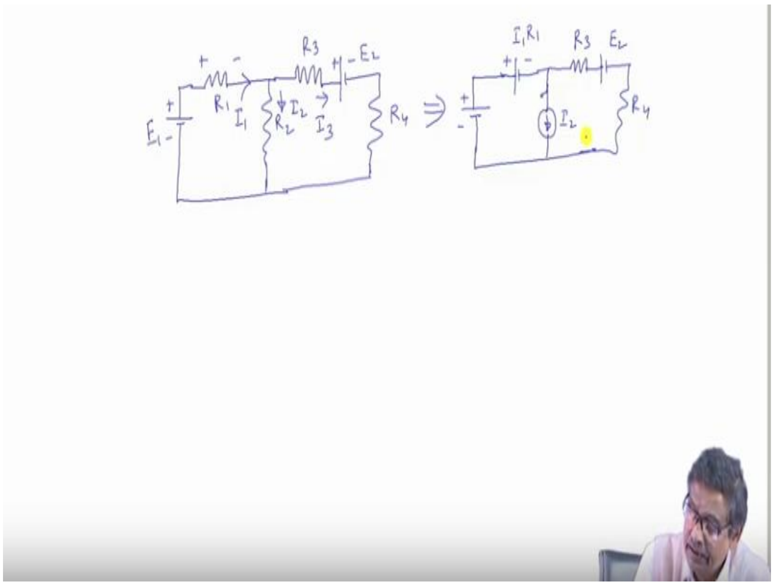

In fact, substitution theorem, replacing this thing is not meant for the circuit analysis because you have to know the value of I1, R1, then only I1, R1, but you can represent it like that, that is the way. KVL equations, mesh equations, in this will be same as mesh equations here. Why it will be different, got the point, that is the idea. Now, let us tell you a problem. Suppose you have a network, which I will now show like this.

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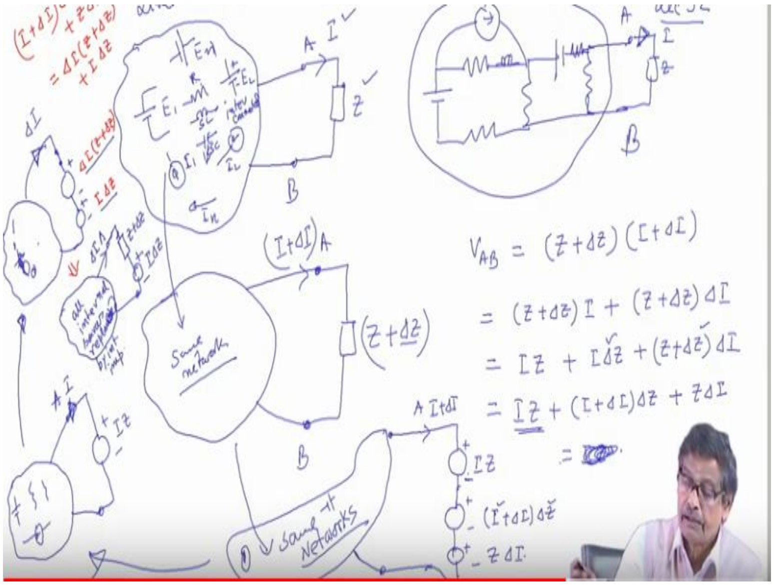

Inside this, a linear network, always linear network will be considering. There may be several voltage sources are present, E1, and they are connected, although I am not showing connection, they are connected in very peculiar fashion, E1, E2…En. Then may be number of voltage sources, En.

There may be several current sources present in the network, I1, this is I2 and In. Apart from this, there may be impedances. All are interconnected, which I am not showing R, SL, 1/Sc. This way you look at the network,1/Sc. These are all interconnected, which I am not showing in a particular fashion. All of them are interconnected and this is the network, and to this network, two terminals are fixed up, you got the idea. That is like this.

Suppose, let me draw it here. You should not have any doubt about this. This is one source, this is another source. There is current source. All are connected inside. There is resistance, another voltage source and so on. Two terminals, these two are also connected at some two suitable nodes of this whole network, which are interconnected with all these elements in a particular fashion.

For a given network, it may look like this. These are the two points I am telling, A and B and this is the big thing, which I have circled it here. There may be inductances, SL in s-domain, you think like that. Now, across AB an impedance is connected, J' or Z. I will simply write, this S, I will not carry on. General, it will be J'.

All the voltage are Vs, current sources are Is, like that. In this network, if I ask you, find out the current in this branch through this Z, what is the current flowing. This insight thing, topology is known to me. So, I will calculate this current, applying mesh analysis or node analysis, whatever it is, I know, I will calculate the current. You will get the answer.

Now, what I say listen carefully. Suppose, in this network, same network, if I say, I have changed this impedance to Z+ some delta Z. I have buried this impedance. Earlier, it was 5 ohm, I have made it 8 ohm. That means, there is a change of 3 ohm. So, this delta Z is not calculus delta Z. It can be anything. With respect to the older value of Z, I have made a change in the value of Z. So that the total impedance now becomes Z + delta Z.

Suppose, in the original network, when Z was connected, the current was I. Same network, linear network, I have simply buried Z + delta Z. Then, I ask you what will be the new current. Now, one answer could be, we solve the circuit, find out what is the new current. That is one way of doing it. But, we will do it in a slightly different way. I will say and from one onwards, you please listen carefully what I am telling.

Okay, if you have changed this impedance to Z + delta Z, this current cannot remain at I. It must have changed to some other value and that change in current, I say, it is I +delta I, where I was the original current, it has changed by some amount. Let that changed amount be delta I. This is what I say.

So, my goal is to find out the new current, Z has been changed to Z + delta Z. These two points A, B are same. This network is same. There may be several sources connected. Therefore, solving the circuit once again may look tedious, what is the point with all sources considered, simply because you have changed impedance in some branch of this network. I have to go through all these ordeal to find out this new current.

Now, there may be another way of thinking to attack this problem. It is like this, okay. The voltage across AB. When this impedance is Z + delta Z, first see what is this, Z + delta Z x I + delta I. These are all S in terms of you can think, general delta Z. Now this can be written as Z + delta Z x I +Z + delta Z x delta I. This way I can write. One impedance x I, plus this thing. And this one, I can write it as I x Z+I x delta Z+Z + delta Z x delta I. Like this, I can write.

This whole voltage across AB when the impedance is like this. I can write it. Now, what I will do is this. IZ + this turn, I x delta Z, and delta Z x delta I, this turn, I can write it as I + delta I x delta Z, and then + Z x delta I. Correct these four terms. This way, I will write it. Now, see this interesting argument. Okay, here between these two points A and B, across this A and B only I am drawing. Here, the network is connected. Here, I can look at it, some voltage source, this drop.

This current is I+ delta I, mind you, in this network. From this network only, I am drawing. I am telling that, here is a battery, of magnitude IZ. Do I know this value. Yes, you have given me the value of I and Z. Earlier, I have told you in the statement of the problem, I know the value of I when Z is connected, so I can replace that impedance by a voltage source with the help of substitution theorem, that is what I will do. So, there is a source like this. Then, I will say, there is another source I + delta I. Here is an impedance I x delta Z. This turn, IZ+ I x delta Z.

About this term, I x delta Z, it is also known, because I was the original current, when Z was connected. It was given to me and delta Z by which amount Z has been changed, that is also known to me. So this is known. So this IZ and all this remaining terms, I can write it as another voltage source, I x delta Z, plus another turn is there. What is that turn. Got the point. IZ, then I + delta I delta Z. So I x delta Z will be there.

First, I will do like this. There is a voltage drop. I will write it as, that is what you should do it. This I will write it as I + delta I x delta Z and plus another voltage source, Z x delta I. This way I can write it. With the help of substitution theorem, I may think this voltage drops are nothing, but polarities are important, like this. No problem. Three voltage sources are connected in series in this fashion and what is between A and B, it is this network.

This same network. See, arguments are so interesting. It is like this. I know Superposition theorem. I will say, look in this equation, how many sources are there. Okay, all the internal sources that present in the network inside, several voltages, current sources are there. Those sources present, and I will apply Superposition to this sources. So, let me redraw here, so that you do not miss the point.

So, what I am planning to do. Inside the networks, let all the sources be present. Do not disturb that impedance sources. This is A, this is B. What I am telling, here, these three sources are present of which I will tell, only IZ is present. Whatever will be the current, that I will note down, then I will consider these sources only present. Then other sources, replaced by this short circuit, and this shorted and all the internal sources of the network and this IZ present, what will be the current here.

This circuit is the original circuit. All the internal sources are present, Z is present. So, this current is I. It is already known. Then, what I will tell, I will draw here only. Let it be slightly clumsy, so that we understand what we are doing. So with all internal sources and IJ present, this current has to be I, because this is what we started. This network and this network is same because IZ can be replaced by Z, because the current is I.

That is what we learnt from the substitution theorem. Okay, then I will say, only these two sources are present and this is shorted. So, this I will short, and these two sources are present. What are these two sources, one is this source, that is I + delta I x delta Z, and then Z delta I. These two sources are present, suppose I say. Are you with me with what I have done so far.

What I have done that this was the given network, Z is the current, I is the current. Problem statement is very simple. I simply changed Z to Z+delta Z. I want to find out the new current. New current, I assume it to be that old current, plus that changed component, I + delta I. Then, what will be the voltage drop in this network. This Z x I. This can be expanded in this way.

Then I say that okay, there are now, these three sources, so this IZ can be replaced by a voltage battery with IZ magnitude. Why this polarity, I was entering. Similarly, I + delta IZ. Now, what I am telling all these sources are present, and IZ is present. These two sources are absent. You get this network and this network is same as this network. Current is I. Then, all the sources are present here. Network source is present. Then this to this. This fellow is absent. I have taken this into account and other two sources are present.

Now applying Superposition, so I will tell that these two sources are present, and all internal sources should be replaced by their internal impedances. Correct absolutely. Current sources is opened, voltage source is shorted, so this will be the network now. Now then, I will say in this network, delta I must be present. This source is alone present with internal sources replaced by their internal impedances, must have produced delta I. That is why, all the networks are present, it should be I + delta I. So who is the contributor for this delta I. It is these two sources.

It looks like, cleared. Now, this quantity I + delta I x delta Z, that is this one, + Z delta I. This is the whole voltage drop here. Now, this can be written as is equal to delta I x Z + delta Z + I x delta Z. These two things can be written like this. Therefore, I will say that here, this thing can be also replaced by these two things, one is I x delta Z+ delta I x Z+ delta Z, crucial step. These two are same as this network. Nothing changed. Current is delta I.

There is a battery here, delta I x Z+delta Z. Therefore, I will say that this network. After this I am proceeding here. This is the network. All internal sources replaced by their internal impedances, and these are the two points A and B, where this current is delta I, and this drop is delta I x Z+delta Z.

Therefore, I can represent it by some impedance, Z + delta Z, because this is the drop between these two points, delta I x Z + delta Z, and then a source of voltage, whose magnitude is I x delta Z, and we are done. Got the point, therefore, I will say, okay, that one option is connect new impedance Z + delta Z, resolve the network will all the sources of network present with this impedance, Z + delta Z, you can solve for this current.

The same way you did when only Z was present. That is straight-cut solution, no problem, but we were looking at some different way, whether it can be solved. What did I do, there are how many sources present, all internal sources are present. There is no source here, but when you change this impedance to Z + delta Z, the voltage drop between A and B should be this current into this impedance. Now, this can be expanded in the way like that.

Therefore, I can represent it as 3 batteries with 3 voltage sources, one with IZ, one is I + delta I x delta Z and so on. So, this is IZ, I + delta I, delta Z, and this one I have done like this. I can do it like this, IZ. After doing this, I am saying, when all the internal sources of the network are present, and this voltage source is present, this will be the network. What is that network, all internal sources present and only this source is present.

Then what should be the current. From this, I know it must be I. It was known, current is I. Then I will say, current in this network will be when this is replaced by a short circuit, all these sources are replaced by their internal impedances, then this current must have been contributed by this turn and this turn, because this can be manipulated as IZ, I have taken into account, I x delta Z is there, this turn and then delta I and delta Z plus this thing will give you delta I x Z + delta Z.

So with these two sources present and these sources must contribute to delta I. That is why this Superposition theorem is, and then this delta I, I will calculate and I will add to this original current, then say Z + delta Z you have connected, current is I + delta I. Let us take a simple example, what I mean by this.

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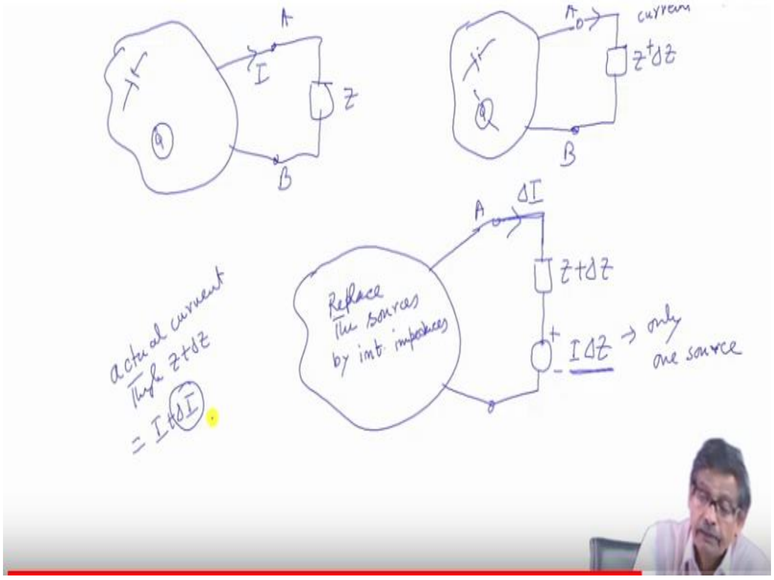

That is, in another words, what I am telling, once again, the final result is this, A,B was there, there was Z, this current was I . There was several sources present. Several elements are present. All are connected, things like that. This was I. Now, my problem is all network should be present once again as it is, all the internal sources are present, these are A, B and I will change this impedance to Z + delta Z and I am interested to know, what is this new current. New current, let me call it I + delta I, that old current I, plus that change.

Then I am telling to find out that current, there is an option. Take the network, replace the sources by internal impedances. You will have A,B here. Then, connect this impedance, Z + delta Z, which is known by what amount I have done and here you replace it by voltage source whose value is I x delta Z. So, in this network, it is expected, necessary steps will be less because no sources are present here. Absent of any sources and this quantity, is it known? yes.

This old current was I x by what amount you have changed this Z, I delta Z with correct polarity. Z + delta Z is known, yes. So, I will solve this network with only one source, that is the advantage, and what current you will get, delta I and after you get delta I, then you say the actual current through Z + delta Z in this network when all the sources are present is equal to I + delta I. See, target is to calculate this delta I. Take a numerical example to calculate this.

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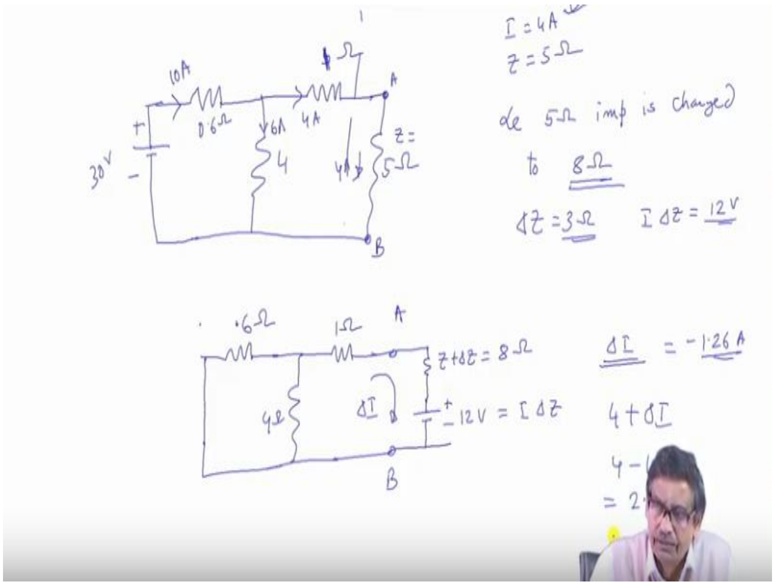

Suppose, I will take a very simple example. Suppose, you have a network that previous network only let me say, 4 ohm, this is 1 ohm, and this is 5 ohm. Here is only one source. That was 30 volts and we have already solved this circuit. This is 0.6 ohm. The currents were known to be 10 amperes here, and this was 4 amperes, and this was 6 amperes. We know this, therefore, suppose these are my A and B points.

And this current was known to be 4 amperes, so here I was 4 amperes and Z was 5 ohm. Like that. Now, I say that this Z has been increased by 5 ohm. Let 5 ohm impedance, is changed to 8 ohm. Then I will say delta Z is equal to 3 ohm. I x delta Z is equal to how much, I can calculate, this will be 12 volts, 3 x4, because this current was known. Then I am telling with this impedance changed to 8 ohm, delta Z 3 ohm, you did draw this circuit, with these are the sources present in the network.

This source is replaced by short circuit, 0.6 ohm, let this be 4 ohm, we have not done anything with them and this will be 1 ohm, no change here. This was my A and this was my B, and there you connect a voltage source, + - 12 volt, I x delta Z, and this impedance is only 3 ohm, Z + delta Z is equal to 8 ohm. Now solve for this current, delta I. Can this be easily solved, difficult. Anyway, in this network what I am trying to point out is, it is a very simple circuit with single source.

So, calculate this current, you calculate, delta I. If possible you can tell, otherwise, I leave it to you to calculate delta I in this direction. Let it come positive, negative, I do not mind. It might come negative in this case. So after you calculate delta I, then add to this initial current 4 amperes, to get the new current, -1.26 A, so it will be, 4- 1.26 ampere, If you calculate this current, how much it is, 2.74 amperes.

So it is crosscheck with this new value, that is 8 ohm and 1 ohm in parallel, and it should come. See the idea is that you need not consider this once again, resolve the circuit in its totality. You have to replace only one source I x delta Z, this impedance Z + delta Z, and solve for the current, which will give you delta I. So, it will come same. I leave it as an exercise, with this replaced by 8 ohm, solve this network, get this current, and then solve this network, with 5ohm, it was already known, so it is a nice way of thinking this.

Suppose a big network is there, very big network, only one-branch impedance I change. Then better try to solve for delta I, then add to the previous current, it is suppose solved ones, and get the answer. Thank you.