Network Analysis
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Lecture - 54
Thevenin Theorem

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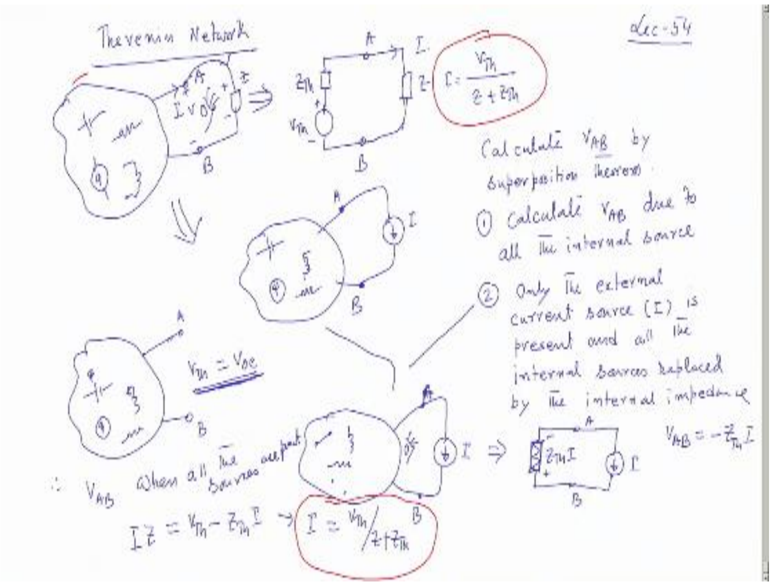

So welcome to Network Analysis course 54th lecture and today I will be telling you about Thevenin's network any network first I tell the statements across point A and B and here is the network having several sources, several current sources it might be there all are interconnected (()) (00:39) whatever it is. Then this network looking from this end into the network can be shown to be equivalent to behind all this complicated thing here a single impedance which is called Z Thevenin and in series with a voltage source V Thevenin.

And here is your point A, B. Therefore, any network given network can be converted to this across a pair of terminals then if you connect some load impendence here if here load impedance is connected so current in the circuit will be V Thevenin//Z + Z Thevenin that is the idea clear. Now why it is so it is because how why can we represent a linear network in this fashion across a pair of points.

The idea is once again similar suppose here the impedance is connected Z which is external to the network I have connected across AB chosen a points where I have connected a network I. So if you connect it this current suppose will be I and I can get that current by applying any method that is the thing. Now we have learned here once again I will use the concept of substitution theorem so here is the point A and here is the point B.

And all the sources are present in the network several current voltage sources, several circuit parameters all in S domain I can convert and write it down. So across AB so here maybe V Thevenin S Z Thevenin S like that this will get IS. So in general I am writing now this is AB now in the actual network there will be this impedance connected and in this branch a current I is flowing.

Therefore, I can place it by a current source I that is what from and nothing will change all the branch currents in this network in this path they will remain unchanged if you replace this by current source. Then what you do calculate V AB voltage across this impedance by superposition theorem that is the thing. To calculate by superposition theorem V AB what I will be doing this is the network.

In this network first step I will say that all sources internal to the circuit are present all the parameter everything are there and the current source represents first step calculate V AB due to all the internal sources that is all the internal sources are present and this current source should be replaced by its internal impedance it is an ideal current source so it is internal impedance will be infinite open circuited.

So I will calculate V AB in this network for all the internal sources and this is called V Thevenin or V open circuit voltage. So given this network calculate what is V AB when all internal sources are present nothing is connected here that will give you V Thevenin. Then second step is only the external current source that is I is present and all the internal voltages, all the internal sources replaced by the all the internal sources replaced by the internal impedances.

What will be the network so for step 2, for step 2 the network then will look like all the parameters will be there R, L etcetera, but voltage source should be replaced by short circuit, current source should be replaced by open circuit and here is only your this current source present I and this is the point A, this is the point B (()) (07:22) that will be the thing. Now here is a current source which enters here comes out through A.

Therefore, here there is no sources now therefore between A and B this network will have some equivalent impedance. So between A and B I will say this is nothing, but the equivalent impedance of the network across A, B and here is the current source and this equivalent impedance looking from this end into this side is once that Z Thevenin that will be the thing. So current source is present and this is the thing here.

So I first calculated V Thevenin oc so this will be this voltage. This voltage will be this is + this is – Z Thevenin into I. So V AB under this condition with this potential of this with respect to this is – B to A (()) (08:51) – Z Thevenin into I. Therefore, V AB when this current source and all the internal impedances are present that will be then equal to. So V AB when all the sources are present will be equal to V Thevenin that is open circuit voltage – Z Thevenin into I.

This sum of this two this will be this voltage present, but in the network I know this voltage this is the situation original network situation. Here was the current source this II replaced by current source so this is the network this voltage and this voltage are same when all sources are present. Therefore, this must be equal to this V, but what is this V this is I into Z because I assumed okay this was the network Z is connected current is supposed to be I.

So what is the voltage between these 2 points I into Z. When everybody is present then this IZ should be equated to this and from this I will say that current to the load if you bring it to this side is nothing but V Thevenin/Z + Z Thevenin this is the final thing that is the thing here. Therefore, you see however complex the network is the theorem says that across a given pair of points of your choice you may be interested to know what is the Thevenin equivalent of this big network across points A and B.

To find out that what you have to do is this you have to find out the equivalent impedance of this network with all internal sources replaced by their internal impedances that is what I have to do Z Thevenin I will get and I will try to find out V Thevenin by calculating nothing is connected across a V open circuit voltage because of all the internal sources. For that of course I have to solve the network.

When all sources are present I know how to calculate VAB and that I call V Thevenin and you will get that. So a simple example so we took a previous example 6, 4, 4 let us do that.

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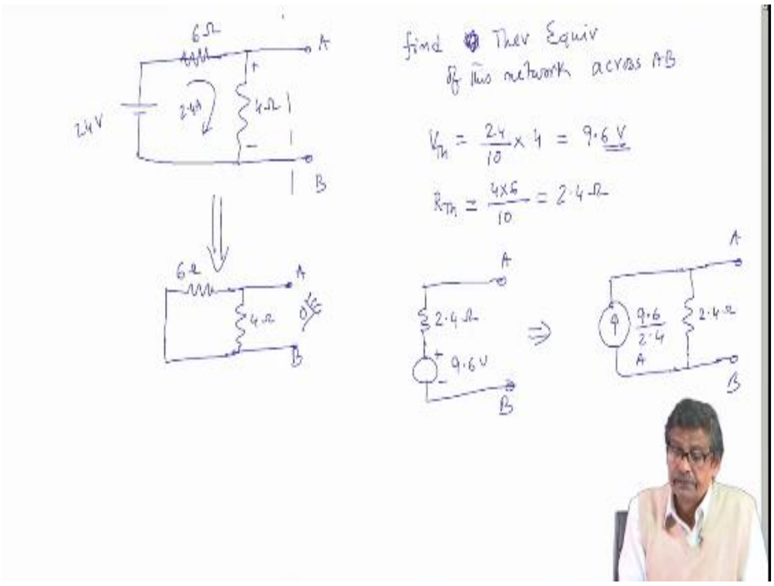

So suppose I say that I have a network 24 volt here what was the resistance 6 ohm some 6 ohm is there, here is some 4 ohm. I say that let us take a simple example this one I say that find V AB Thevenin equivalent of this network Thevenin equivalent of this network across AB. So first thing what I have to do I have to calculate V Thevenin nothing is connected across AB this is the network left hand side.

So V Thevenin will be simply 24/10 is this current that is 2.4 ampere and this into this resistance 4 ohm so into 4 this will be the voltage with this is + this is -. So how much it will be 2.4 into 4 = 9.6 is it 9.6 volt that is the one thing. Second thing is what will be the R Thevenin. R Thevenin will be redraw the circuit with all internal sources replaced by their internal impedances 6 ohm this is 4 ohm.

And these are AB look into this network from this end find out what is the R equivalent which is very easy 4 and 6 are in parallel so 4 into 6/10 that is 2.4 ohm. Then I will say the Thevenin equivalent across AB you can think that AB you want to find out current if you have connected 4 ohm okay it will be 9.6/2.4 + 4 ohm. So this is the Thevenin equivalent network of a circuit.

So I have taken a very simple example to highlight the main steps and you get this values. Now sometimes while solving problems to find out particularly R Thevenin. So Norton's and Thevenin Theorem are reciprocal things. So this thing we have already seen in our very initial lectures a voltage source in series with an impedance can be replaced by a current source 9.6/2.4 that is the short circuit current.

So what is the short circuit current 9.6/2.4 (()) (16:23) and in parallel the same resistance and this is your Norton's equivalent so much ampere. Therefore, if somebody has already got Thevenin theorem translating into Norton theorem is no problem or you have got Norton theorem then come back here very quickly, but nonetheless sometimes Norton theorem is also helpful you should be very careful.

I mean try to adopt a method whether should I find out Thevenin equivalent or Norton's equivalents it depends. You look at the circuit and try to find out, but what I am telling is now this thing that sometimes the calculation of Z Thevenin become somewhat complicated.

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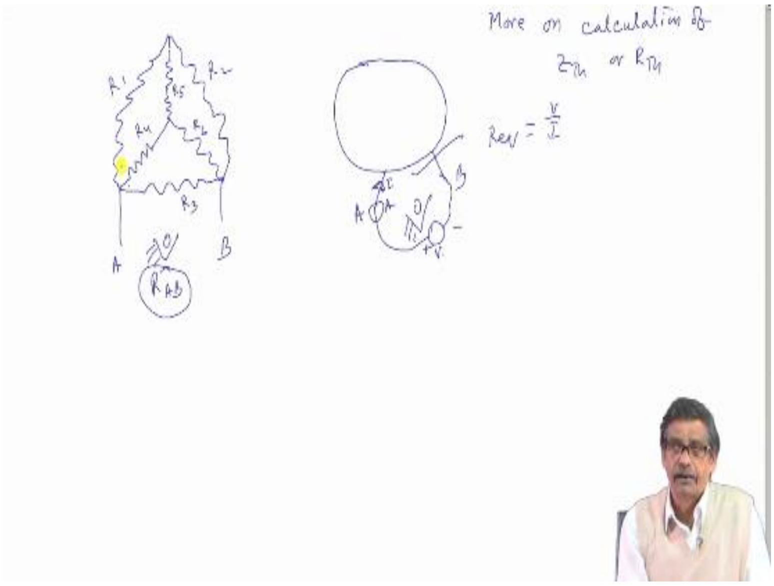

For example, if I say I have a network like that more on calculation of Z Thevenin or R Thevenin you understand what do I mean by Z Thevenin in S domain also it is Z Thevenin S R Thevenin. So if it is resistive circuit suppose A have a circuit like this there may be situation when you have disconnected all the network to calculate the equivalent resistance series parallel rule may not always apply.

You may find that resistance between any 2 points very difficult to compute. For example, if I say that I have an while calculating R Thevenin if I ask you calculate R AB here why I have drawn this because in some circuit I found to calculate R Thevenin between some 2 points circuit looks like this. Then how to find out the R Thevenin that is R equivalent looking from this end.

You see it is very difficult I do not know suppose this is R1 this is R2 this is R3 and this is suppose R4 this is R5, this is R6. I am not sure I cannot apply series parallel rule here because I cannot say R3 is in parallel with this combination, but whether R4, R6 is in series. No so somewhat difficult in this situation particularly in this form if the impedance has appear.

We know that if 2 resistances are connected in series R1 + R2 parallel R1 R2/R1 + R2 similarly in Z1, Z + Z2 or Z1 Z2/Z1 + Z2, but sometimes what happens impedances may appear to be connected in this fashion then calculation of R AB is not impossible, but looks like difficult. Suppose there is a one way of solving this problem if you find you cannot decide upon whether the resistances are connected in series or parallel you have to find out the impedance looking into the circuit.

So best thing is then you apply some voltage between these 2 points find out this current apply some non voltage V apply some non voltage here and see how much (()) (20:58) here and see what is the current drawn by this network in fact you do not even do not try nothing is known about how this impedances are connected. One way of doing is apply some voltage see how much current it is drawing from the supply.

Then we will say R equivalent from this 2 points across AB will be V/I that way it can be solved that is you have to solve another network now apply some non voltage see how much current it is drawing and then this V/I will give you the current that is one way of handling the situation if it is DC circuit, but what I will tell you in general what happens is this.

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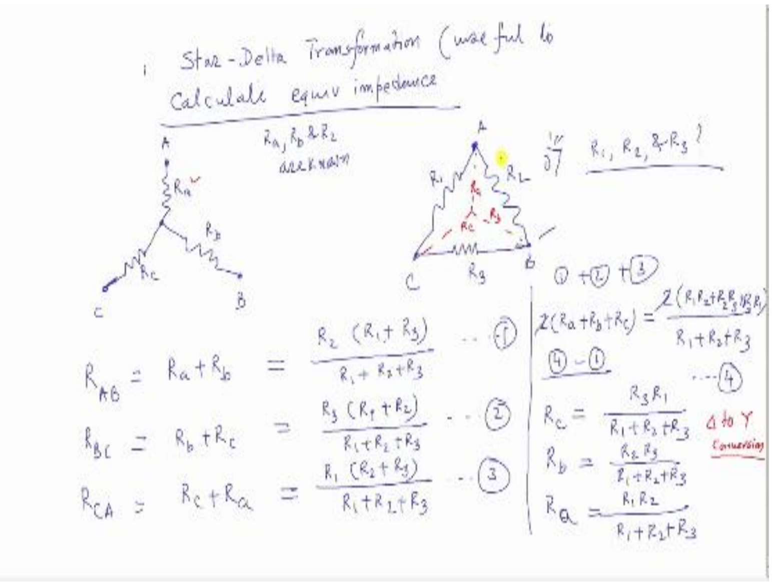

I will tell you about the Star Delta Transformation this I never told earlier Star Delta Transformation. Where it will be useful? Useful to calculate equivalent impedance. The point I want to tell is this suppose you have got 3 points okay 3 resistances this has nothing to do with Thevenin theorem, but it will be very useful. Suppose we have 3 resistances say Ra, Rb and Rc Ra, Rb and Rc and this 3 points are A, B and C.

I ask you okay with respect to this 3 points A, B, C points are fixed I say that this is R1 this is R2 and this is R3 and I say this 3 points remain same. In other words, what I am telling 3 resistances known value Ra, Rb, Rc they are connected in star. Can they be replaced across this 3 points by some delta connected resistances? So Ra, Rb and Rc are known question is R1, R2 and R3.

How I can calculate and replace this star connected impedances by R1, R2, R3 that is the question that can be easily done in this way. Suppose okay if this 2 networks if this 2 things has to provide you equivalent impedance. So R AB suppose between points A and B only what is the equivalent resistance of this network. At the point C I have not connected anything so it will be Ra + Rb (()) (25:08) R AB.

If nothing is connected at C it will be Ra + Rb and this R AB if these 2 are equivalent must be same if you see from this end what is the equivalent impedance at C nothing is connected. Now in this circuit this must be equal to this R2 and R1 +R3 are in parallel. So I will write R2 into R1 + R3/R1 + R3 + R2. So R1 + R2 + R3 mind you this can be replaced by ZS because VS = IS into ZS as V = (()) (26:03) so no problem so this is one equation.

Similarly, across Bc if you calculate R BC from this circuit and from this circuit they must be equal then only this 2 will be equivalent. In that case B and C A you have connected nothing. So I will say R BC with nothing connected to A is Rb + Rc and this should be equal to R3 it will be in parallel with R1 and R2 (()) (26:48) that is R3, R1 + R2 divided by once again R1 + R2 + R3 this is equation 2.

Thirdly, across Ca I will calculate resistance equivalent resistance with nothing connected to B here and in this circuit what is the equivalent resistant here Rc + Ra and this must be equal to across Rc it will be R1 in parallel with R2 + R3. So R1 into R2 + R3/R1 + R2 + R3. So I have got 3 equations Ra, Rb, Rc are known and here is R1, R2, R3 so I will be able to solve it, but nice way to do it is this way.

Suppose you add all this 3 equations you see you add all this 3 equation that is 1 + 2 +3 if you do on the left hand side you will get 2 Ra + Rb + Rc and on the right hand side denominator is same R1 + R2 + R3 and on the top you see R1, R2 appears 2 times similarly R2, R3 appear 2 times it will be 2 into R1, R2 + R2, R3 + R3 R1 this will be the thing this 2 goes.

So Ra + Rb + Rc is equation 4 no new equation just adding this 3. In which way it will help me you suppose say that I will do 4 from this equation 4 I will go on subtracting equation 1, 2 and 3 so 4 – 1 you do. If you do 4 – 1 on the left hand side, you will be left with Rc 4-1. Below it is R1 + R2 + R3 no doubt and this minus this R2 R1 and R2 R3 goes R2 R1 and R3 R2 goes you will be left with R3 into R1. So Rc will be R3 into R1/R1 + R2 + R3.

Similarly, by subtracting 4 – 2 etcetera what you will get is Rb = R2, R3/R1 + R2 + R3 and Rc I have got Ra will be = R1 R2/R1 + R2 + R3. It is easy to remember suppose I am now telling that if R1, R2, R3 are known then equivalent star representation I will be able to calculate quickly that is this one can be represented by one Ra here that is Ra this one can be replaced by Rb and this one can be replaced by Rc what will be the value of Ra.

This one product of this two R1 R2/sum of this two. What will be Rb R2 R3/sum of this three. What will be Rc Rc will be R1 R3/R1 + R2 + R3. Therefore, this is called this will be helpful delta to star conversion. Okay, so similarly you try yourself in the next class I will just tell another few lines will be necessary to calculate the reverse one that if okay if Ra, Rb, Rc are known then what should be the R1, R2, R3. So I will take up that in the next class and then also come back to other interesting network theorems. Thank you.