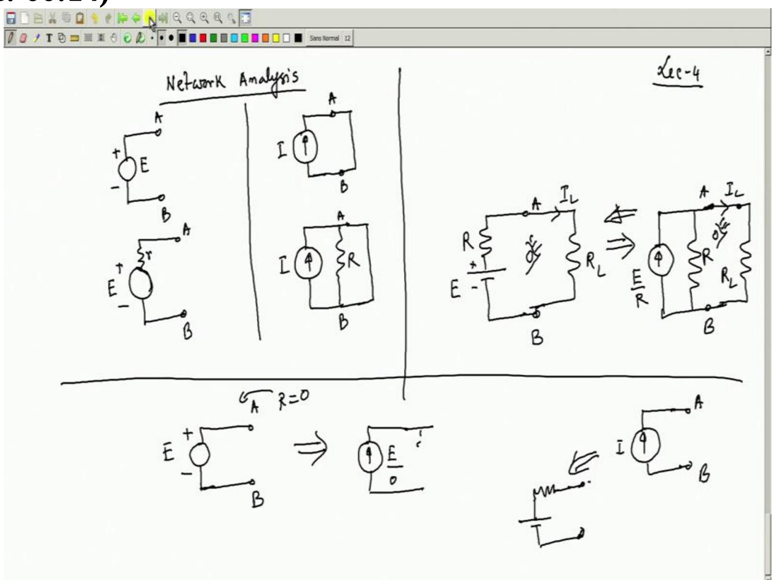
Network Analysis
Prof. Tapas Kumar Bhattacharya
Department of Electrical Engineering
Indian Institute of Technology-Kharagpur

Lecture # 04
Mesh Analysis-I

(Refer Slide Time: 00:14)



Welcome to lecture number 4 on network analysis and in our first three lectures I introduced to you various kind of sources means the sources could be ideal or practical and it could be also either a voltage source or a current source. Only thing you should remember is that ideal voltage source will be represented like this without any internal impedance in series, and it is EMF will be shown in this diagram and two terminals, I am just telling A B.

So, ideal voltage source should be kept open circuited and practical voltage source will be represented like this with its internal resistance which is supposed to be small A and B these will be the terminals of the source and then I told you the current source and the open circuit EMF is z and this voltage source should be kept open circuited when not in use, otherwise it should be connected to the other network, we tweak you want to energize this voltage source.

Similarly, the current source a practical current source will have a magnitude of current specific magnitude of current this is ideal this 1 without any internal impedance, in case of current shorts we discussed will be connected in parallel with this and ideal current source of course, the internal impedance or resistance is very large. So, it is open circuited and since the current source will try to drive current.

In whichever branch you connect in the circuit irrespective of what impedance you have connected therefore, the impudent connected when open circuit It is very large therefore, the large voltage may appear therefore, an ideal current source or a practical current source should be kept open circuited like this here also should be open circuited so that the current will flow like this, and potential difference between these two part will be 0 mind you internal resistance is there.

But if you keep it in short circuit condition there will be no power loss here. Also because all currents will be flowing like this So, it should be kept short circuited, then this current source we have shown is nothing but equivalent to internal resistance R and a and EMF I am sometimes showing circle + - or a battery generally large DC voltage sources are shown with these symbols.

Small battery voltage is shown like that. So, it is like this. Similarly if such a situation occur so, it can be represented this I will and others cut it down here. So, any circuit with this thing in a practical voltage source and a load impedance connected RL is equivalent to current source across AV whose value will be E by R these we have discussed E by R and in parallel with this desistance are internal resistance of the battery and then the load resistance.

These 2 circuits are equivalent we have shown that by parallel conversion of these R and RL This current load current here and load current there will be set. Now, only problem is what happens if the, so, this way you can go also you can always transform a circuit having a current source in parallel with a resistance like that, who had E by R into RL is the see these are the terminals so if you look from side.

Maybe into the circuit through the terminal AB in the circuit to the user, it does not matter whether you're representing the source as a voltage source in series with a resistance or a current source in series with a resistance external volt that is RL we never know now can never distinguish between these 2. So, anyway, so, it is always you can convert it is necessary. My personal suggestion will be heap in a circuit that is current source.

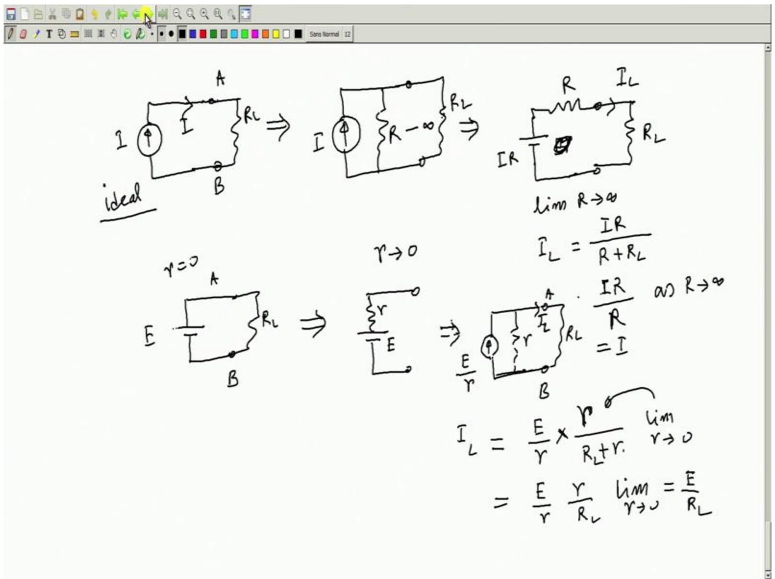
Leave with it why unnecessarily you change to a voltage source. Of course, if you get some very great advantage you do that, but in general you should not do similarly voltage source. Let it be voltage source, but, after learning these then there is the awkward situation will be, you have an ideal voltage source E no internal resistance A B. Can I represented draw and equivalent current source circuit.

For this because the internal resistance of the battery is 0 and if you want to do that following this rule this magnitude of the current internal resistance been 0 here, E by some sort of 0 number and in parallel we are telling it will be shorted it is not because parallel this R if R is 0 here internal resistance of the battery 0 then there are awkward situations it looks like it you cannot do it.

Similarly, if you have an ideal current source I with terminal AB and there is no internal resistance of the current source which is in parallel. Therefore, it is very difficult to represent it in this fashion a source and then internal impedance what is the value of this resistance. What is this resistance this is infinitely large. So, infinitely large resistance here they were what do I do with this if you try to convert in this way.

You connect anything this circuit tells me or nothing can be done because this is an open circuit watch well. Therefore, these are some awkward situation but I will tell you 1 thing that you note down very carefully.

(Refer Slide Time: 08:45)



That it disturbs me what I will do in a circuit if there is a ideal voltage source and current source first of all I will never attend to convert them from voltage to current source or from current source to voltage source, because there are difficulties because in case of ideal voltage source internal resistance is 0 if you want to convert it to a current source, E by that 0 in series with parallel with 0 resistance. Does not help me to analyze this circuit or the load current.

Which will be connected there. Similarly, by passed as I pointed out, but nonetheless 1 point I must tell you that suppose you have an ideal current source I if that discharge you why what should I do if it is an ideal current source what you can do is this, you can Imagine that it is not ideal I current and in parallel with at resistance. I just do that and across A B circuit disconnected AB some load resistance is connected.

But this one I can convert it hard tending to infinity this much if you say then this is the situation live with these are these R value is not known. I mean no fine at value then what you can do is this you can convert it to no problem like right ER here no I into R here in series with R limit extends to infinity like that to you right no problem. There are feeling comfortable this is what I can always do.

And then your circuit is their load current you want to find out suppose you connect to the circuit a resistance of RL. So what I am telling RL equaling then solve this heartbeat what will be the load current IL will be this EMF which is I into R divided by R + RL this will be the current in the circuit is that clear. So, now you say R extends to infinity means RL these are is very large compared to RL

So this will be equal to IR divided by R as R extends to infinity compared to RL it will be large and this will be I itself so what I am telling if somebody connects a resistance RL. Better do not try to convert it if you wish, you bring this resistance and pretend that it will be infinites all these circuit then at the end say R capital R extends to infinity, what I am telling you will get the same result.

If you connect RL what will be the current in RL ideal current sorry over but this point should be understood, got the idea. Therefore, if it is disturbing you at all, then pretend that and infinite resistance is connected. Then do this and then find out the current and at the end, so, whatever current you find out it will be a function of this capital R and capital R extends to infinity. Similarly, a voltage source ideal voltage source E these are the terminal E internal resistance is 0

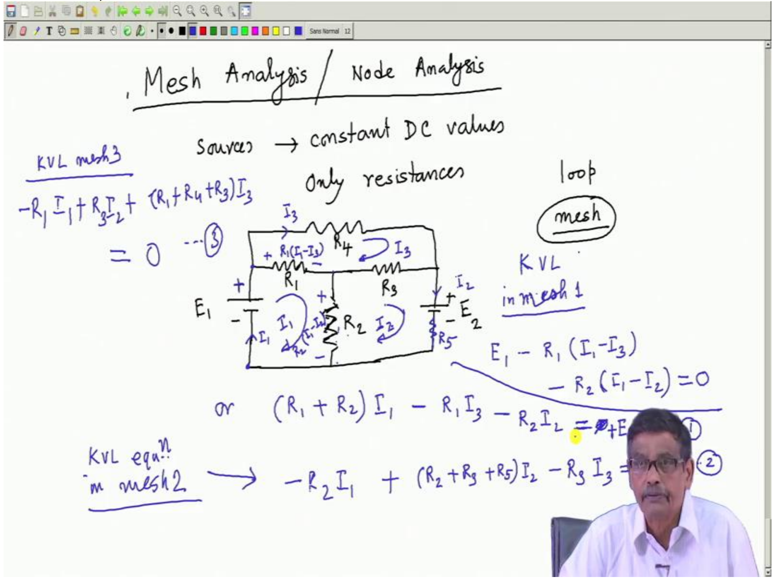
I want to convert it to a current source which I cannot if R is strictly speaking 0 what I am suggesting in that case you show this resistance like this E by R remembering that r extends to 0. This is the correct representation and then I will say if that be the case, then it should have an ideal current E by R and in parallel with a resistance are now whatever you connect across A B solved this network to get the load current.

Suppose RL is connected, solve this network then when you find out this current, it will become a function of small r IL whatever IL you will get for example, this current I want to find out So, IL will be in this case it is so simple. this current is E by R total current, you want to find out current through this branch of this into R other resistance which are in parallel divided by RL + r division of current in parallel resistances.

Then you say limit as tends to 0 try to find out this magnitude, what it will become, it will become r as tends to 0. So, this can be straight away written like this E/r into R/RL and then limit as tends to 0 what is this value. This will be simply E/r so, same thing. I mean battery connected across RL this is the current and I the point I want to make it in this case I told conversion is not possible if somebody insists no convert it and try to do it.

Then imagine there is series resistance are. So, this you can then do E/r parallel r find out whatever network is connected there be solved the currents in that network and then do not forget to take limit that as tends to 0. You will get similar r anyway have let my point you have understood that

(Refer Slide Time: 16:39)



Therefore, this can be solved. (FL: 16:45) Now, what I am going to do is this, as I pointed out earlier also that KVL, KCL is the main thing one need to know to solve any given network to find out currents or voltages across various branches and so on, that is fine. But, we will try to use some techniques to simplify your calculations or understanding of the subject. To begin with, I will discuss these 2 methods.

So, will be first discussing about two very popular method 1 is called Mesh analysis which you will know, but let us review those things Mesh analysis and then Node analysis of subject and this 2, I will first do assuming your sources are of constant values that is DC. If it is voltage source, no time varying thing of course, that restriction will remove after few lectures. So, I will assume some circuits where sources are constant sources.

Constant DC values and only resistances are present in networks I want to find out the currents to understand these what I am telling suppose you have a network like this. Suppose you have a network and there are sources connected said this is E1 this voltage is may be known and these are the resistances R1 said R2 and R3 and suppose there is another resistance here connected R4 and I want to find out currents in the various branches.

In this network that is the thing. Now, to solve this network problem as I told you I can solve it by assuming this current that current applying KCL KVL in various tools, but let us be methodical, how to do it. Now, in this network you find there are several windows like this are several closed path for example, this is a closed path this whole thing is also a closed path like that. So, first I distinguish between loops and mesh. So, it is like.

If you considered this is window panels. Now, any closed loop you identify in a network, these are loops. For example, this whole thing is a low similarly this is also a low and this is also a low But you see in this outer loop, this this bigger loop, there are several sub loops present in this particular loop within that, there is no other loop present and when such a thing happens then we say this is a mesh.

For example, this is a closed loop, but it is a mess. Similarly, this is the mess within which there is no sub loops. Similarly, this is a mess but is the whole thing is a mesh no within that there are several loops present therefore, meshes are those closed Loops within which there you will not find any other loop to be present. So, so, even given a network I can distinguish between mesh and loops. So, this is the thing Mesh.

If so, in this network there are three meshes this is one, this is two and this is three the mesh analysis tells you that you assume the Mesh currents So, I can say that all meshes are loops but all loops are not Meshes. Obviously, this is a loop this loop is a nothing but means this is also a loop nothing but Mesh so, distinction between loop and Mesh I hope you understood. Now what will do is this 3 mesh you assign currents which are called Mesh currents.

I would not this current I will say this is I2 and this mesh current you say it these are called Mesh currents which have assumed it is preferable because I told you while solving circuit detection of the currents is your priority you choose any way you like. But since I want to develop a systematic method to solve a network by Mesh analysis I telling that assume the currents in the clockwise direction like that.

Now, what really I have assume, I have assumed actually this branch currents to be isle in it is not this current is isle in has to be that is what I have assumed. Similarly, this branch current tab assume diver this branch current I have assumed I2 got the point these are the currents I have assume therefore by applying KCL here I see that the current from left to right will be I1 – I2 because I1 is coming then I3 is going so I1 – I2 or one can say I3 – I1 from right to left.

In whichever way you feel it stand righting similarly, this branch current this is I got it to be I1 – I3 coming in and you can apply KCL layer. So, this current will be I1 – I2 from top to bottom this branch current will be I2 – I3 from left to right and in this branch of course this is I3 this is I2 also I will connect at this point which is not necessary but let me connect another resistance here R5 in this network.

So, in mesh analysis you first identify the mashes and then assign loop currents in a following a particular logic that is clockwise current I will do then what you do, you write down KVL in this 3 meshes, for example, I would like to write down KVL in Mesh 1 I will write mesh 1. Now while writing KVL I know this current here in this R1 plan is I can say + - and this drop will be R1 into I1 – I3.

Similarly, this current from top to bottom is I1 – I2 their opposite and these drop can be written as R2 into I1 – I2 with this polarity mind it that is very important if somebody says no current is I3 – I1 from right to left if he writes, then we have to write plus here minus here for the voltage drop R1 into I3 – I1. So, I have done this, then I start from this point and try to reach this point traversing this mesh so, from these to these it is E1.

From these to these it is + to - so - R1 into I1 – R3 and from this to this once again – R2 into I1 - I2 and you reached here From here to here nothing. So, I have come back to the same point where from I am started and KVL says me that this must be true. So, if you test for this side, so, keep, so strongly on one side, you will find this is nothing but R1 + R2 into I1, this and this you bring it to that side, - R1 into I3 and – R2 into I2.

This must be 0 that is the no 0, this must be equal to E1. So, this is the KVL equation in mesh 1. Similarly, I can write down the KVL equation in mesh 2 which I will just tell you see there is a pattern in this case what is that in mesh 1 if you want to write down the KVL equation, there are three unknowns I1 I2 I3, because if I somehow can solve I1 I2 I3, I will be in a position to find out the currency in any branch I like that will come as a difference of these 2 Mesh currents, but there is a common element present.

In this branch current will be I1 in this branch current will be I2 and so on. So, this is the equation 1 but I must form 3 equations. So, this is equation 1. Similarly, in mesh 2 so, if you see there is an emerging pattern coefficient of I1 will be nothing but some of the resistance is present in dismiss R1 + R2 into I1 coefficient of I2 when you are writing KVL equation in mesh 1 will be coefficient of I2 will be the common resistance.

Whatever is present preceded by a negative side coefficient of I3 is the common resistance whatever is present between loops 3 and mesh 3 and mesh 1 that will be - R1 that is the thing equal to any sources present in this network. S there is a source E1 and whose positive polarity such that it tells in it E1 to circulate in the direction I have a assume Current comes up from this from the positive end of a battery in general.

Therefore that is why it is + E1 why + E1 because plus of this battery is in the same sense as that of I1 current sense. So, if that be the case, one can write down once again in the same way KVL equation. In mesh 2 where I2 is present, I will say, Look here the coefficient of I2 will be some of all the resistances R2 + R3 + R5 into I2 That is what it will come R2 + R3 + R5 in this mesh these are the resistances present that is why I2 will there be a coefficient then mesh 2 of I1.

Yes, there is a common resistance and that will be – R2 into I1 + this then what will be the contribution of I3 it will appear as a drop in R3. So, - common resistance existing yes R3 into I3 that is all so, all the drops have taken and on the right hand side I will connect this is + on the right hand side. I have to check whether there is any source present. In this case voltage source only and should I write + E2 or – E1 in this case.

See the polarity of E2 that battery is such that it opposes I2 therefore, it must be - E2. So, these will be equation 2 in mesh 2 similarly, in the third loop KVL So, this is KVL in this 1 and where should I right KVL Mesh 3 will be coefficient of I3 will be some of all the resistances that is it will be something like R1 + R4 + R3, R1 + R4 plus I3 into I3. That would be then coefficient of I2, yes it will be common resistance preceded by minus sign.

That will be the coefficient of I1 in mesh 3 so R1, - R1 into I1 + will there be a turn involving I2 here is there is a common resistance - R3. So, - R3 into I2 and this is + and the right hand side should be any sources present those terms will appear and in this case there is nothing present. So, it will be 0. Therefore, after assigning the Mesh currents you can go as I did for the first equation, you repeat for the second and third loop showing the polarities.

This that and then I am telling you the final equation in will be like this is the thing original thing KVL I had applied noting down + - sign this that. But finally, it will come like that from where I told that there is an emerging pattern because coefficient of I1 will be in mesh 1 you are writing So, come here some of all the resistances we will be coefficient of I1 coefficient of I2 will be is there a common resistance in the common wall between this two meshes.

Yes, there is my – R2 coefficient of I2 should be - R2 into I2 I should have written this term earlier anyway does not matter then – R1 into I2, because there is a common resistance following the same logic I do there will you see writing down of KVL equations. 3 equations you required to solve this here been able to write down 3 KVL equation and for that I should not take practically much time very quickly I can write if I know this rule.

This is what is going to happen that is the advantage Mesh analysis you generate 3 independent equations and then of course, these 3 algebraic equation not to be solved only one point I will tell that I can have choose any other loop for example the outer loop KVL will be satisfied yes it will be it has to and one can say. I will get another fourth equation and that is not to me it will also give you another equation no doubt, but that equation can be will not be an independent equations.

That equation can be generated from these 3 equations only. Therefore, you identify the masses right down the KVL equation in each Mesh which following this logic becomes very simple and you get your solutions. Therefore, how many independent equations, will be there as many meshes out there so, this is about mesh analysis we will continue with some example in the next class, what to do when current source is present. Thank you.