

Networks and Systems
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Lecture - 34
Network Theorems (1)
Superposition Theorem
Substitution Theorem

The next topic, we will take up for discussion is Network Theorems. I am sure that you had acquaintance with various types of networks theorems in your earlier circuit analysis courses. Like, the superposition theorem, Thevenin's theorem, Norton's theorem and so on. So, we will have a brief review of the various network theorems. And this will be as I said a review of, what you are already know.

But, perhaps it will deepen your understanding of the theorems, in one or more respects in the respect of certain theorems. You may also learn a few additional theorems, which you have been not exposed to in your earlier courses. But, the normal feature of what we are going to discuss here, from your point of view. May be the application of these theorems in the Laplace transform domain, which is of course, a new feature, which you would not have had in your earlier courses.

Now, network theorems, furnish a particularly simple solutions of network problems in special cases. So, often times, the solution of a particular problem using the routine methods, may enter long computation or calculations. But, if you use a particular theorem, which is relevant to the problem on hand. Then the solution, may become quite simple and straight forward.

So, after studying the various network theorems, one should develop the facility of identifying a particular theorem, which fetches us the solution in the most direct and simple way, from the whole lot of theorem that are available to you. So, this discrimination and the facility of choosing a particular theorem, relevant to the context is something very important. Certainly network theorems also provide us special insights into the network behavior, quite often.

And this is an additional reason why, we study network theorems. As you are aware by now, there are three main realms of network analysis, using the algebraic method. One is the DC circuit analysis methods, then the AC circuit analysis methods. Then the methods using transform diagram in the Laplace transform domain. All these three methods have a common set of techniques of network analysis.

Whether, you use the loop current method or the node voltage method. The principle, the essential basics of the network analysis methods are the same in. However, in the case of DC circuits you write the equations in terms of various constants, which are the resistance of the network or the conductance of the network. And the variables, which are DC quantities, which are constants.

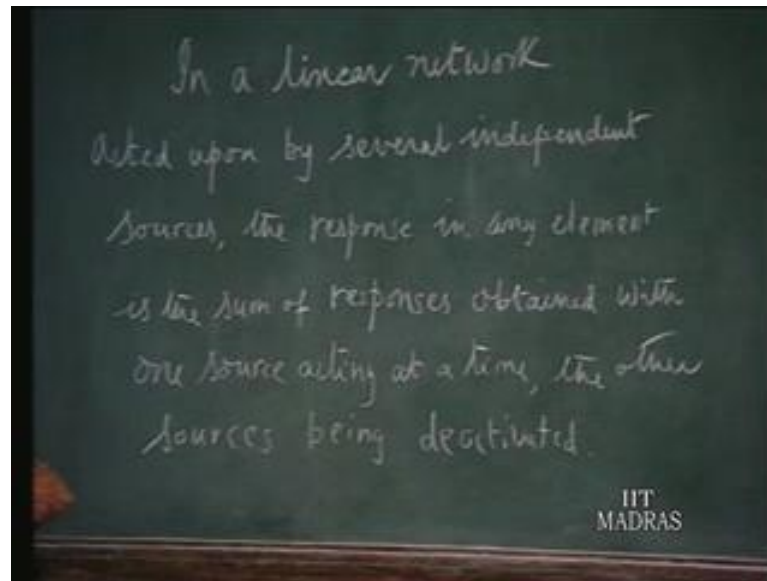
In the case of AC circuit analysis, the constants are complex constants and the variables are the phases of the voltage and currents, which you are trying to solve. In the case of Laplace transform technique, the equations once again turn out to be algebraic. But, the coefficients of the various variables that you are trying to solve for are functions of s , algebraic functions of s . The impedance functions, the admittance functions are the functions there of. And the variables themselves, which you are trying to solve for are functions of the complex variables s .

The transform of the voltage, the transform of the current as the case may be. So, all the three domains. Whether, it is a DC circuit analysis, the AC circuit analysis or the transform domain, essential techniques are one at the same. However, the details will vary. And so provided, you pay special attention to the small details, which are demanded by the requirements of the particular realm. We can be assured that the general principles, governing the network analysis are the same.

Consequently, the network theorem that we are going to talk about also have validity in all the three domains. Whether, the DC circuit analysis, AC circuit analysis or the transform domain. So, what we will do is, try to give the statements of the various network theorems. And try to discuss them in the most general context, which is the Laplace transform domain. And it is simplification when, it is the AC circuit analysis or the DC circuit analysis will be almost evident.

So, let us now start with a review of superposition theorem, which you are sure, all of them you are familiar with already, in the context of DC circuits or AC circuits.

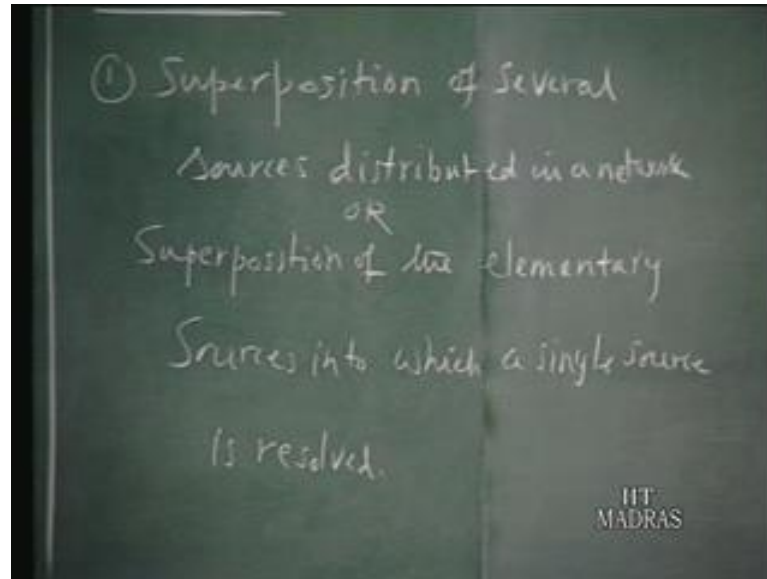
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The statement, of the superposition theorem would be something like this. In a linear network, acted upon by several sources. I would say, let us say several independent sources, the response in any element of the network. Of course, is the sum of the responses obtained with one source, acting at a time the other sources being deactivated. Since, I am sure you already know about this. We will not elaborate on this except of course, to point out that when you have a whole lot of sources acting upon a linear network, the crucial statement is a linear network.

In a linear network, acted upon by several independent sources then if, you want to calculate the response in any particular quantity, in a particular element say the voltage response or current response in a particular element. It is obtained, by the superposition of the responses, obtained by the individual sources. One each one acting at one time and when, the particular source is acting all the other sources are deactivated. So, we specifically mention what is meant by deactivation in a moment.

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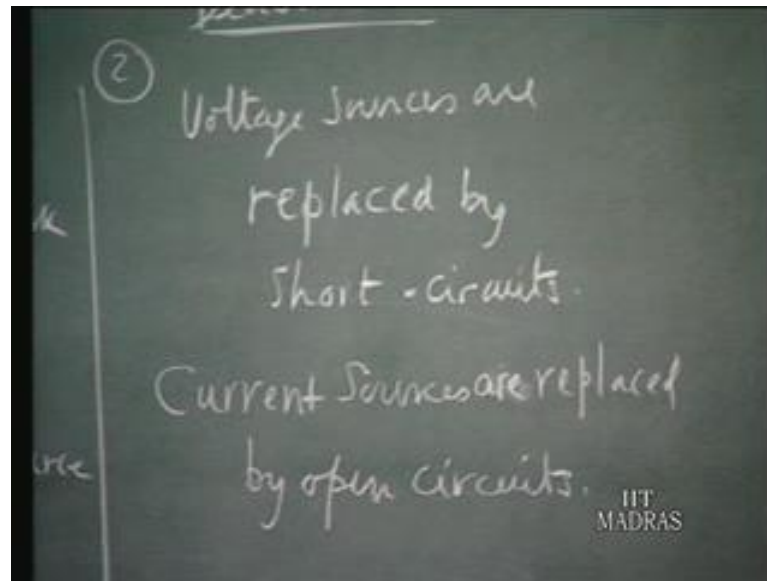


So, comments on this, is the superposition when you talk about superposition, it may be you have several sources distributed into the network. So, then you take one source at a time. It can be superposition of several sources distributed in a network. So, each source you take at a time. Alternately, if there is a single source, you can decompose that you can resolve that into several elementary sources, much as we have done in the case of Fourier analysis.

And consider the effect of each source at a time or superposition of the elementary sources, into which a single source is resolved. So, in other words, it may be the spatial distribution of the sources, which you have super positioned or a single source at a given location, which is resolved into a sum of several elementary resources. And then you find the effect of each source in turn. So; that means, a temporal or if it is a waveform, there is a. It may be a particular source, may be resolved into several functions of time independent functions of time like, a Fourier analysis.

So, the resolution of a periodic waveform into a several sinusoids or it could be exponential type of distribution, in which you take the effect of one source at a time.

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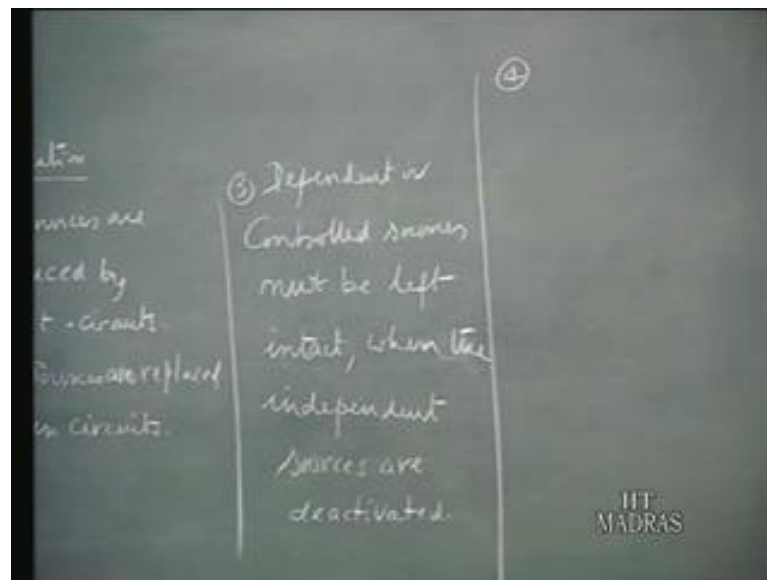


Second comment is deactivation means, voltage sources are replaced by short circuits because the voltage strength is made equal to 0. That means, a particular voltage source is replaced by a short circuit. Current sources, if there are any and when you are considering the effect of other sources, a particular current source is replaced by an open circuit. Current sources are replaced by open circuit.

In other words, you are reducing the strength of that source whether it is a voltage source or a current source to 0. So, when you are reducing this strength of voltage source to 0, it means you are replacing it by a short circuit. If you are replacing this the strength of a current source, if you are reducing the strength of a current source to 0, it means it is replaced by an open circuit.

Third point is when we are considering the effect of this various sources at a time, it is only the independent sources that you should consider, dependent sources if they are any, they form part of the linear network. A linear network contains, linear elements and the linear elements include, the dependent sources also because the dependent voltage source is linearly dependent on the controlling quantity.

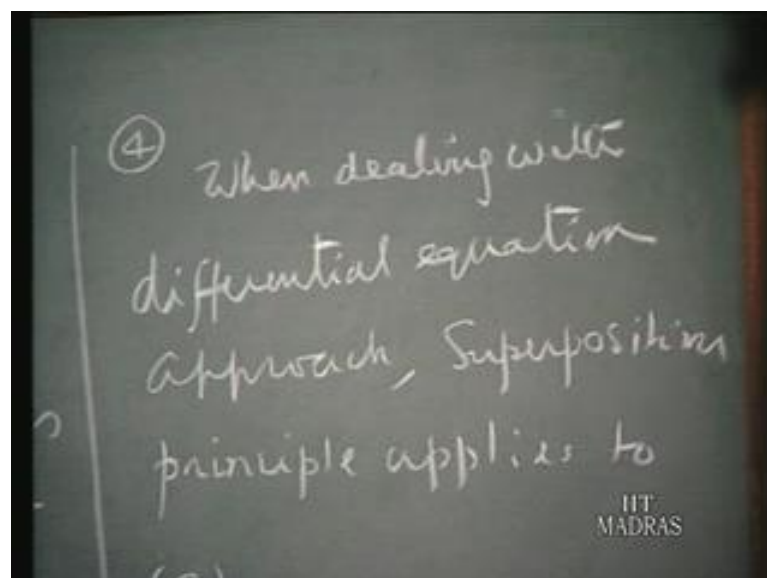
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So, therefore, dependent sources must be left intact, dependent or controlled. Controlled sources must be left intact; that means, you should not disturb them, when the independent sources are deactivated. So, that is important So, if you have dependent sources, those dependent sources must be allowed free play as far as computation of the effect of a one particular independent source is concerned, dependent sources should not be disturbed they should be there.

Of course, their value depends upon the particular situation, in the circuit.

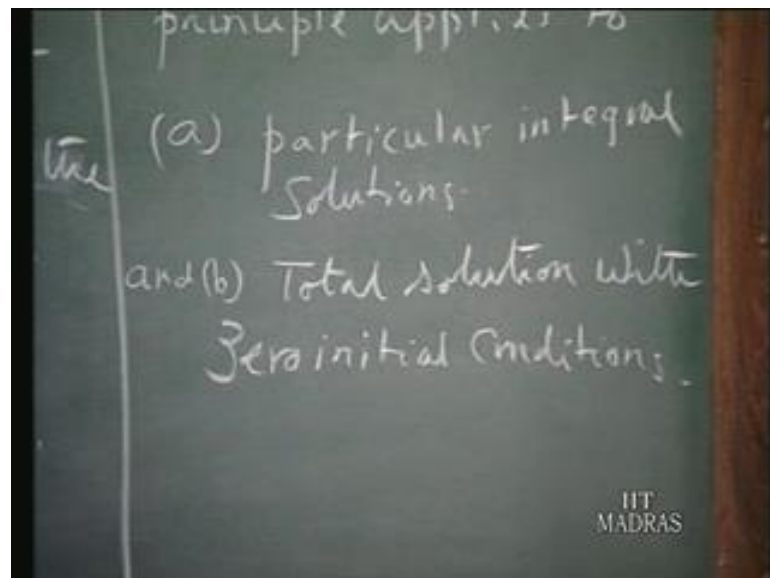
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The fourth point, which we should like to observe, is when dealing with differential equations. When dealing with differential equations, differential equation approach, the superposition principle applies to a. Suppose, you are taking up a differential equations approach to solution of a network problem and then you have several sources. And you consider one source at a time then you would like to find out the response due to each source in turn.

Then, you can superpose the responses to the individual sources, provided the response that you are talking about is a particular integral solution.

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So, superposition will be applicable to particular integral solutions alternately, the total solution with zero initial conditions. So, you can superpose the responses, if they are in the form of particular integral solutions or alternately, if the total solution is what you are looking for and you want to superpose this total solution due to each, individual source acting at a time. Then the superposition principle is valid, provided the network has zero initial conditions

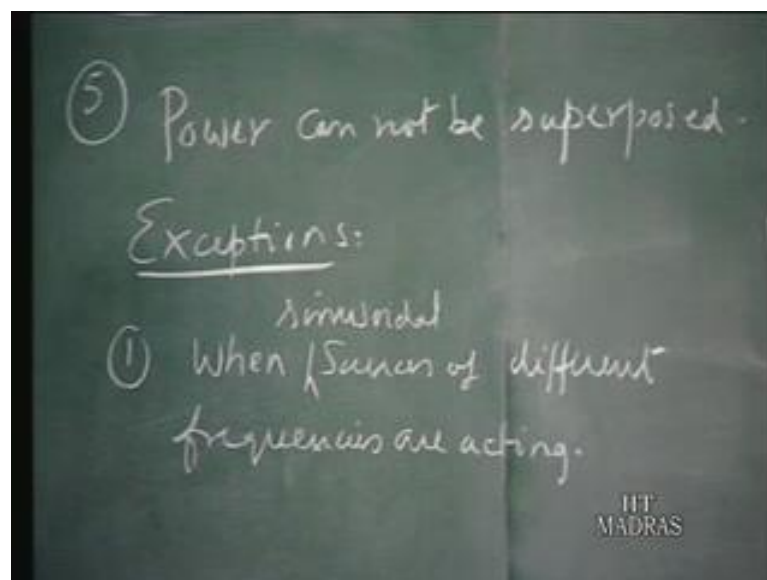
This is because, when you have an initial current in an inductor or an initial charge in capacitor. It spoils the linearity of the terminal relations, of the equations terminal relations between the voltage and current in an inductor or a capacitor. You may recall,

that all such non-zero initial conditions associated with inductors or capacitors, can be replaced by equivalent independent sources, whether DC sources or impulse sources. And the Laplace transform domain analysis incorporates such equivalent sources to replace the initial conditions.

Therefore, it turns out that in the Laplace transform domain. If you replace each initial condition by an equivalent source, then we are essentially dealing with a network with zero initial conditions acted upon by several independent sources including those sources, which you have replaced the non-zero initial conditions. Therefore such a problem does not arise; that means, in a Laplace transform domain when you have several sources including, the replacement sources for non-zero initial conditions.

You can take the effect of each individual source at a time and superpose those effects. In fact, the statement here a linear network emphasizes that (Refer Time: 18:17) we are talking about a network with zero initial conditions. Additional points, we can also observe that when you are superposing the responses, you must understand that the superposition principle will not be valid for super positional power.

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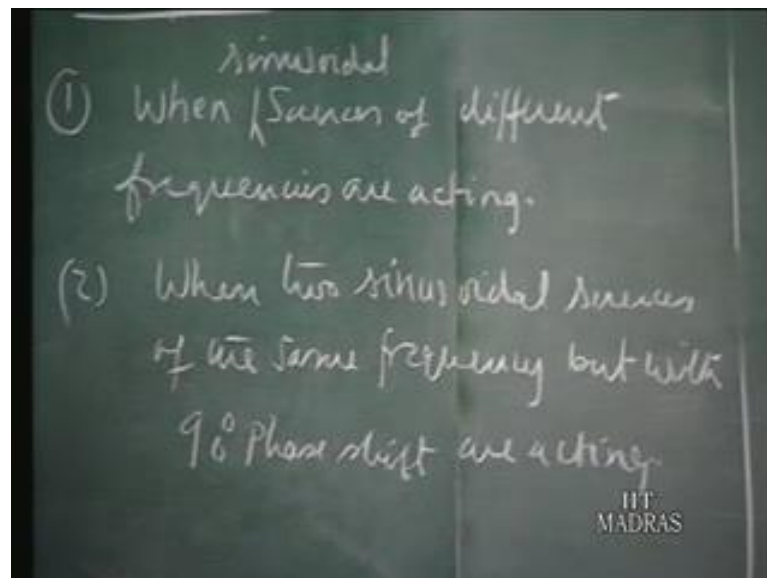
Powers cannot be superposed. In general, when you want to calculate the power in a particular element, you cannot calculate the power due to each individual source at a time. And add up the powers and say this is the total power, when all the sources that are acting up at a time. Because, power is nonlinearly related to a voltage or a current as the

case may be; however, there are special exceptions to this because in such cases, the power can be superposed.

Exceptions are 1, when sources of different frequencies, when sinusoidal sources of different frequencies are acting in which case, because as you have seen when we talked about in fury with short. In terms of a calculation of power, when we are discussing the Fourier series that the cross products of two different frequency terms. We will have a zero average therefore, it turns out when sinusoidal source have different frequencies are acting; you can calculate the power due to each source at a time, each frequency source.

And then superpose them, the total power will can be superposed in this context.

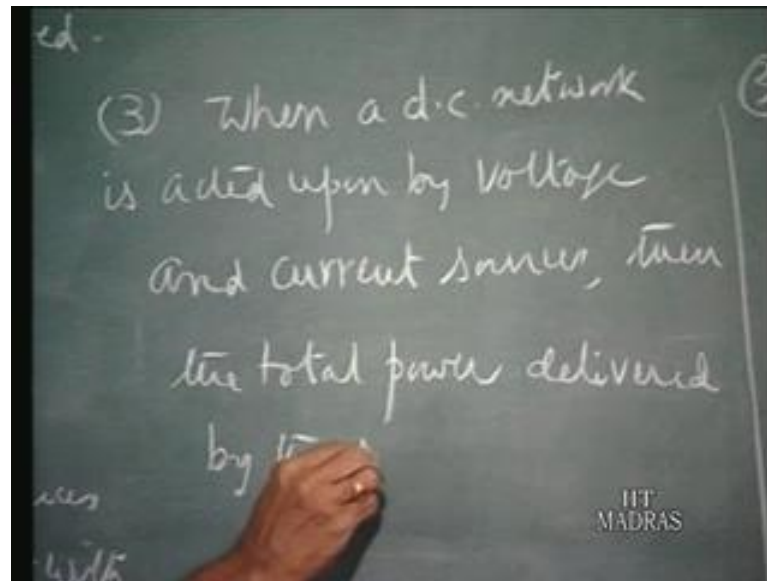
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Secondly, it may arise that when two sources when two sinusoidal sources of the same frequency, but with a 90 degree phase shift are acting. So, if I have one sinusoid, which is $\sin \omega t$ type of thing and the other is $\cos \omega t$. You can find out the power due to each individual source and add them up because, it turns out that the magnitude of $a + jb$ is square root of $a^2 + b^2$

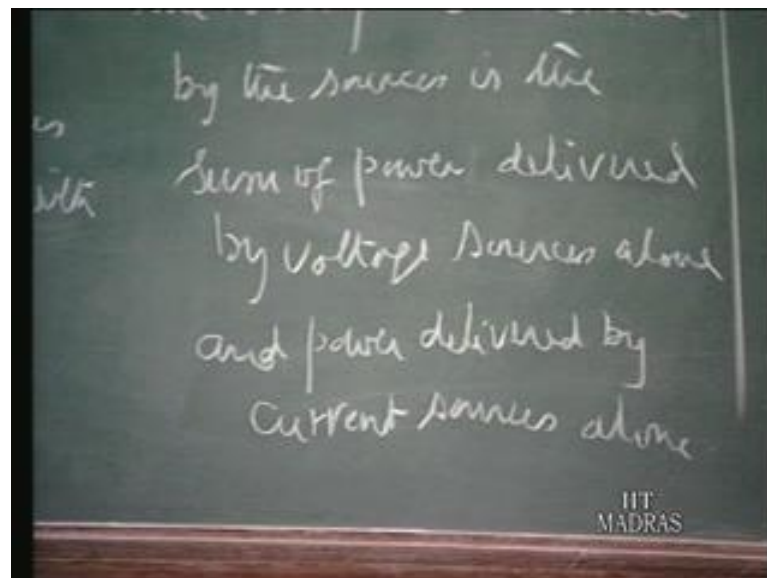
Therefore, from that relation, you will find that when two sinusoidal sources of same frequency, but a 90 degree space shift act then also power can be superposed.

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A third interesting situation arises, when a DC network that is a resistor network acted upon, is acted upon by voltage and current sources.

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Then, the total power delivered by the sources is the sum of powers delivered by voltage sources alone. And power delivered by the voltage by the sum of power delivered, power delivered by the voltage sources alone and power delivered by current sources alone. This is a very special result, which is interesting that if we have several voltage sources

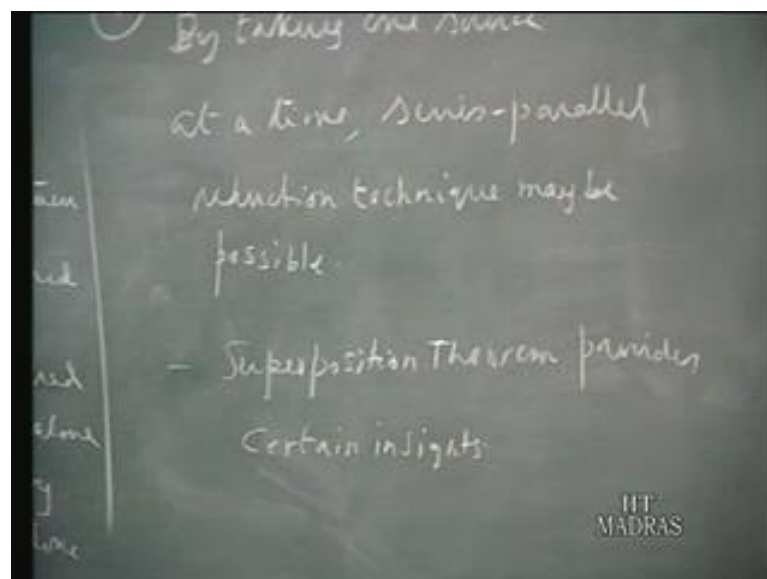
and current sources, acting upon a resistive network then you calculate the total power delivered by the voltage source acting alone.

All the current sources are open circuited then, let us call that P_V then, find out the total power delivered by the current sources acting with the voltage source deactivated. Let us call that P_i then the total power is P_V plus P_i , which is the superposition of these two powers. These are exceptional case, special cases. Then, lastly we might like to ask at this point, what is the advantage of this superposition theorem, application to superposition theorem to network analysis.

One answer to this is that, if you have a complicated network acting upon by several sources. Then the network analysis method that you have to apply, may be a general one like, the loop current method and the node voltage method, which requires a considerable algebra. On the other hand, if you are taking only one source at a time. It may be that the whole network configuration may be one of the series parallel type.

Therefore, the analysis technique that you would employ would be one where, you combine two elements in series or in parallel and analysis may be that much simpler. So, this will not be possible if you are two or three other sources plus two or three sources present at the same time. Therefore, by using the superposition theorem, you may reduce the complexity of the network or the configuration of the network to a simpler form and the analysis may be that much faster.

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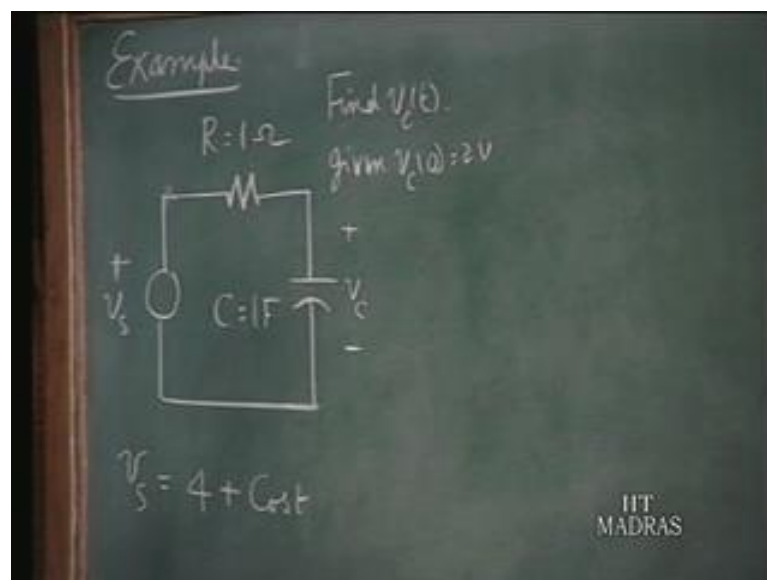


So, by taking the effect taking one source at a time, series parallel reduction technique may be possible, which is precluded when all this sources are acting together. Secondly, superposition theorem provides certain insights in the network behavior, when you apply that superposition theorem. You may be able to find out certain characteristics of the network behavior using the superposition principle.

And also you may use this for proving other results. For example, you have already seen that using superposition we can see, that the response of a linear system to a composite signal can be thought of, as the super position of the responses due to an impulse functions or step functions. And you have got superposition integral or the. So, called fault to integral or convolution integral.

So, superposition principle can be employed to derive some other results and get into additional insights, with the behavior of the system. So, with this introduction about the superposition theorem, which as I said is a quick review of certain points, which you already know and may refining some concepts, which earlier have been exposed to. Let me work out a couple of examples.

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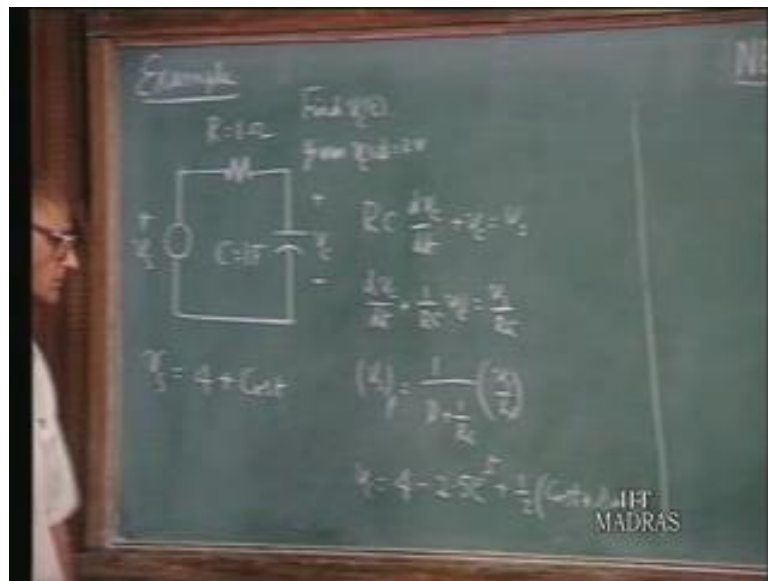


Now, let us now consider an example where, a voltage source V_s , which is 4 plus $\cos t$ is acting upon a series RC circuit and it is given that $V_c(0)$ is equal to 2 volts. Now, if you set up, you are interested in finding out V_c of t . So, if you want to find out the

differential equation joining V_c as the output quantity with respect to V_s as the input quantity.

We see that V_c plus the voltage drop across the resistance must be equal to V_s . The current in the capacitor is $C \frac{dV_c}{dt}$. Therefore, the voltage across the resistance is R times $C \frac{dV_c}{dt}$.

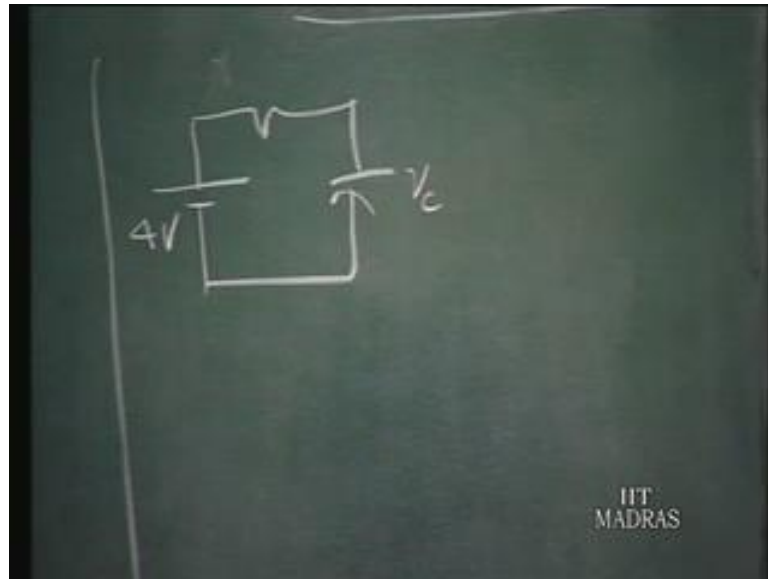
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Therefore you have $R_C \frac{dV_c}{dt}$ that is the voltage across the resistance, plus the voltage across the capacitor must be equal to V_s . And this can be written as $\frac{dV_c}{dt} + V_c = \frac{V_s}{R_C}$. So, the solution for this can be obtained in the usual manner, the particular integral solution for this would be of course, $\frac{1}{D} + \frac{1}{R_C}$ operating on V_s upon R_C . And using the forcing function that we know, we can find out the particular integral solution.

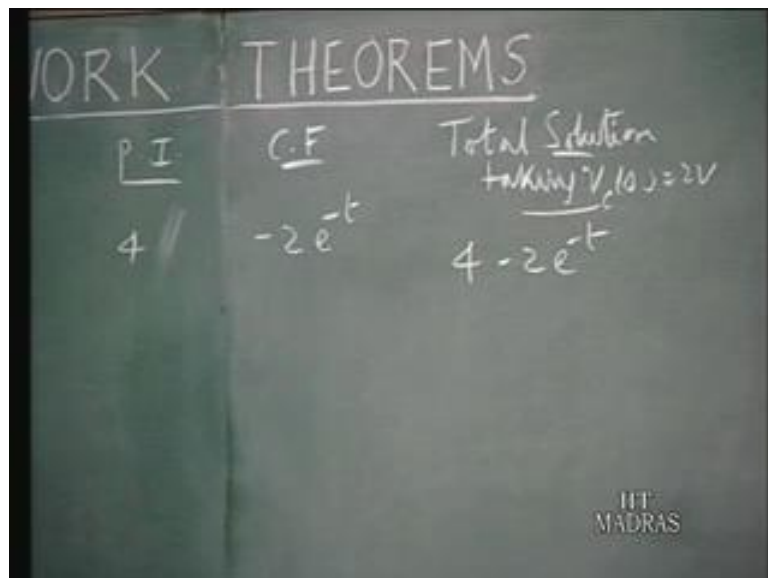
And using the initial condition finally, you can arrive at the solutions, total solution for V_c as $4 - 2.5 e^{-t} + \frac{1}{2}(\cos t + \sin t)$ that is the total solution for V_c of t . Now, let us use the principle of superposition and try to find out the solution in the classical differential equation approach itself. So, let us take V_s to be equal to 4 volts a DC source at once. And then let us take V_s is equal to $\cos t$ as (Refer Time 29:18) and superpose the effects.

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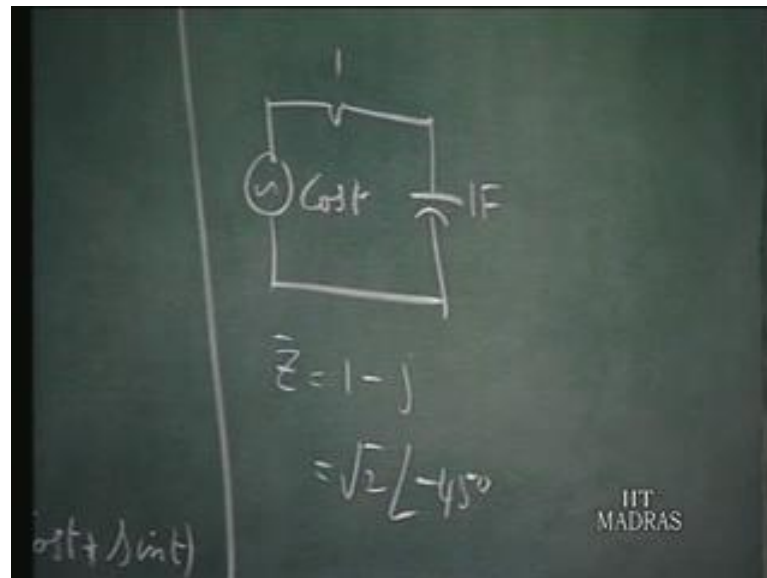
So, if I take V_s as 4 volts. So, you have a 4 volts source and then you have a resistance and capacitance V_c .

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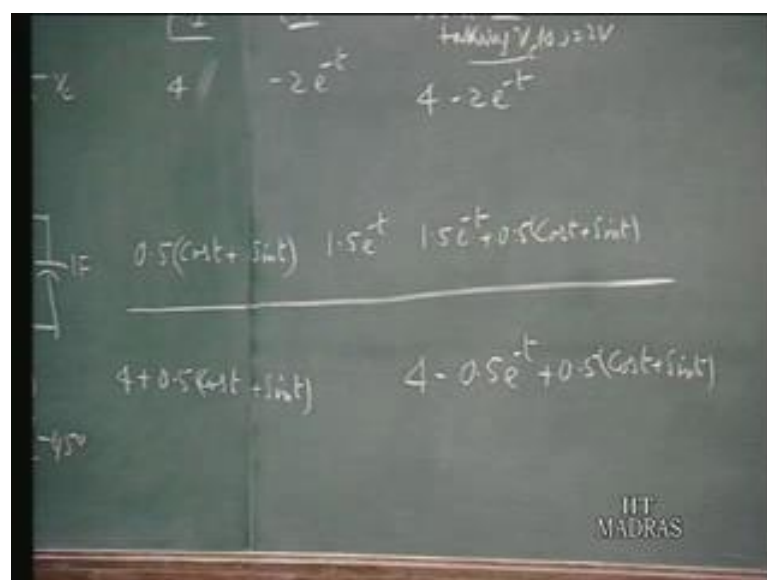
So, the particular integral solution for that when, you have 4 volts DC, V_c will also be equal to 4 volts. The complementary function for this V_c will turn out to be minus 2 e to the power of minus t therefore, the total solution taking $V_c(0)$ to be 2 volts. So, if you take the total solution, this is particular complementary is also taken with that initial condition this will turn out to be 4 minus 2 e to the power of minus t volts that is V_c .

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Now, on the other hand you take the source to be a sinusoidal function $\cos t$ and then you have RC network. And if, you have 1 ohm resistance and a 1 farad capacitor, so you find out the impedance of this. This is $\cos t$, omega equals 1 impedance is 1 minus j that is root 2 at an angle of minus 45 degrees. So, if $\cos t$ is a driving voltage and the impedance is root 2 at the angle of minus 45 degrees.

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It turns out that the particular integral solution is $0.5 \cos t$ plus $\sin t$, that is the particular integral solution. And complementary function will turn out to be $1.5 e$ to the power

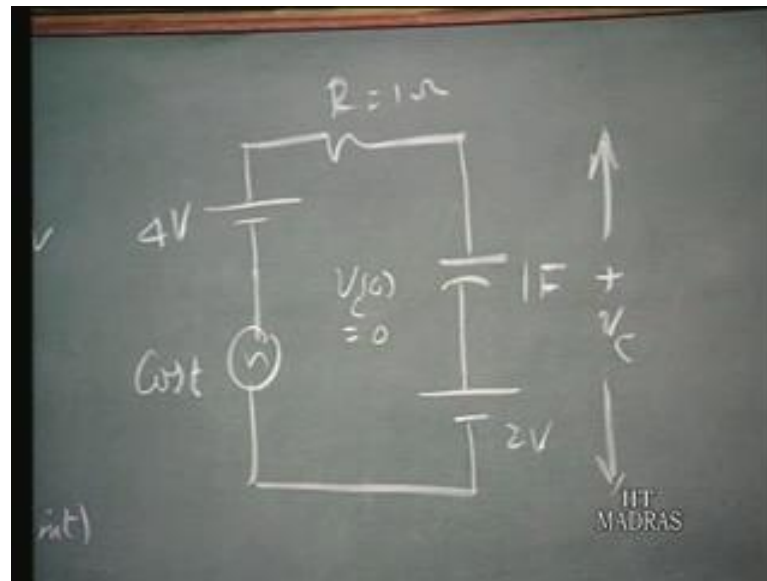
minus t . Therefore, the total solution is $1.5 e^{-t} + 0.5 \cos t + \sin t$. Now, if you add these, the total particular integral solution is $4 + 0.5 \cos t + \sin t$. If, you take the sum of the total solution this is $4 - 2e^{-t} + 0.5 \cos t + \sin t$. If, you take the sum of the total solution this is $4 - 2e^{-t} + 1.5 \sin t$.

So, therefore, $4 - 0.5 e^{-t} + 0.5 \cos t + \sin t$, this is what you get. Now, if you compare these two expressions, with the result that you would obtain under normal calculations, you will observe that $4 + \frac{1}{2} \cos t + \sin t$, the particular integral solution here is the correct one. However, the total solution you have get $4 - 2.5 e^{-t} + 1.5 \sin t$ whereas, here you get $4 - 0.5 e^{-t} + 0.5 \cos t + \sin t$.

The discrepancy arose because when, you are calculating this total solution you have taken the initial capacity voltage to be 2 volts. When you have taken this, the cap with this the second source, you have taken the initial capacitance voltage once again as 2 volts. Therefore, when you are adding this up, you are getting the initial capacitor voltage as 4 volts. And that is what this gives when t equals 0.

So, the total solutions will not add up because, you have taken the initial capacitance voltage as 2 volts. On the other hand, if you have taken the total solution taking the initial capacitance voltage to be 0 volts, you would get some value. And if you replace the initial voltage, across the capacitor by an additional DC source of 2 volts then you get the total solution correct. So, you can work that out, I will leave the details to you.

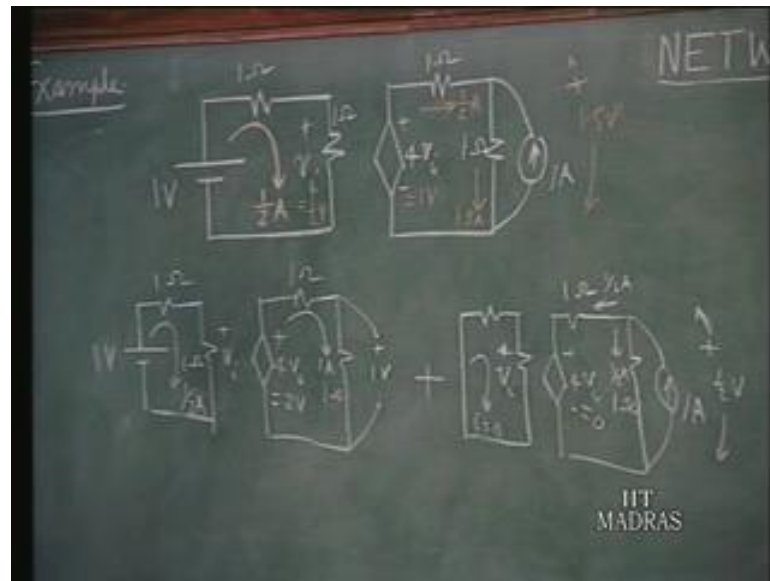
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Then you take three sources, now you replace the initial capacitor voltage by 2 volt source; that means, you take a 4 volts DC source here as before then a $\cos t$ term, a resistance here R equals 1 ohms. And the capacitor you replace it by an uncharged capacitor, plus a 2 volt source represent the initial conditions. And you take this your to be your V_c and calculate this V_c using this source as one time and this source as another time, you will get the correct solution, even if you superpose the total solution.

So, that is what we meant earlier that you can superpose the total solutions with 0 initial conditions, because now this capacitor is assumed to have 0 voltages. Because whatever, non-zero initial conditions was there it is replaced by the equivalent source. Let us take another example.

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Let us consider a second example, in which you have an independent voltage source and independent current source and a dependent voltage source. So, we would like to use the superposition principle to analyze this network. So, we consider this voltage source acting therefore, 4 volts and you have 1 ohm resistance another 1 ohm resistance and you have a dependent source, dependent source as I said should be kept intact, you should not disturb that.

So, if this is V_i this is 4 times V_i and you have 1 ohm resistance and another 1 ohm resistance and this current source is open circuit. So, in this network, we have 4 volts driving a 2 ohm resistor in this circuit therefore, a current of 2 ampere flows through that. And consequently this should this is 1 volt I have 1 volt here therefore, this is 1 volt and consequently the current here is half an ampere and V_i is 0.5 volts and 4 V_i is therefore, is 2 volts.

And this 2 volts will drive a current of 1 ampere through this. And you will develop a voltage of plus 1 volt across these two terminals. And that is the complete analysis of this circuit with, 1 voltage source only acting Now, we also have a current source therefore, let us find out the performance of this circuit when, this 1 ampere current source is only acting and this 1 volt source is replaced by short circuit. So, you have circuit like this, this is V_i and once again you have the dependent source 4 times V_i and you have 1 ohm resistance, another 1 ohm resistance and you have a current source of 1 ampere.

Now, let us see what happens, as far as this loop of 2 resistances are concerned there is no driving voltage here. Therefore, the current here is 0 and the voltage V_i also is 0, if this voltage V_i is 0 this is also 4 V_i is also 0 which means, that this 1 ampere current source is acting on two 1 ohm resistance in parallel which means a current here must be half ampere and the current here must be half ampere.

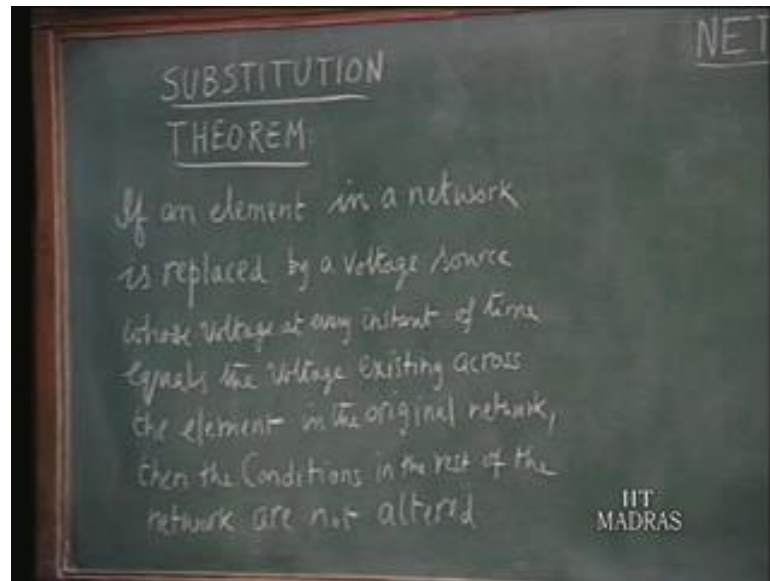
So, that completes the analysis of the circuit with 1 ohm ampere source acting alone. Now, you can put these two results to find out, what happens in the original circuit So, you can see in the original circuit, the current in this loop is half ampere here and 0 ampere here therefore, in the original circuit also the current is half an ampere. The voltage V_i let me put this is in a different color. So, that we understand the result that we have obtained. So, this is half ampere, the voltage V_i is the voltage here plus the voltage here.

The voltage here is 0 the voltage here is half volt therefore, this is half volt, 4 V_i this is 2 volts here, this is 0 this is of course, 0 because V_i is 0 this is also 0 therefore, this will be 2 volts. The current across the current source, this current source drives a current of half ampere here half ampere therefore, the voltage across the current source is half volt here, this is half volt, this is 1 volt. So, the voltage here is 1.5 volts across the source. And the current here this is 1 ampere in this direction, half an ampere in the other direction therefore, this is 0.5 ampere half ampere.

The current in this element is 1 ampere here, half ampere here therefore, this is 1.5 amperes. And this must be because 1 ampere in this direction, half ampere in other direction this current must be half an ampere in this direction. So, this half ampere and this 1 ampere together will go as 1.5 amperes in this 1 ohm resistance. So, now, this particular example, illustrates the application of the superposition theorem when, they have a dependent source also dependent source also at present.

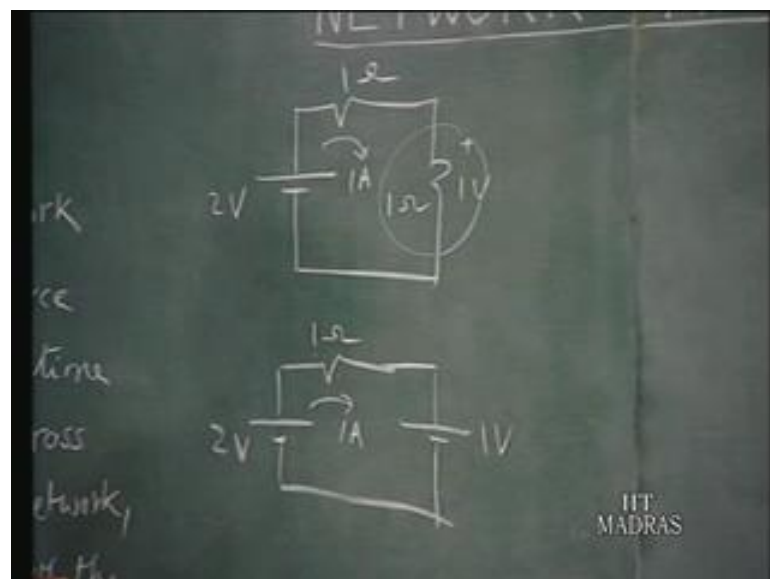
As I pointed out, the dependent sources must be kept intact when you are considering the application of each independent source at a time.

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The next theorem that we will discuss is what is called the substitution theorem. It reads like this, if an element in a network is replaced by a voltage source whose voltage at every instant of time equals the voltage existing across the element in the original network, then the conditions in the rest of the network are not altered. Let me illustrate this, first by means of simple example and then later on I will discuss this.

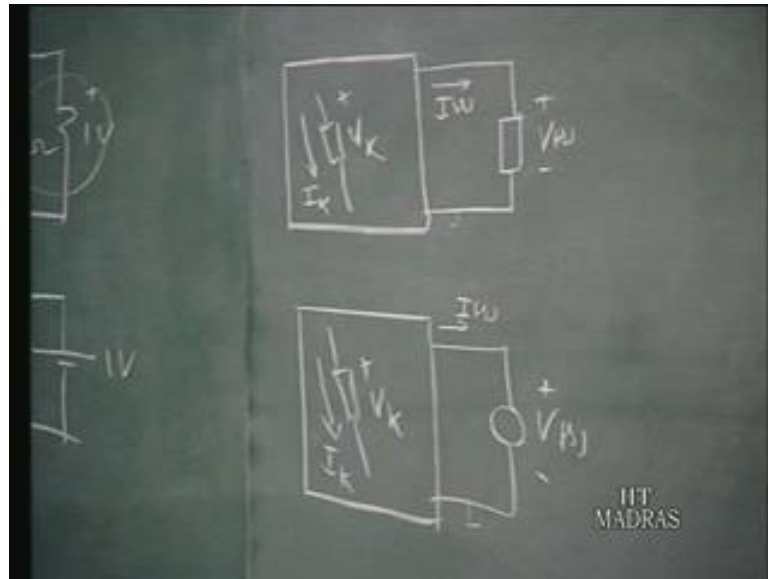
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Suppose, I have a 2 volt source acting in on a circuit like this then the voltage across this 1 ohm resistance is now; obviously, 1 volt. So, suppose I replace this by a 1 volt source

and consider this network 2 volts 1 ohm then the current in the network, everything else will remain the same, here we have a 1 ohm, 1 ampere current here also you have 1 ampere current. The voltage across this resistance here and here are the same; that means, this element which had a 1 volts potential drop across this is replaced by a source. So, that is the statement of this theorem.

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In general, you have a network here and let us say that we have an element here, may be linear, may be non-linear that element we have not made in this particular stipulation. It has in the Laplace transform domain let us say it has a voltage V_s . And it has a certain current, I of s . Now, what this substitution theorem tells us is that in this network, if you replace this element by a voltage source whose voltage is V_s , which is the same as this then all the other conditions in the network will remain the same.

Suppose, I have an element here, whose voltage is V_k and whose current is I_k in this will continue to be V_k and the current will be I_k . What is the justification for this, justification is that if you are doing the node voltage method of analysis. Let us take this as datum node, take this as the datum node then the node equations at all other nodes inside the network will remain the same.

As far as this node is concerned, (Refer Time: 42:32) in the original network V of s is the solution for this node voltage. Now, here we are stipulating that node voltage to be V_s . So, this node voltage stipulation is consistent with the solution that is obtained in the

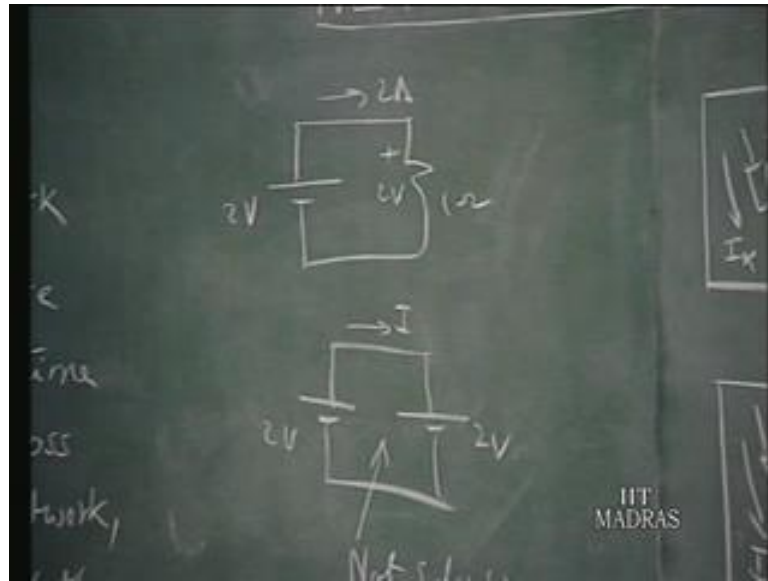
original network. The other node equations are the same, for this particular node you are giving the solution itself as the data therefore, it is consistent. Therefore, whatever solution you have obtained here, will be the same as this as far the other nodes are concerned.

Similarly, if you are using the loop equations, the other loop equations are the same. In this loop equation corresponding to I of s across this in particular element you have some fair example, as $Zs I$ of s something would have written. And now whatever, solution you had obtained for this is now incorporated here. So, this stipulation for this loop equation is consistent with the solution, the other loop equations are the same. Therefore, the solution for the other element responses will be the same this is the principle of the substitution theorem.

Now, there were couples of points, which I would like to emphasize here. We do not have a tremendous advantage in using the substitution theorem to solve the network problems. However, it turns out to be very useful, in proving some other theorems using the substitution principle we can use several other theorems. Also in some cases where, the switches are opened and closed you can apply the substitution theorem and get special insights in the circuit behavior and also the total solution with fairly straight forward fashion. So, that is the usefulness of the substitution theorem.

Second point I would like to emphasize is that the element that you are replacing, can be linear or non-linear does not matter what it is. A third point is when you replace for example, when you in this particular let us take the same case here.

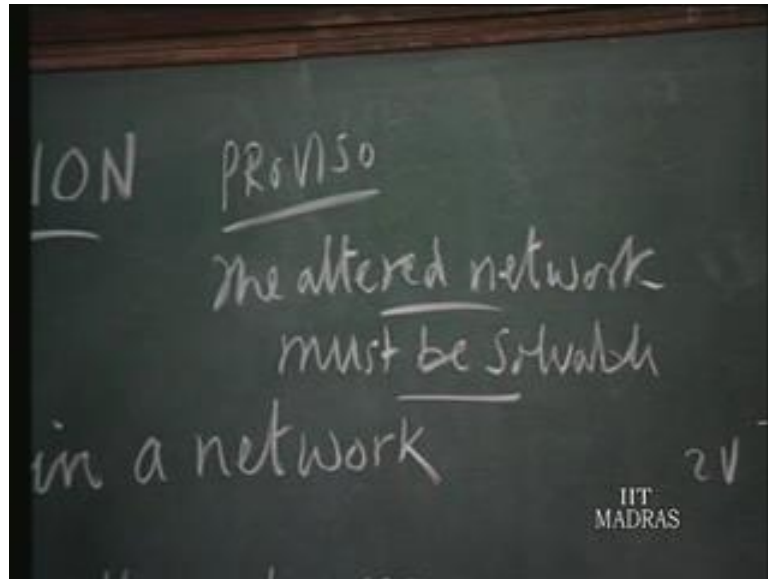
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Suppose, I have a similar case, I mean not the same case suppose I have a case here you have a 2 volt source acting upon a 1 ohm resistance. So, the voltage across this is 2 volts. Now, suppose you replace this 1 ohm resistor by another 2 volt source. So, we have this resultant circuit and what is the current in this. It can be anybody's guess, because this is a particular type of circuit, in which any current I is a possible solution. So, this network we can say is not solvable, because you do not have a definite solution for this network.

So, we have used this substitution theorem, this is the one particular solution which is equal to 2 amperes is also solution, but that is not a definite solution for this network.

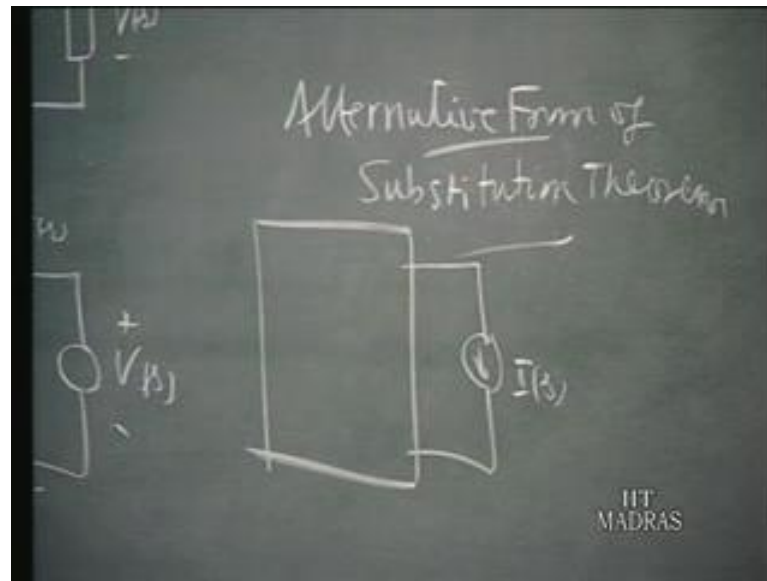
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So, when you use the substitution theorem, we must also have a proviso that the altered network must be solvable, otherwise you get indefiniteness, you may have end up with a situation where, multiple solutions are possible there is no definite solution and such a circuits are said to be not solvable. So, when you use the substitution theorem, you must ensure that the altered network is solvable.

As an extension of the substitution net theorem, you can also say when a current is flowing through a particular element, you can replace this by an equivalent current source.

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So, you can also have a current source I of s . This is alternative form of substitution theorem you can replace this particular element by a current source, whose value at every instant of time is the current in the original network. So, you can replace this element by a voltage source or a current source. This is also a substitution theorem, which is an alternate version of the main theorem in which, we said an element can be replaced by a voltage source.

As I mentioned, the substitution theorem gives us some special insights in circuit behavior when, particularly when switches are opened and closed, which we will see in later. And it is also used to prove several other theorems this is the special advantage of the substitution theorem. So, in this lecture, we have started the discussion of various network theorems. I mentioned, network theorems are used to simplify the analysis of networks, in particular cases. And depending upon the problem on hand, one of the network theorems may be quite appropriate to apply it provides us a solution in a straight forward fashion.

So, we should develop the ability to choose the particular theorem, which facilitates the solution in the most effective way in a given situation. And we talked about superposition theorem, in which we said the response of a particular element situated in a network linear network. When it is acted upon by several independent sources, can be obtained by finding out the response in that element with each source acting in turn,

keeping all the other source as deactivated. And superposing, the individual responses to get the total response.

We mentioned that in the case of deactivation, what we mean by deactivation is that the voltage source strength is reduced to 0 and current source strength is reduced to 0 which means, that the voltage is replaced by the short circuit, the current is replaced by an open circuit. And this is to be done for all independent sources, dependent source if they are any must be kept intact, they are part of the linear system.

Secondly we observe that when you want to find out that transient solution in a network. Then, the superposition principle can be applied with 0 initial conditions in the system or with all initial conditions replaced by equivalent sources. And therefore, the principle of superposition can be extended to the sources, which stand for the non-zero initial conditions. And this is what we do in the Laplace transform domain where, non-zero initial conditions are replaced by equivalent sources.

We also mentioned that the superposition principle, will be can prove to be effective, when we are when we take one source at a time, the network configuration becomes simpler like in the series parallel structure. Then, we can use the analysis with each source in turn by request taking request simplify it in form of network analysis, provided by this series parallel structure, where as if you had more than one source such a series parallel reduction technique may not be possible.

We observed that power cannot be superposed in general, but there are few exception, which we pointed out. Then, we discuss the so called substitution theorem where, in a given network. If, you so choose a particular element can be replaced by a current source or a voltage source. The current source being having a value, which is equal at every instant of time to the actual current that, was existing in network, original network and similarly the voltage source.

Then the question that you will naturally ask is if, you know the current in the network then what is the purpose of using a network theorem to follow for it. The answer to that is, we do not use the substitution theorem to find out the current in a network in most of the appropriate cases. We use this as a kind of artifices or tactic to prove other network theorems.

Also in some cases, it turns out that where, you are opening or closing the switches replacement of an open or a close switch by a suitable current source or a voltage source as we will see, will be effective in providing us a solution, which is a straight forward one. We will discuss other network theorems, in the next lecture. But, before that let me mention that we a third network theorem, which is called the reciprocity theorem is something which you have already discussed.

And you can just read right, now that if in a linear reciprocal network, which consist of bilateral elements and reciprocal elements. The ratio of the Laplace transform, the response emolument, response to the excitation Laplace transform is the same when, the locations of the response and the excitation are interchanged. This is true in a network containing bilateral elements and reciprocal elements, this is a something which we have already discussed, when we talked when we have discussing the two port network characteristics.

So, we will not discuss reciprocity theorem specially, here as one of the network theorems. This we will assume as already being discussed with this, but; however, some ramifications of reciprocity theorem will be discussed, when we talk about Thevenis's theorem at a later point of time.