Basic Electrical Circuits
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Lecture - 75

Now, we look at another theorem, which can be considered the dual of the Thevenin's theorem, it is known as the Norton's theorem.

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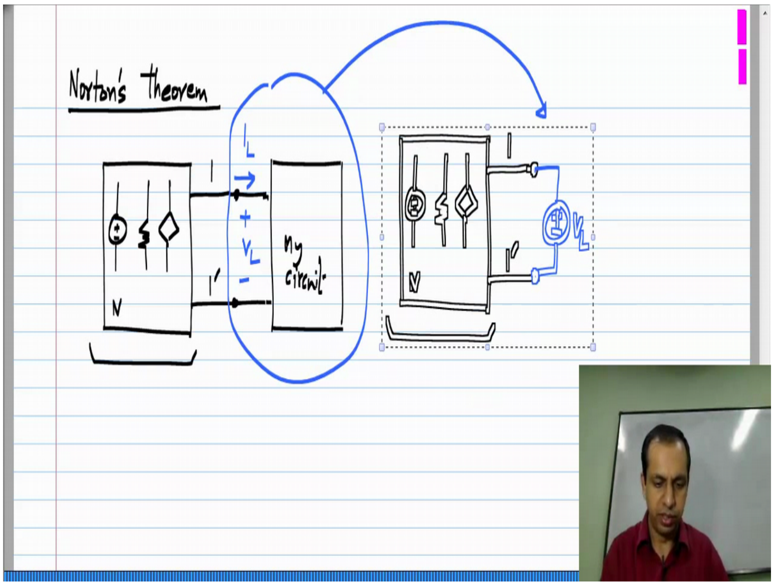

Just like Thevenin's theorem gave us the representation of a complicated circuit at two terminals with a single voltage source and a single series resistance, Norton's theorem will also give us an equivalent circuit at two terminals, which consists of a single current source and single resistance in parallel and the derivation of this equivalent is similar to the derivation of the Thevenin's equivalent. So, let us say we have a network N consisting of independent sources, I will show them by a single source like this, resistors and linear control sources and it is connected to some other circuit.

Let me call this my circuit, now what we wanted was a representation of this circuit N at the terminals 1 and 1 prime. So, it can be a stand-in for the circuit regardless of, what you connect through it. Now, if you recall while deriving Thevenin's equivalent we replaced this with a current source based on substitution theorem. What will do here instant is, let me again say this volt is happens to be V L and this current is I L, I will replace it with a voltage source instance.

So, I will substitute this whole thing by the voltage source whose value is the voltage that actually occurs in the circuit V L. As before we see that, the derivation will be independent of whatever V L is, so it applies to any circuit, anything that you connect. Again this is the circuit for which we are computing the equivalent and this circuit needs to have only independent sources, linear resistors and linear control sources. This can be anything, it does not matter what it is, because whatever it is, between these two terminals it can be substituted by a voltage or a current source of that specific value, whatever voltage or current it is drawing. And finally, whatever we are going to derive for this, the equivalent for this will be independent of the value of V L. So, let us take this and proceed as before.

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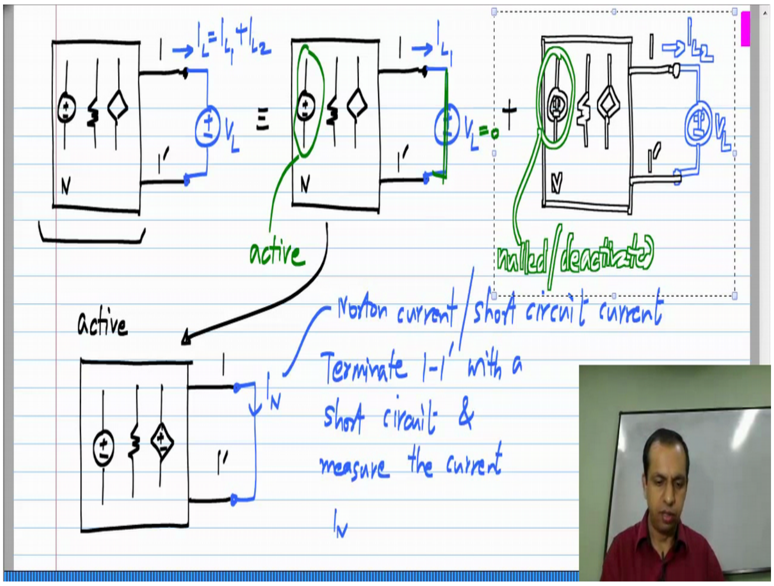

Now, let say I have given the circuit and ask you to compute I L. Now, there are independent sources inside and there is one independent source outside, which is V L. How would I go about solving for I L? I could use super position, I can think of this as super position of two cases, I will indicate a plus here to indicate super position and what are the two cases, one in which the internal sources are active and V L is set to 0; that is, V L is replaced by a short circuit, I will compute I L 1.

The other case is, where the internal independent sources are null or deactivated, I will have only this V L to be active and I compute I L 2. My I L in the original case would be the sum of these two cases I L 1 plus I L 2. Basically, I have these independent sources V

L and all of the internal independent sources. In one case I activate all the internal independent sources, but null V L and in the other case I deactivated all of the independent sources and activate only V L.

Now, let us go step by step. What is this in this case, what I have done is to have all the internal independent sources to be active. So, these are all active and I terminate the output or these terminals 1 and 1 prime where I want to find the equivalent with a short circuit. Because, when I said V equal to 0 that is, what I get. I have a short circuit and I measure the current through that short circuit, here I called it I L 1, but this is usually called I N the Norton current. It is the Norton current or the short circuit current.

So, I terminate 1 1 prime with a short circuit and measure the current in the short circuit in the right direction going from to 1 to 1 prime, that gives me the short circuit current or the Norton current.

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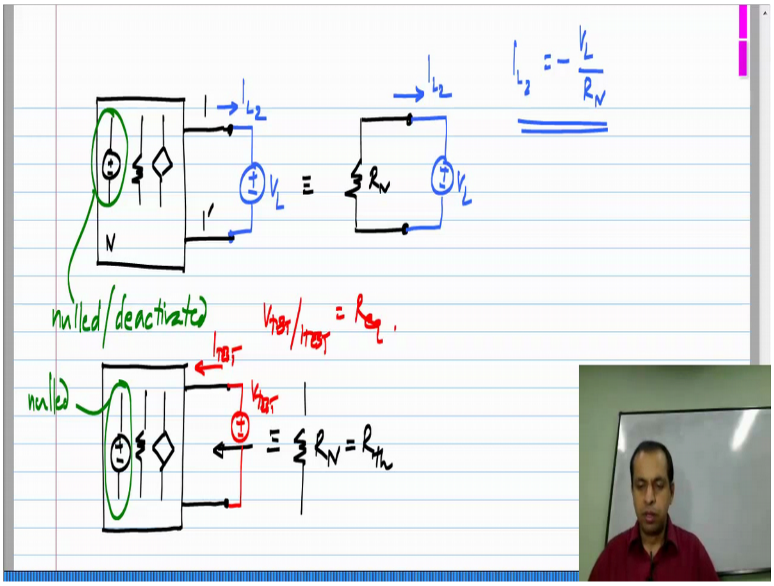

Let me look at the second case, where all the internal sources are nulled, independent sources are nulled. We have only linear resistor and linear control sources and we know that, such a network consisting of linear resistors and linear resistor and linear control sources looks like a resistor from these two terminals. And I am considering the case with this nulled and looking in here, it always looks like some resistor. What it means is that, if I applied some V test and measure I test, V test by I test would be some constants, which is given by R equivalent.

In this particular case I will call it R N, the Norton resistance. So, this is equivalent to having the Norton resistance R N and it is driven by this V L and measuring I L 2 in that direction. So, clearly I L 2 would be minus V L divided by R N and I have to super impose this with the short circuit current to get the total current, I will do that later. If you recall, what we calculated for the Thevenin equivalent, in Thevenin equivalent also there was a resistance Rth, it was exactly the same thing.

We deactivated the internal sources and found the resistance looking in. The only difference is, there we are applying a current and here we happen to be applying a voltage, but it does not matter. If you apply a voltage or current, the ratio V test by I test remains exactly the same. So, although I call it R N just to be consistent with the notation for Norton's equivalent it is exactly equal to Rth the Thevenin resistance, the Thevenin resistance and Norton resistance are one and the same thing.

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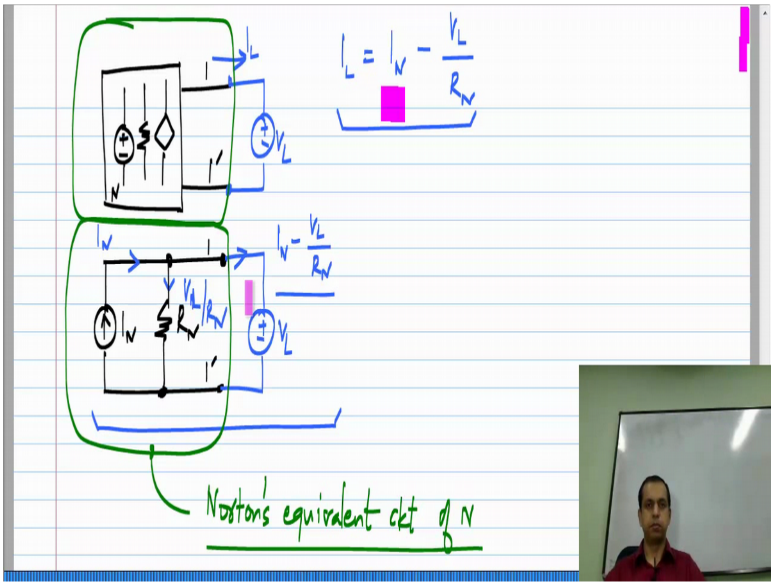

So, now let us go about our super position with the full circuit; that is, with the independent sources active and we have all the components in place. If we apply V L, we have a certain current I L and from the two cases that we took for super position, we know that this I L equals I N, the short circuit current or the Norton current minus V L divided by R N. Now, this entire thing can be represented using a simple equivalent, the current N which corresponds to this particular term, then I have the voltage V L over there and to get this term, I simply connect the resistance R N.

So, clearly you see that the current flowing here is V L divided by R N, the current flowing that way is I N the short circuit current. So, the current flowing here is nothing but, this current minus that current which is I N minus V L divided by R N, this is fine. If you recall with the Thevenin equivalent we have got V L to be V t h minus I L times R t h and we have a similar equation here. There we could emulate the output voltage using a voltage V t h in series with the resistance R t h, here he emulate the output current I L using a current source I N in parallel with a resistance R N, which also is equal to R t h.

This particular circuit is the equivalent of this at the terminals 1 and 1 prime, this is 1 and 1 prime and this is known as Norton's equivalent circuit of the network N. So, as I said it is the dual of the Thevenin's equivalent, there we have a voltage source here we have a current source.

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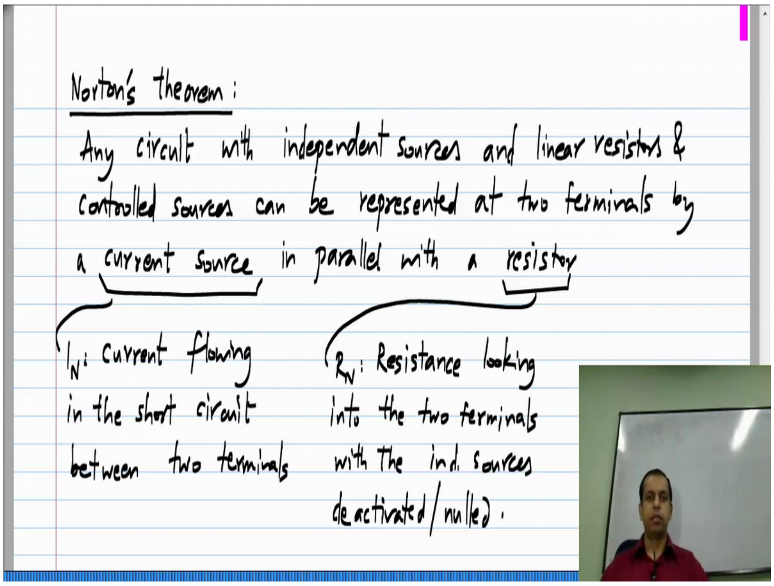

We can stay Norton theorem can way similar to Thevenin's theorem any circuit with independent sources and linear components that is linear resistors and controlled sources can be represented at two terminals by a current source and parallel with the resistor. And, what is this current source this is in which, is the current flowing in the short circuit between two terminals and this resistor R N is nothing, but resistance looking into the two terminals with the independent sources deactivated or nulled; that is they are said to 0, so exactly the duel of Thevenin's theorem.

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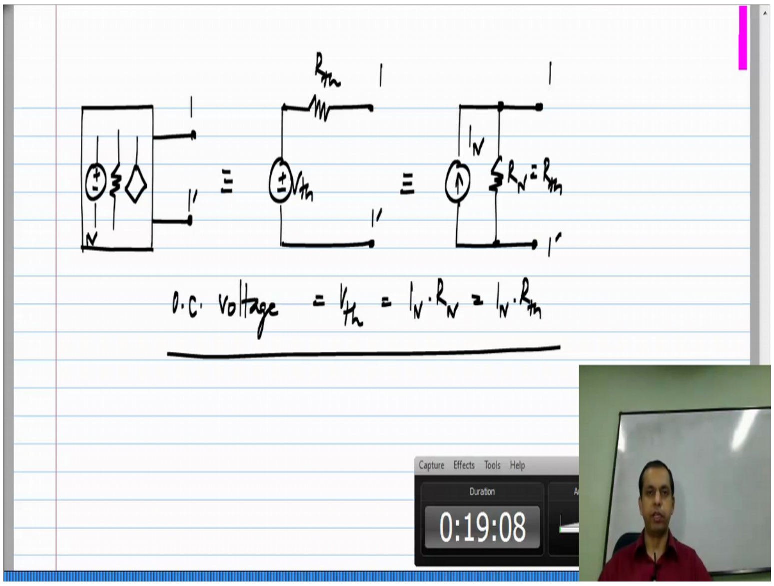

Now, the same circuit n can be represented by its Thevenin's equivalent V t h is series with R t h or by Norton equivalent, which is in parallel with R N, R N of course, is equal to R t h. Again the equivalent holds for the circuit between these two again the equivalent holds at these two terminals 1 and 1 prime and what it means say that any circuit is connected to these to terminal to 1 1 prime you connected to either the full circuit or the Thevenin equivalent or the Norton equivalent the currents and voltages at these terminals will be exactly the same and consequently those in the circuit that you connect will also be the exactly the same.

So, in are interested in the module in this circuit you can you can either use this or that 1. Now, one thing I want point out is the relationship between the values V t h and I N these two are also exactly equivalent to each other that is, what is means right because this circuit equivalent to this which is equivalent to that. So, these two also equivalent each other what the relationship between in and V t h can be easily found out by considering the open circuit voltage between these two, because this circuit should also have exactly the same open circuit voltage as this one if they are to be equivalent open circuit voltage in this case in the Thevenin's case; obviously, equal V t h no current flow through R t h, V t h is the open circuit voltage in fact, that is the definition of V t h.

In this case if you do not have anything connected 1 and 1 prime all of this in flows into R N, so the voltage across in 1 and 1 prime in simply in times R N `or in times R t h this is the relationship between the Thevenin voltage and Norton current of a given circuit.