Basic Electrical Circuits
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Lecture - 29
Power and Energy Absorbed By Electrical Elements

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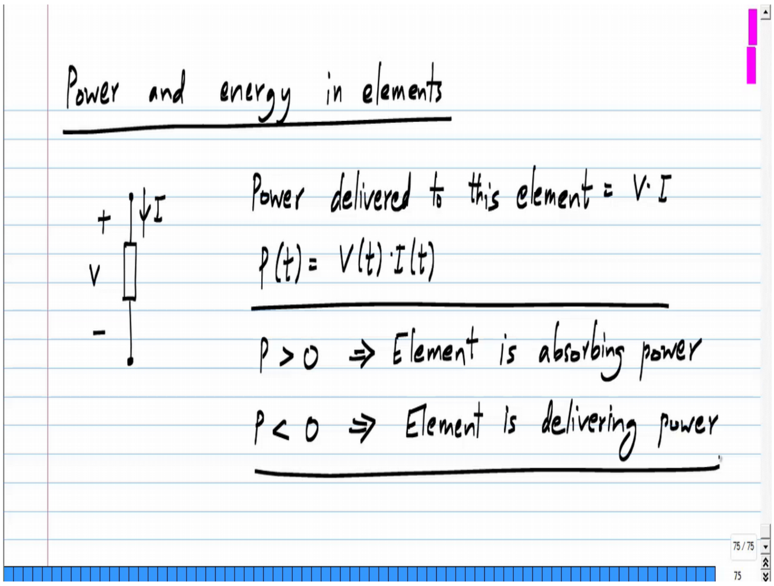

So far in this course, we have looked at a number of electrical elements like the voltage source, current source resistors and so on. And we have discussed the current voltage characteristics of these elements. In this unit, we will look at energy and power in these elements. First, I will discuss power and energy in general, and then look at what happens in the particular elements that we know. If you have a two terminal element, first we will define the voltage and current according to passive sign convention that is we take the current as going into the terminal, which is defined as the positive for the voltage. So, now the power delivered to this element equals V times I. Now of course, we and I could be time varying that does not change the definition; it simply means that the power delivered will be a function of time.

Now, if this P is more than zero, remember V and I can have any values, we are not discussing any particular elements here; V and I can have any values; and the product P can be either more than 0, 0 or less than 0. If P is more than 0 that means that the element is absorbing power at that instant. And if P is less than 0, the element is delivering power negative power is being delivered to the element, which means that the element is actually generating power or delivering power to the rest of the circuit. So, P is greater than 0 means that the element is absorbing power; and P less than 0 means the element is delivering power so that is about the definition of power in a two terminal element. Now I have not derived this you can consider a charge that is flowing through the element from the upper terminal to the lower terminal in this case. So, it goes through a certain potential drop which means that it loses certain energy and some work is being done on it. So, the rate of change of work is the power and from that we get this definition that the power is voltage times the current.

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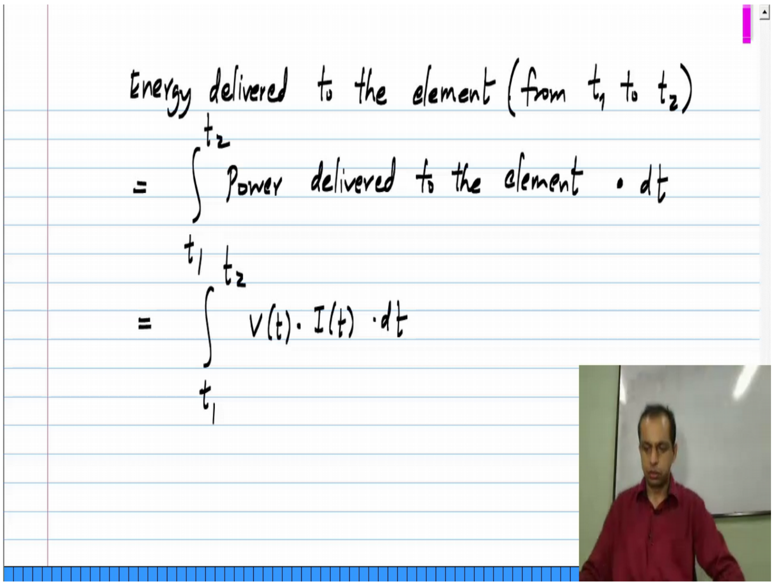

Now, let consider the energy delivered to the element. And now we have to specify a time interval over which it is delivered. Let say we take it from t 1 to t 2 this will be the integral from t 1 to t 2 of the power delivered to the element with respect to time. In other words, the integral of V times I with respect to time over a certain interval t 1 to t 2 is the energy delivered to the element from t 1 to t 2. This is for a two terminal element which of course, has just one voltage and one current. Now this energy delivered during a particular time can also be either positive or negative of course, we will look at particular elements and see what happens. So, far we have just considered a general two terminal element.

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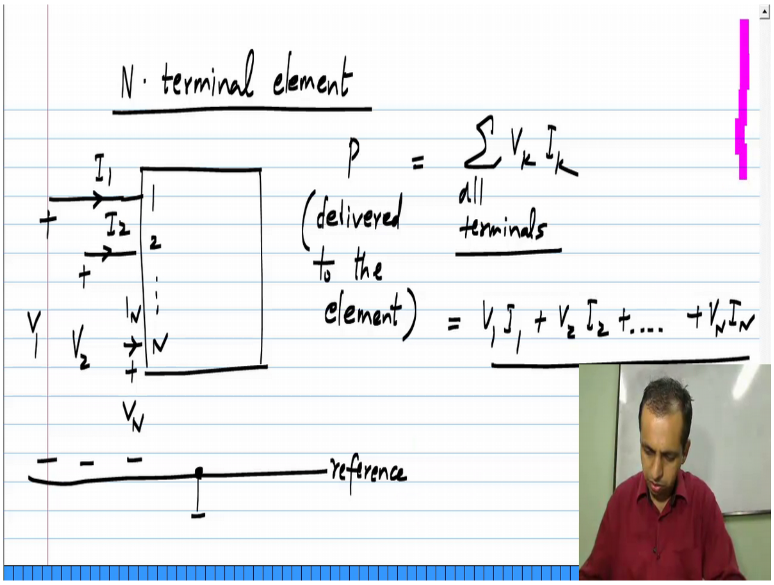

Now, what happens if the element has more than two terminals, for two terminal elements it was very easy; there is one voltage across the element and one current going through the element. And we said the product of these two is the power; like I said it can be derived from fundamentals by considering movement of charges over the potential V. If you have an N terminal element, and let say we have 1, 2 and N terminals, so now I have already told you that the there are N minus 1 independent voltages and currents defined for N terminal element. But for now, let me consider the voltages of all the N terminals with respect to some reference and also the currents going into all of the N terminals. So, let say this is the reference node then the voltage of terminal 1 with the respect to the reference node is V 1; the voltage of terminal 2 with respect to the reference node is V 2. The voltage of terminal N with respect to the reference node is V N. And the N terminals have currents I 1, I 2 all the way to I N.

Now, the power is defined to be the power which is delivered to the element is defined to be sum of V k I k over all terminals, which is basically V 1 I 1 plus V 2 I 2 plus V N I n. So, I am not proved that this is the power, but take this as the definition for an N terminal element and you can sort of convince yourself that this is true by making an analogy between this expression and the expression we had for the two terminal element. Now it appears that there is some ambiguity, because what is this reference node with respect to which we measure all the voltages. Now it can be anything, it could be even be one of the N terminals of the element, but then if the reference can be anything it looks like the power P, there is some ambiguity in the number that we calculate. So, what I am going to show is regardless of what reference you choose there is no ambiguity in the definition of power.

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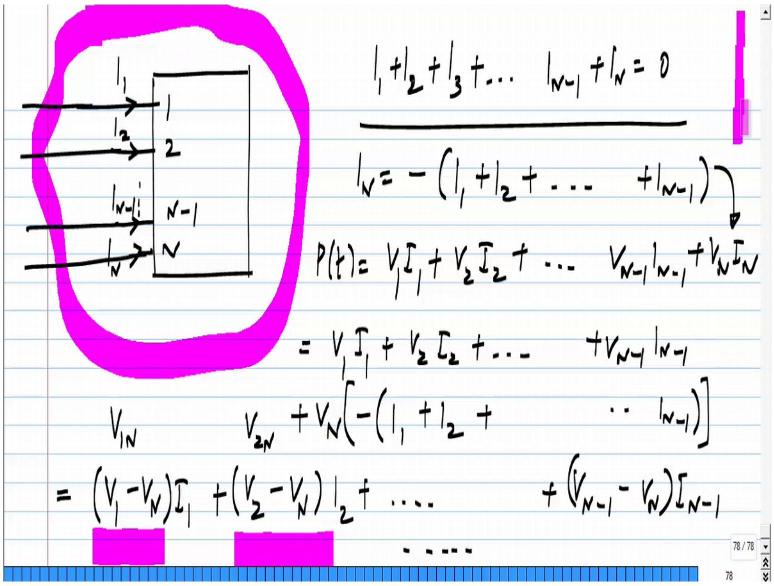

So, let me again consider the same N terminal element and we have N currents I 1, I 2, I N minus 1 and I N. Now of course, there is no other connection to this N terminal element. So, now you know that the sum of these N currents has to be 0; this is because the sum of currents going into any close surface should be 0. We have seen this earlier this is nothing but Kirchhoff's current of law; of course, earlier we had this closed surface containing a single node, but it does not have to be; the conservation of charge and no local accumulation of charge still apply when the close surface encloses many nodes or an entire circuit. So, the sum of these currents I 1, I 2 all the way to I N, which is entering this closed surface is still zero. So, I N can be written as the negative sum of I 1, I 2 up to I N minus 1. Now using this in my definition of power which was V 1 I 1 plus V 2 I 2 plus V N minus 1 I N minus 1 plus V N I N what I will do is, I will use the value of I N from this Kirchhoff's current law expression, this gives us V 1 I 1 plus V 2 I 2 V N minus 1 I N minus 1 plus V N times the negative sum of I 1 I 2 I N minus 1, which is rewritten as this.

So, all I have done is to take my original expression and rearrange it. Now from here, you see that we have V 1 minus V N which is nothing but V 1 N that is the voltage of terminal 1 with respect to terminal N. And the next term V 2 minus V N is nothing but V 2 N and so on. So, basically we have ended up with an expression which says that we have to take N minus 1 V times I products, where the N minus 1 voltages are the voltages with respect to let say the Nth terminals as I have taken in this case times the terminal current that is going into each of the terminals.

So, there is no ambiguity because of this reference, whatever reference you choose, you will get exactly the same power delivered to the element. And of course, it most convenient to choose one of the terminals as the reference terminals, and then you will have N minus 1 independent voltages defined with respect to that terminal and N minus 1 independent currents, and the sum of those products is the power delivered to the element. I had shown all of these to show you that the reference terminal does not matter. You can choose any of the terminals such the reference terminal defined all the voltages with respect to that terminal calculate the power regardless of what terminal you chooses the reference you will get exactly the same number. I shown it for one particular case, you can always try it for something else, let say for in sense you can make terminal 2 the reference terminal and see what happens.