Electrical Machines - I

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Lecture - 15
Approximate Equivalent Circuit

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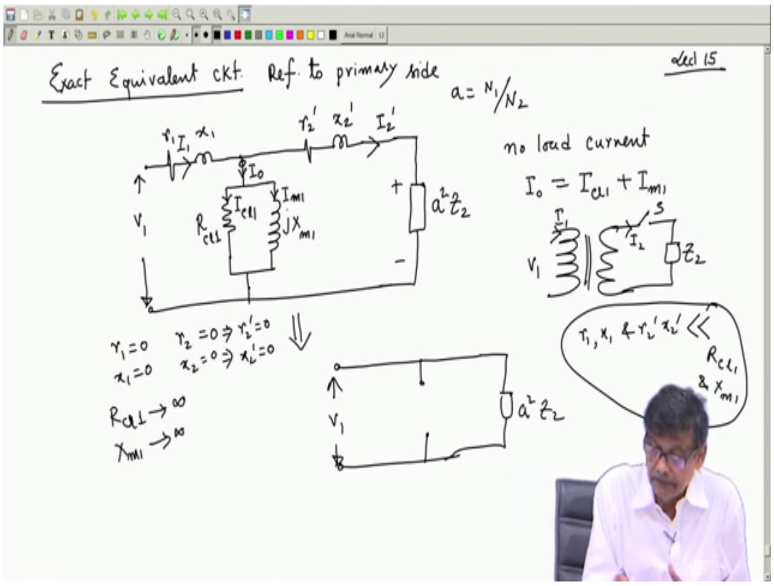

So, welcome to lecture 15. And we are discussing about the Equivalent Circuit of a transformer, equivalent circuit. In fact, this is exact equivalent circuit refer to primary side. And the equivalent circuit we got last time is this one, primary binding resistance r 1, primary binding leakage reactance x 1.

Then you have this parallel branch; one is this resistance I am showing by several lines indicating that it will be high V square by R will be this power. And this is I will call it R core loss we referred to primary side one. And here is magnetizing branch of reactance j X m 1 and then the reflected resistance of the secondary side is r 2 dashed and x 2 dashed.

And here there will be the load impedance whichever you have connected to the secondary side of the transformer a square z 2, and a is equal to N 1 by N 2. So, what are the impedances which will be higher, would like to see they must be very high. This resistance this square, this voltage square by R c l is the power loss in the core, I would like to reduce them. Similarly, this reactance I would like to make it as high as possible so that magnetizing current is less. So, this current is called I m, and this current is the core loss component I c l, you can write 1, 1 refer to primary side this current is your I 2 dashed.

And this current we call it to be I naught the no load current, because I naught is now having two components no load current is I naught will be some of the core loss component of current plus magnetizing current is it not, these two currents will make I naught. Why, it is called no load current, when the load is not connected on this secondary side this will be open circuited, z 2 is infinity. Recall that this is equivalent circuit of what practical transformer is connected like this.

So, let me put this figure also alongside this is what I am examining. This is z 2; this is v 1; this is your core material. And when this switch is opened, it is under no load open means infinite impedance. So, here a square infinity is also infinity. So, this will be open, but transformer then I 1 then will become equal to only I naught if I 2 dashed is 0, this is I 2. In practical transformer, this is what you will observe, you cannot separately see this branches, it is our logic which brought us here. It must be something we are modeling this practical transformer into an equivalent circuit ok.

So, what are the things r 1 x 1 should be small, r 2 dashed x 2 dash should be small, but R cl X m should be high. In fact, from this if you can easily get the equivalent circuit of an ideal transformer by making r 1 is equal to 0, x 1 is equal to 0, because no resistance, no leakage flux, no leakage reactance. Similarly secondary coil resistance is 0, r 2 is 0, x 2 is 0, which implies r 2 dashed is 0, x 2 dashed is 0 and R c l 1, R c l core loss 1 going to infinity X m 1 going to infinity.

So, this equivalent circuit then we will simply reduce to this one, nothing is connected, and here also nothing is connected. These two are shorted, these two are shorted and only a square z 2 and this is your V 1 is it not. This is the equivalent circuit of an ideal transformer. So, always keep this in mind ok. These impedances are small and so on ok. If somebody wants to draw the equivalent circuit it refers to the secondary side of the same thing that is to the load side, how it will look like?

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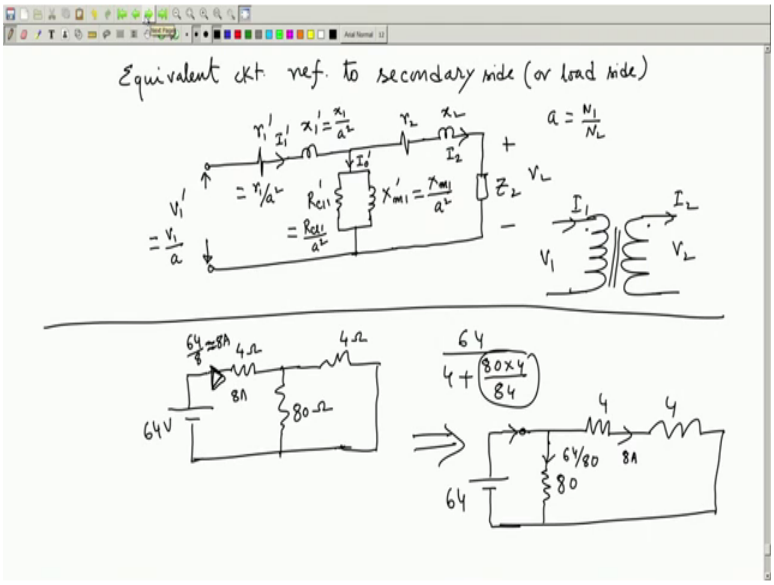

Equivalent circuit refer to secondary side or load side it will remain same except that this one will become r 1 dashed this one will become x 1 dashed. Here that those two parallel branches it should be like this, and here it will these two will should not be disturbed, secondary side we are going. And this impedance should be z 2 and this of course, should be R cl 1 dashed X m 1 dashed.

Now, what is this r 1 dashed, this r 1 dashed will be equal to r 1 by a square opposite thing. What is this x 1 dashed actual leakage reactance by a square, r 2 x 2 will not suffer any change similarly actual impedance. What is this X m 1 dashed it will be X m 1 by a square. And what is this one R cl 1 by a square. What is a? a is N 1 by N 2. What is this voltage V 2, what is this current I 2, what is this current, I naught dashed and what is this current I 1 dashed reflected here. And what is this voltage should I write it should be V 1 dashed. And what is this V 1 dashed, it will be actual V 1 by a.

Now, in this way, I can draw the equivalent circuit either refer to load side or to the source side and about this coupled circuit present in the circuit to be solved, either way you can do ok. Your practical transformer is this, this is the real thing I 2 this is I 1, but these things practical transformer can be viewed as this one. So, either way you can now solve the circuit even nothing is now neglected, but as you know the parameters value entered into the ideal transformer concept to represent a practical transformer that is what the thing is.

After I have told you this one, so this is the equivalent circuit referred to the primary side, the same thing referred to the secondary side with respect to any side you can work. Now, in general this r 1 x 1 refer to the equivalent circuit refer to source side, I will be always doing this refer to the source side ok. Let us stick to one, no point in just complicating thing, remembering so many things this is what I am always going to do. Refer to primary side i will always draw the equivalent circuit ok.

Now, in this equivalent circuit I know that r 1 x 1 and R 2 dashed x 2 dashed are much smaller compare to this parallel branch R cl 1 and X m 1. What I am telling is r 1 x 1 and r 2 dashed x 2 dashed, these are much smaller than your R cl 1 and X m 1. Therefore, people started thinking, this is a circuit if I know all the parameters, I can solve it, but computationally it will be somewhat heavier.

In the sense that these are all ac circuit, phasor you have to draw, these voltage will be present and so on. Then add these drop to get these voltage, then to these voltage you add this one all phasically, and you will get exact solution no doubt about that.

But knowing this fact people also thought that whether some simplifications still can be make to this equivalent circuit based on this knowledge because this parameters value series parameter values are smaller compared to core loss resistance and X m. For example, what does that mean is consider suppose a circuit like this, what i am telling suppose you have a circuit like this.

Suppose, I say this is say 4 ohm, suppose I say this is 4 ohm, this is 4 ohm, and this is a 80 ohm I say that. So, this impedance is 20 times higher than this. Suppose, I say I connect a say some 64 volt to the circuit, I am interested to know this current ok. You can parallel this, this is a very simple circuit 80 into 4 by 84 plus 4 64, it divide with that resistance get this current.

But suppose you are a very practical man, practical engineer, you will be happy to know what will be the current drawn from the battery and I will sacrifice some accuracy. I will say that this current will be you solve it 64 by 8 ampere. Looking at this circuit you can say oh this current, why, because this parallel resistance is 20 times higher than this fellows you solve it this 64 divided by 4 plus 80 into 4 by 84 [FL] this quantity is close to 4 only 80 by 84, what is that 0.99 something.

Therefore, and we always know the equivalent resistance of a very high resistance and a load resistance is of the order of the load resistance itself. Therefore, is it not, just looking at the circuit I will tell look here this current in this branch will be close to 8 ampere that is all. He calculates correctly, he will maybe he will come to something very close to 8, but he will save lot of computation. Of course, in a dc circuit resistances are manipulated just like that, but in ac circuit it is not you have to complex algebra, you have to do to find out the z equivalent of this branch, this branch and so on.

So, coming back to the equivalent circuit refer to the primary side, if I know that this impedance is much higher compare to these values and this values. Then I will rather sacrifice some accuracy not too much, at the same time I will reduce my computational burden. What I am trying to tell is this, this parallel branch ok, I will take it better draw it in a separate page.

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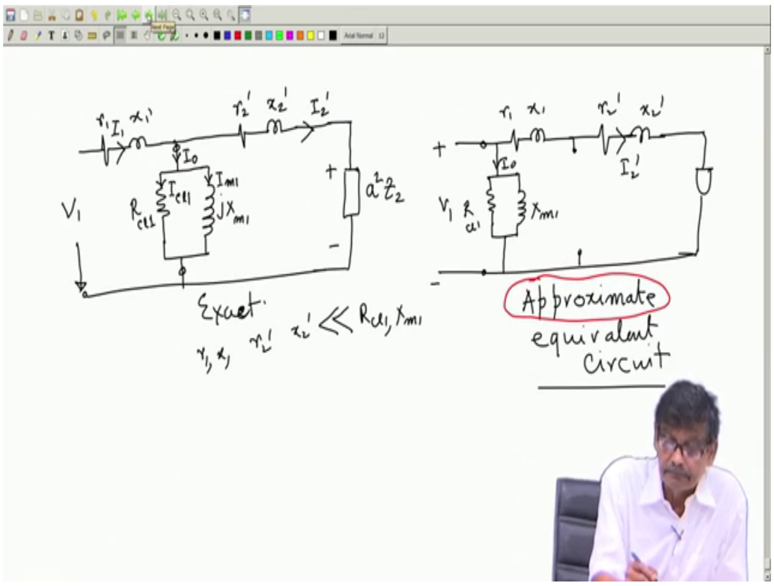

So, this you remember it is exact equivalent circuit; suppose, it is the equivalent circuit. This is V 1 ok, this is the equivalent circuit we have seen. Now, what I am telling that this equivalent circuit you just select it and push it here. This is the equivalent circuit. Now, in this equivalent circuit, this branch which is high impedance value compare to this. So, this branch I will first remove, I will not take considered this branch. So, r 1 x 1 and r 2 dashed x 2 dashed and this one I have removed; I know I am making a mistake. This is the exact equivalent circuit, but what I will do is this I will remove this. And here

I will that load impedance is there, but this branch I will remove and say that this is approximate equivalent circuit. Somebody says oh you have you are totally neglecting this branch, then I will say I will not neglect that branch, but I will show it at the beginning. So that I have got some computational advantage now that branch present here makes it much more complicated than what it was here that is what I am telling. And this I am just not doing just out of nothing because of the fact that r 1 x 1 r 2 dashed x 2 dashed these are all small compare to this R cl 1 and X m 1 for a well designed transformer.

I will presume that whoever has design this transformer, they must have kept in mind that core loss should be made as small as possible, magnetizing current should be made as much less as possible which indirectly means that R cl 1 is high and X m 1 is high. If that be the case this being smaller, you forget about this branch and show it on this side, just bring that branch forward.

So, you are neglecting approximating something, but at the same time you are not totally ignoring this part to take into account, like the previous problem. In this problem, somebody says ok, this will be something like this 4 ohm, 4 ohm you connect load resistance. And you are skeptic also would like to improve upon your result simply by ignoring this totally, show it here, 4, 4, 80. And the current supplied from the battery will be not 8 ampere, it will also take this into account, but the result will be improved upon, this is also approximation and totally neglecting this is also an approximation that is fine.

But what I am telling you do not neglect too much, but get a tremendous computational advantage, why, because this current I can easily calculate 64 by 8, 8. And this current whatever it is 64 by 80, these two can be added series parallel (Refer Time: 21:06), and still you will be very closer to the correct value what I am telling. They will not be exact I agree with that.

So, with that, so this circuit keep in mind what exactly we are doing then you will get pleasure. And all said and done nowadays powerful calculator is available everything is there. So, one can leave with the exact equivalent circuit as well, but nonetheless even with calculators you have to this then parallel these, these, these are to be paralleled complex numbers, lot of computational effort then that should be added with r 1 x 1 get the values.

So, I think I have been able to put in your mind that why that approximation is done, simply to reduce the computational effort. So, this is called approximate equivalent circuit. So, the parallel branch in front of the supply V 1, and then this current is your I 2 dashed. As if we are pretending r 1 x 1 only I 2 dashed is flowing, how does it matter, and this current is no load current.

Let us see how much difference it will have. Ok, V 1 minus this draw that voltage divided by this branch gives you I naught, now I am telling that this drop you neglect, why you will neglect that drop r 1 x 1 is small, because r 1 x 1 will be small. So, these voltage is approximately equal to this. These are the anyway think about it and try to do. So, it reduces lot of computational burden.

Once you draw the circuit like this, then I then this is the key word approximate equivalent circuit. We will almost all the cases we will refer to [FL]. Now, I will come to the phasor diagram which I have not drawn for this circuit. For example, I will draw once you, in fact, can avoid that after learning approximate equivalent circuit, but nonetheless let me at least draw the equivalent circuit of this exact transformer.

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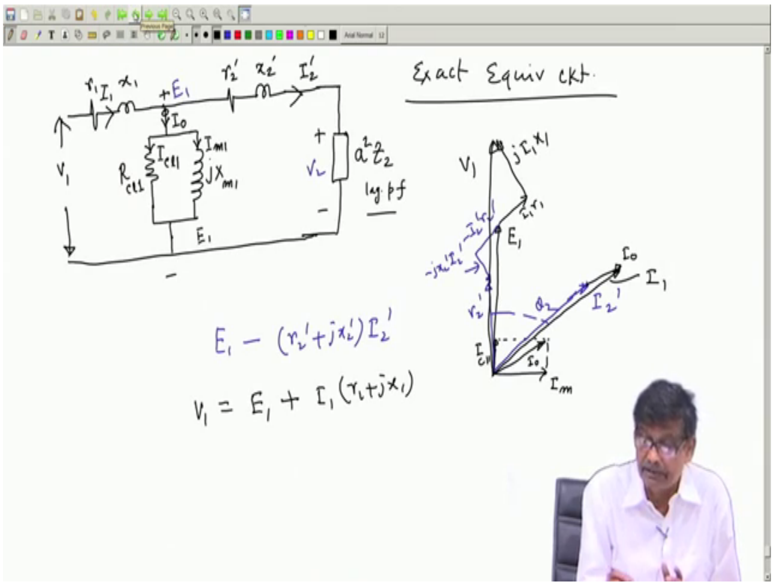

For example, suppose this is the, suppose these could not be copied this was r 2 dashed x 2 dashed, and here was a line, this is the exact equivalent circuit. Let us see how to draw the phasor diagram, which will not be doing in fact but let us see suppose this voltage is E 1. You start with this voltage to draw the phasor diagram this is E 1, refer to the primary side. If this is E 1 you know you are I cl 1 will be in phase with this. This current resistive, magnetizing current will be like this I m. And the sum of these two currents is called no load current I naught; this is the no load current. I have got I naught ok.

Then E 1 divided by this whole impedance will give you the current I 2 dashed is it not. So, E 1 divided by this whole impedance will give you this current. So, suppose that current this is lagging power factor let us assume, so I 2 dashed will be suppose somewhere here I will just give you the idea so that so, suppose this is I 2 dashed. What is this angle, this angle is not the power factor angle of the load, it is the power factor angle of r 2 dashed x 2 dashed and a square z 2, whatever it is.

So, I 2 dashed is suppose this one. If this is this, then from this voltage is E 1. From E 1 if I subtract from this phasor minus r 2 dashed plus j x 2 dashed into I 2 dashed, I will get then V 2, is it not. That is this E 1 minus I 2 dashed r 2 dashed I will make it dirty, but you just try to understand how complicated it becomes, but it can be done. I 2 dashed minus R 2 dashed minus I 2 dashed r 2 dash, then minus j x 2 dashed I 2 dash j x 2 dashed is perpendicular to this. So, subtract that whenever you will end up that will be minus j x 2 dashed I 2 dashed. And then what I am telling this will be your V 2, is it not.

Then this angle will be your power factor angle and so on. This is the load power factor angle whatever it is. This diagram we get. Then I naught plus I 2 dashed will give you I naught plus I 2 dashed I am sorry I naught plus this I naught dashed, I can do that and get I 1. I am looking for where is my V 1? V 1 is nothing but E 1 plus I 1 into r 1 plus j x 1 I 1 I have got I know you are, therefore, I 1 r 1 parallel to I 1, I 1 r 1 plus j I 1 x 1. And this you add you will get V 1. I mean this is the idea what I am telling if you know this voltage you can completely draw the phasor diagram.

So, it can be done in several ways, all though we will you will see later this complicated diagram is not necessary if you have a powerful calculator and if we have decided, we will use the approximate equivalent circuit, things will be much more easier. And we will see it in the next class.

Thank you.