Electrical Machines - I

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Lecture - 09
Modelling of Practical Transformer - II

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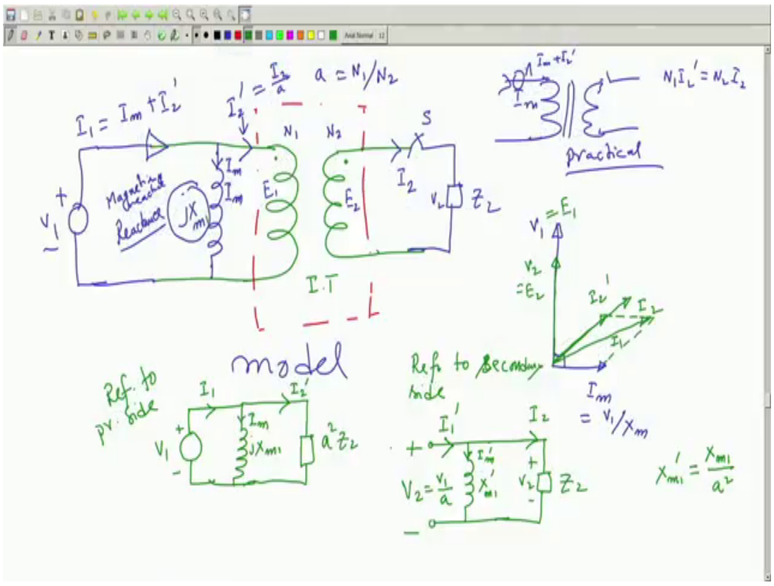

Welcome to the 9th lecture and you recall we were gradually going towards a practical transformer. And in my last class, this was the slide, where this is a practical transformer. Here there is no X m connected; you must understand that this is a practical transformer in the laboratory ok; two secondary, two primary, there was nothing like X m connected there.

But it was our thought process, which lead us to believe that this whatever is happening to a practical transformer, what is happening with S opened, current turn from the supply is finite, magnetizing current I m and when S closed, it must be I m plus I 2 dashed, because net MMF in the circuit has to be N 1 into I m, why? Because flux in the core is decided by supply voltage and frequency, nobody has any say on that.

But if you are trying to disturb the secondary, I mean if you are trying to pass some current through the secondary, primary cannot be a mere specter at to this happening. It will react immediately by drawing an extra current I 2 dashed, and that I 2 dashed cannot be of any magnitude; it has to be I 2 by a, so that N 1 I 2 dashed becomes equal to N 1 I

2 dashed becomes equal to N 2 I 2, so that net MMF once again is N 1 I m and this is what we have discussed last class.

So, this is a reactance, this is an ideal transformer and it correctly models it. So, V 1, I m I have drawn, then I am completing the phasor diagram once again. And suppose, this is V 1 to the ideal transformer applied voltage is V 1, so this is E 1, this is E 2 and this is V 2; V 2, E 2, etcetera, they are all same.

So, depending upon the turns ratios your, so this V 1 is nothing but E 1, they still remains nothing in between, and your this will be your V 2, which is same as E 2. And this is suppose the load power factor decide what is the current here I 2, then current drawn from the primary will be I 2 dashed, I 2 we have got, get I 2 dashed.

And then this I 2 dashed, plus this I m if you add, you will get primary current I 1, understood. This is how magnetizing current can be taken into account of a it is somewhat a practical transformer, still not a full practical transformer. I have neglected, so many other things till now, only magnetizing current, I have been incorporated and for that an external element j X m is to be selected.

If you like you put j X m1; side 1 ok, because we have seen parameter value changes from side this side to that side and so on. Therefore, what will be the equivalent circuit looking from the primary side, it will be V 1, here is a reactance; no windings this one j X m and here will be the impedance a square z 2, you know this will be the equivalent circuit refer to the primary side j X m1.

So, whatever impedance, voltage, this that are there and this current I will show as I 2 dashed reflected current and this current I will show as magnetizing current and this current is your I 1. Mind you I am not drawing, but these are dots that is very important with respect to this. So, this is the equivalent circuit refer to the primary side.

What will be the equivalent circuit refer to the secondary side, refer to source side; refer to primary or source side, primary side. And refer to load side or secondary side, it will be secondary voltage remain secondary voltage; this will be z 2, secondary things I should not disturbed, they are already there z 2, this voltage is V 2, this current is I 2, I will show it.

And this fellow the transfer of impedance from this to that side will be X m1 dashed, what is X m1 dashed; it will be X m1 by a square and what is this V 2? V 1 by a. So, this is the equivalent circuit refer to the secondary side. So, you solve this you write I m dashed (Refer Time: 06:46) reflected current. And then you will what current you will get, I will get I 1 dashed.

So, you either solve this circuit get everything, because if this somewhat practical transformer, solve this circuit get I 2 dashed and then predict what will be I 2. So, people always refer to work on a equivalent circuit instead of drawing some coupled coils, then individually calculated. We can do that, but this is a better way of doing things.

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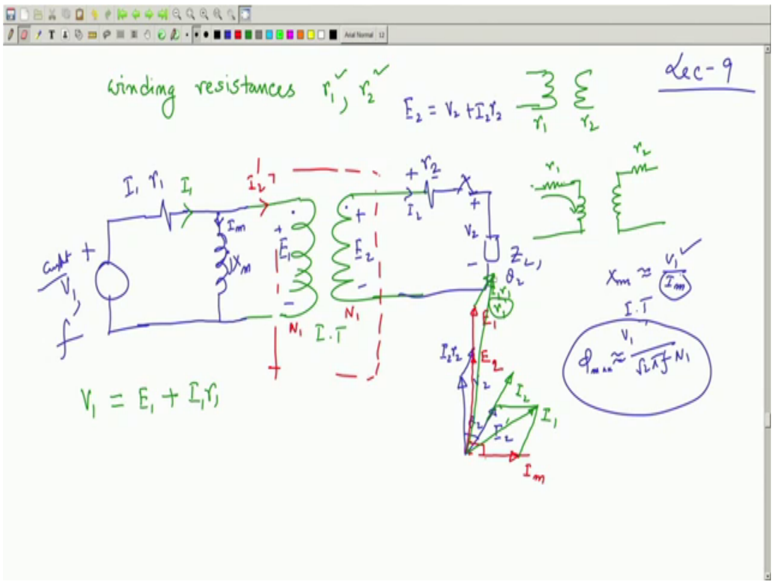

After I have done this, our next reality which is present in a practical transformer is let us assume, I will assume winding resistance. Till now, I have neglected winding resistances r not 0, that is r 1 is present, r 2 is present that is the what is r 1, this winding; one side, side 1 resistance and this winding as also got r 2, because resistance is after all rho l by a.

So, there is some resistivity of this conducting material, some cross sectional area, so many turns are there, so many length. Of course, the resistance will be pretty small, it is made of very good material for example, copper. But none the less there will be some finite resistances of primary side and secondary side.

And it looks like, this is resistance which is of course, distributed can be considered to be lumped and I can show it like this. Similarly for this coil, this resistance, I will considered it to be lumped and represent it like this, this is how I can represent.

Now, the question is how this r 1, r 2 should be shown in this transformer. In this transformer, there was finite magnetizing current; no resistance, no leakage flux, fine and this is I m magnetizing current taking care of by n Xm.

So, now once again I will add some parameters to this circuit that is r 1, r 2 in appropriate place that is very important, so that effect of r 1 and r 2 will be addressed by this model. Question is where should I put r 1, should I put it here, should I put it there, where that is an interesting question.

This portion is ideal mind you therefore, if there is winding resistance, what it is going to do. There will be whenever this coil will carry current your practical transformer, there will be a voltage drop here in the resistance. Applied voltage minus this drop is going to create flux, not this full voltage is going to produce your magnetizing current, because a portion of the voltage will be dropped in r 1, got the point.

Therefore, in this circuit I will spoil this circuit, do not mind; what I will do now if I add something here, our previous thing will also get disturbed. So, what I am telling is this what I will do now listen carefully, here I will draw the ideal transformer and I will put a dotted box around it in order to indicate that and then these are the terminals of the ideal transformer ok.

And then I am telling to this ideal transformer, this winding is not purely this thing. So, so you are there will be resistances in series, I will connect it here; which is small resistance none the less r 1, it will come in series.

Now, the question is should I put that magnetizing current branch X m, before this or after this, I must put it after this j X m. Similarly here of course, there is no magnetizing branch, r 2 is simply comes here. I have shown only one way I am showing not like this resistance; because these resistances are small, it only indicates that a small resistance in series. Therefore, you know this is this thing and here is your supply voltage, frequency f.

So, whatever current it supplies which is decided by it may be the load connected here, ultimately some current is drawn and when that current flows through the winding, there will be a voltage drop r 1; and that voltage drop must be subtract it from your supply voltage and the remaining voltage is responsible for creating flux and giving you the transformer action, so that is why r 1 should not be shown here, it must be after this. Therefore, this is V 1, this is ideal transformer, this is r 2.

Now, the moment r 1 is present I must also distinguish between E 1 and V 1, there will be a drop here in series. X m what do you think; its value will be low or high, its value will be high you should not choose a magnetic material which requires very large magnetizing current. See X m is what, X m is approximately V 1 by I m, I should not choose a magnetic material which requires very high value of magnetizing current, then X m will be low. Better and better material I use, which is not certainly ideal its mu r tending to infinity, may be mu r is equal to 5000 quite a large number.

So, I m will be small, V 1 is fixed, so X m is general high that is why, I have written capital letter and we so many turns, just to indicate that ok, r 1 is small, small r 2. Therefore, the magnetizing current which will be flowing here, I m is not V 1 by X m; V 1 minus this drop divided by X m.

And as you know, depending upon the degree of loading the magnitude of the current drawn from the supply will change. Therefore, drop in this resistance, V 1 minus this drop is the voltage what is coming here across the ideal transformer. Therefore, the magnitude of the voltage apply to this ideal transformer is will also we will not remain constant, as we were thinking in case of ideal transformer apply V 1. I was telling the level of flux phi max is equal to applied voltage in an ideal transformer is equal to root 2 pi f into N 1 and if applied voltage and frequency is constant, phi max gets decided.

But now I come to know ok, the applied voltage to this ideal transformer strictly speaking will not remain constant because of the presents of r 1, this is constant mind you; V 1 is constant no doubt, but V 1 minus this drop is what is applied here, what is this drop, this drop depend on the magnitude of I 1 this your practical transformer is carrying and the magnitude of I 1 has I 2 dashed plus I m, I 2 dashed depend on I 2 and depend on z 2.

So, by as you change z 2, I 2 is going to change, I 2 dashed is going to change therefore, I 1 is also going to change, therefore drop in r 1 is not constant as you change loading. Therefore applied voltage to this ideal primary winding of this ideal transformer; strictly speaking is not constant, only consolation is this r 1 is quite small.

Therefore, what people say is this ok, phi max will be approximately constant, because you have not certainly designed a transformer with high value of r 1 and r 2, then no one is going to buy your transformer I mean why, there will be unnecessary power loss in the windings. Therefore, you must see that very good material is used for example, copper whose resistivity is very low. So, rho l by a the winding resistances are small, so that that way this assumption that phi max practically remain same from no load to full load is good enough.

Anyway none the less, let us see try to draw the phasor diagram of ah this one and try to understand the implication of this. Now, what I will be doing here listen carefully; here I will start with E 1 and E 2 ok, this voltage and this voltage. Mind you, here is now that V 2 and E 2 will not be same is not, similarly V 1 and E 1 will not be same, because in between this two sources some I 1 r 1 drop here, some I 2 r 2 drop here will come, they cannot be same.

But none the less, we can do this things. Suppose how to start the phasor diagram drawing, I will do it like this. Suppose, I draw it will be slightly clumsy, but let it be, but follow my argument ok; you will draw V 2 first whatever it will be; I draw V 2 arbitrarily, vertically. If I know V 2, then I can fix up where the I 2 will be is not, because load power factor angel is known. Suppose, power factor angle of the load is theta 2, V 2 I 2, I have drawn with S closed.

Then I will say, look here your E 2 is equal to V 2 plus I 2 r 2 follow the logic, the diagrams may be a bit clumsy, but this is what is going to happen. Suppose, V 2 is known, V 2 I 2 you draw; then I have to add to V 2, this I 2 r 2 drop. Then I will add it what is there and I 2 r 2 drop will be very small, because r 2 is small, I 2 r 2 follow the logic that is all.

If you do that, then what I am telling you will get your E 2. The induced voltage in this ideal transformer, which I will draw by a red line here, this will be your E 1; E 2 sorry. It is an ideal transformer, this is E 2, then you can confidently draw your E 1. If number of turns of this side is higher, then it length of E 1 will be higher than E 2, E 1 is drawn. So, this will be your E 1.

And if this is E 1, this is E 2, your magnetizing current will be perpendicular to E 1, 90 degree lagging. Here is your finite magnetizing current, I m is not? I have got E 1, so E 1 by j X m I m, I get; so, this is the magnetizing current. And it is an ideal transformer with S opened, I 2 was 0 this current was 0 with S closed, I 2 dashed will appear here, nowhere else it is an ideal transformer this portion.

So, I 2 is known and I 2 dashed will be in same phase with that so I will get I 2 dashed; whether its length will be higher than I 2 or not that depends upon the ratios. So, this will be your. .

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It will be less. So, what I will do is I will make these as I 2, so that; so this is I 2 and suppose, please note this changes and this is I 2 dashed, because I have shown E 1 is higher. So, reflected current must be lower I 2 dashed, so this is your I 2 dashed.

Then I will say that this current I 1 will be I 2 dashed plus I m. So, I m is known, I 2 dashed is known; so I will add this two, mind you I have shown I m slightly higher length it is not so, I m is small, anyway whatever I have drawn. So, this will be your I 1 and if this is I 1, then I will say your V 1 must be equal to E 1 plus I 1 r 1. So, E 1 is known to this add I 1 r 1 parallel to this and from this to this, then wherever you will end up that will be your V 1.

I think you have got the idea, see life will be will not be so much complicated as we proceed, but what I am telling this is exactly what, how to draw phasor diagram. Start with I could start with V 1, but it is better you, because the primary current drawn decided by load, it is much more easier. So, I will quickly go through this step, so that you can understand.

Suppose, switch is closed ok, i will clean this and once again redraw. So, I will just I will (Refer Time: 26:00), but the idea is very important you must keep this in mind. So, I am redrawing once again very quickly, what I am telling ok, you have close the switch the circuit is operating, choose V 2, you start with V 2 ok.

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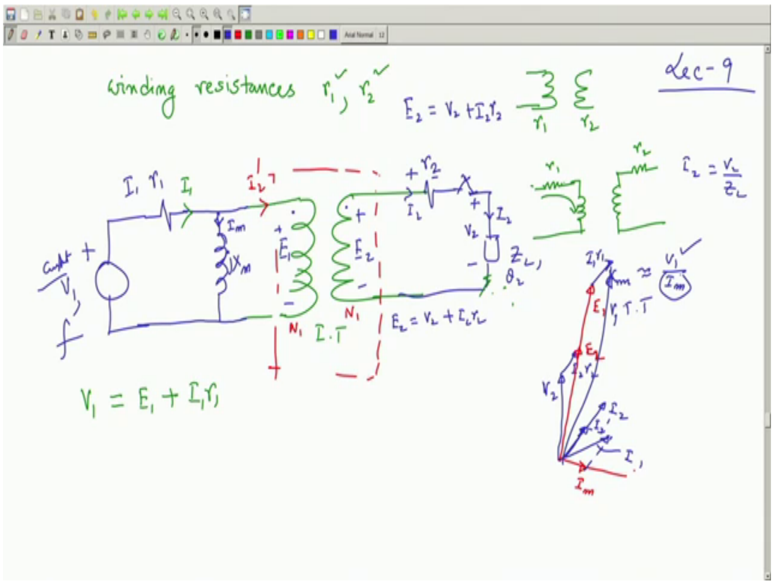

Voltage applied across the load is V 2, then no one can contest me, then the current is I 2 is V 2 by z 2 and I 2 suppose lagging power factor load, I 2 will lag here, I 2 will be higher low voltage side; I assumed I mean, while drawing ok, so I 2. The moment you know I 2 you can find out E 2, because E 2 is V 2 this drop is this plus minus, so V 2 plus I 2 r 2. So, V 2 plus I 2 r 2 you draw, this lengths are small.

And then you get this length to be E 1, I am simply repeating, because for the first time you are doing this you get E 1, E 2 sorry. If you get E 2, this ratio of voltage is N 1 by N 2 absolutely no doubt; mind you this V 1 by V 2 may not be N 1 by N 2 strictly speaking, but this induced voltages are N 1. So, E 2 is this, then I know E 2 and E 1 are in phase, so I can get E 1 assuming N 1 is greater than N 2, it will be this.

Then once I know I 1, I know the magnetizing current which will be 90 degree lagging. And this current is small, let me draw it now correctly I m small current; I m and once I know I m and I 2 is known. So, I 2 dashed will be this one here will be your I 2 dashed. So, current drawn from the source will be this plus this, this is your I 1; and if this is I 1, use this one E 1 plus I 1 r 1, whatever it is, parallel to this I 1 r 1 and you get your V 1.

Anyway I am stopping now, but try to understand. So, this will now truly represent, it is somewhat practical circuit with the finite magnetizing current and winding resistance. In the next class, we will bring other realities into an ideal transformer to get a somewhat better picture of the model.

Thank you.