Electrical Machines - I
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Lecture - 10
Modelling of Practical Transfomer - III

Welcome to this 10th lecture on Electrical Machines-I and we were trying to get a realistic model of a practical transformer. Ideal transformer is real ideal where no winding resistance, no core loss, no leakage flux and things are very simple and I know how to calculate secondary current, primary current, draw the equivalent circuit so on. Then what I started telling you that to an ideal transformer.

If we go on adding some parameters some elements properly then that will be the model of a practical transformer. We are trying to model a practical transformer. In terms of model of a practical transformer, I am trying to get by an ideal transformer plus some circuit elements, we are adding circuit elements.

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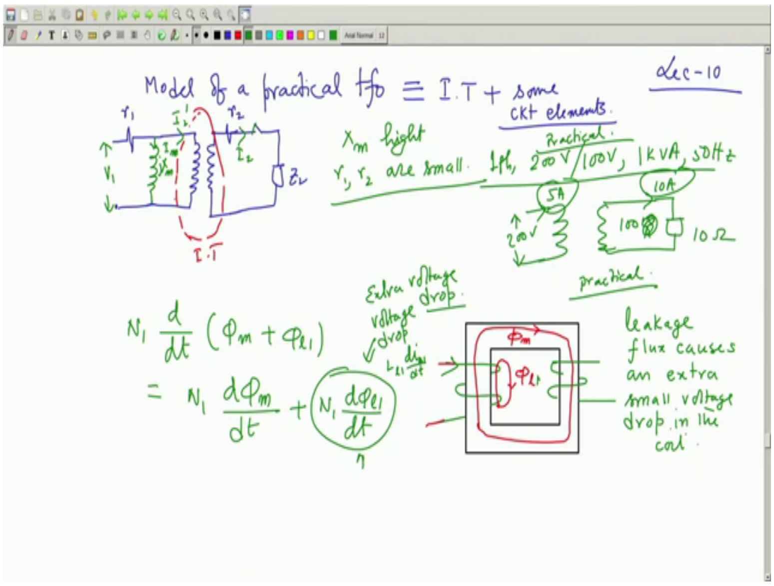

And I told you that till now what we have done is, we have added the winding resistance r 1 of the primary and this is my ideal transformer and here is your actual load on the secondary side z 2, and here also I showed the secondary resistance r 2. And then the magnetizing current was also taken into account and it was not a winding, it is x m, it is my thought process which brought me here. This is my applied voltage.

And these are the current when it is closed it is I 2, remember this is I 2 dashed and this is I m magnetizing current, which is very small X m is high. Mind you I write it here X m high, r 1, r 2 r small that is why people do while analyzing suppose this circuit is given practical transformer ok. Apply the rules of ideal transformer suppose you do not have any parameter values known X m r 1 r 2.

You for example, if I say a it is useful to know, so that suppose the same transformers, one transformer is write it like this 200 volt 100 volt 1 kvA 50 Hertz transformer is given single phase. Suppose I say that it is suppose a practical transformer ok. You apply 200 volt here you and I say you connect an impedance say 10 Ohm. Practical transformer it is, but what I am telling suppose you want to quickly calculate. Assume this transformer to be ideal because after all this r 1, r 2 are small X m is high.

And then calculate the currents this side 100 volt 10 ohm 10 ampere sorry. This current is 10 ampere and say that this current is 5 ampere and this voltage is close to 100 volt if we have apply 200 volt here, if we have apply 200 volt here 200 volt.

So, while estimating this is a practical transformer suppose, but for quick calculations you do this and to this practical transformer you really connected 10 ohm and 200 volt what I am telling is you will not be very far away from this 10 ampere this 5 ampere, it will be very close to that.

So, the concept of ideal transformers in many ways help me or very complicated circuit so many transformer. Each one will have r 1, r 2, X m 1, X m 2, but I know X m is high r 1 r 2 are small neglect them. For getting a quick idea what will be the order of the current, what will be the order of the voltage across the load?

It may be in a practical transformer instant of 100 volt if you have applied 200 volt because of this drop it may be 96 volt. But you care, you get the ideal transformer helps you to calculate the number so easily and you can always say it is very close to the correct answer, it is not a main achievement using the concept of ideal transformer wherever possible you do that.

So, that is there, but still now let us see whether those parameter values can be taken in to account. If it can be taken how and to do this I told you this portion is ideal transformer and go on adding parameters do it like this.

[FL] Next thing is I have assumed in the transformer that all the fluxes are leakage, leakage flux for example, consider the core of the transformer. Suppose we have a transformer ohm (Refer Time: 07:10) this is the thing and what I have assumed earlier is that here is your some winding, and I assume that all fluxes were confined to the core. In reality in a practical transformer it is not going to be like this.

There will be flux lines, most of the flux lines will be confined to the core because it will be highly permeable material. So, most of the lines of forces will be confined may be 2 percent, 3 percent, 4 percent flux line will complete their path through the air gap.

Therefore when the conductor carry some current, it produces flux a little amount of flux will be leakage flux. So, this is called the mutual flux, this is called the leakage flux. It is this mutual flux which is going to give you transformer action is not d phi m dt d phi m this is the voltage induced in the coil is d phi m dt no leakage flux, the flux which is common to both the windings. So, this is leakage flux here phi l 1.

Therefore the induced voltage in the coil of the transformer will be d dt of phi m plus phi l 1 is not into N 1 say this is the induced voltage in the coil and this can be separated out d phi m dt plus N 1 d phi l 1 dt. Now, this portion this term is not going to transfer energy from the primary to the secondary side. It will simply cause a voltage drop and it can be written as L L 1 the I l 1 dt I mean something like that primary current whatever is flowing leakage flux.

A detail analysis I have done it in my machine two course in the first few lectures, electrical machine two course, in the first 2, 3, 4 lectures in the same NPTEL domain. If you please go through that it will, I will put a note on that, but it looks like the applied voltage total flux created by the winding currents will comprise of two portion, one is the mutual flux which will be totally on the core, another is the leakage flux. This leakage flux will complete their magnetic path through the primarily through the iron. Their reluctance is high leakage flux itself will be small.

But nonetheless it will cause an extra voltage drop. Therefore, it looks like applied voltage I have given, there will be a voltage drop in r 1, but there is a small inductance drop which will also take place to take care of this voltage here. In other words what I am telling out of this total applied voltage a portion will be drop in the small resistance r

1 and also there should be a small inductance drop taking place and the remaining voltage is as if going to the ideal transformer giving you mutual flux alone.

So, it looks like it should be like this then let me first draw. So, leakage flux the term I have written leakage flux, you write it leakage flux causes an extra voltage drop, extra small voltage drop in the coil in the practical coil. What does that mean?

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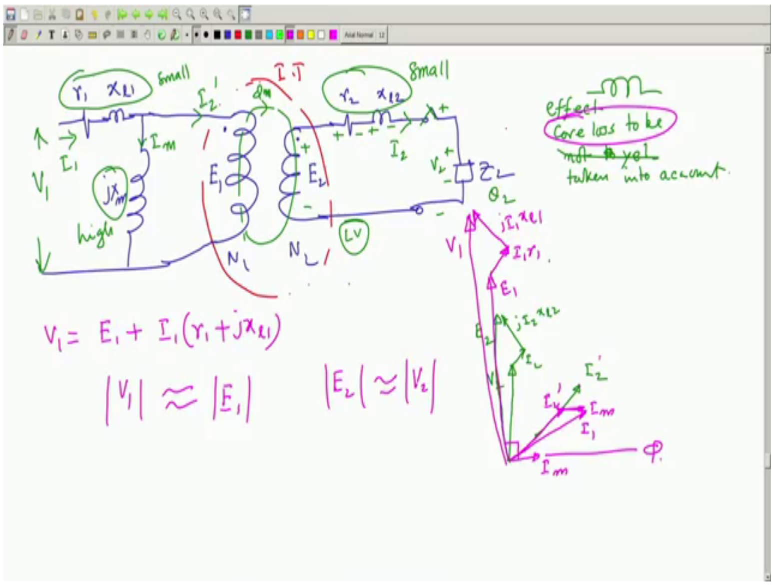

It means that if first I draw the ideal transformer N 1, N 2 and this portion is suppose ideal transformer, it is no connection dotted line and then we have seen we have got r 1.

Now, what I am telling in series with r 1 there must be another small inductance x L 1 and then this is your jX m and then this is your ideal transformer this is your E 1 and this is your E 2. In the secondary side two it will carry current it will produce flux a portion of it may be leakage flux and therefore, winding resistance as well as leakage reactance x l 2 and then this two are the terminals and here is the secondary impedance you have connected.

Therefore this is ideal transformer here all the fluxes are mutual mind you, all the flux here it is phi m mutual flux plus phi l 1, N 1 phi l 1 d phi l 1 dt is shown as a drop here because this is your supply voltage now we know out of this total supply voltage a portion will be dropped in r 1 absolutely no doubt and there will be another small voltage drop because of leakage flux which is not going to create your magnetizing current, no that voltage is consumed by the leakage flux.

As in any inductance you know inductance whatever is the flux that is the drop here and it is not mutually coupling to another coil therefore, no energy transfer because of x l 1 from primary to secondary side. In the same way as in the primary secondary side to then will have winding resistance another I have used by the small letters x to indicate leakage flux also will be small in a well designed transformer who wants more voltage drop takes place elsewhere and less voltage is available for transformer action.

It is this voltage E 1 which is nothing but the applied voltage minus this drop must appear here. If x l 1 is high once again it is a very bad transformer out of this total voltage transformer winding impedance consumes. So, much and little voltage, less voltage is available for energy transformer energy transfer. Therefore, remember that this is the situation now.

So, leakage flux effect of leakage flux can be taken care of once again leakage flux I should not write here no because applied voltage that will be only consumed in the winding and it must be in series with the applied lines jX m this one. And once we do that I will repeat this once again in that I do not know whether I have gone it a bit faster without defining what is leakage inductance and magnetizing inductance. But I request you please go through the first few lectures of electrical machine 2 course which is already uploaded in NPTEL website. You will get a better feeling of this one.

Nonetheless so this is more or less the all the parameters we have added to an ideal transformer to represent a practical transformer. This is the ideal part add these two things and pretend that this is the model of practical transformer.

Only one thing I have yet to take that is called the core losses that I will discuss, but so far as this one core loss not yet taken into account; not yet core loss to be taken into account to be effect of; core loss to be taken into a account, that we will do. But before that the addition of this one mind you I write it emphasis this point this is the small numbers, this is high number high with respect to whom with respect to these numbers quite high, similarly these are small .

Now, in this case once again let me do that because suppose s 2 we closed, what will be the thing? There will be a some current I 2 here. The moment through the secondary of the ideal transformer I 2 flows through the primary of the ideal transformer I 2 dash to inflow and this current is I m and this current is I 1 that is what is going to happen. How to draw the feather diagram? Suppose the power factor are same way.

Suppose, I will sketch once, so let us start. So, suppose you draw first let us assume this is LV side. So, V 2 is first sketch V 2, I know load power factor angle; I will sketch I 2. Let me draw it larger because voltage side current is higher. Suppose this is I 2, all are phases feathers I have not put in those bars I 2 ok.

So, V 2 is there, but V 2 and E 2 are not same in between comes a small impedance. So, what will be E 2? E 2 then will be equal to V 2 plus I 2 into r 2 plus jx l 2 is not the drops here like this is plus minus. So, V 2 to this at this drops get E 2 plus minus, this dot I have put. So, V 2 plus I 2 were to parallel to this and plus jI 2 x l 2 and if you add this you will get E 2.

If you get E 2 then your E 1 in phase with E 2, so your E 1 I will draw a different color. So, your E 1, I will fix up suppose this is your E 1. Once I get E 1, I will say oh my magnetizing current is this voltage by this jx m. So, I will draw a magnetizing current, which is 90 degree lagging E 1 and if this is I m your I 1 will be I m plus I 2 so, add this I m.

Student: Sir dashed.

I 2 dashed I am so sorry. So, I 2 is this one so, I 2 dashed will be less. So, I 2 dashed correct. So, suppose this is I 2 dashed.

So, it will be like this, then this was I 2 mind you this was I 2. So, from I 2 you get I 2 dashed then I 2 dashed plus I m you add I 2 dashed plus I m parallel to this, this I m and if you do you will get I 1; and if you get I 1 then E 1 if you add this two drops I 1 into r 1 plus jx l 1, small l indicates leakage reactance drop and this must be your V 1. My target is to show all the variables. So, E 1 I have reached. So, to this E 1 you now add I 1 r 1; E 1 add I 1 R 1 parallel to this wherever it is I 1 r 1 and to this you add I 1 which is 90 degree; I 1 j I 1 x l 1 and get your supply voltage V 1 this will be the and here is the flux along this line.

I think you have got the idea it looks like oh it is quite involved, no not really. We will see later how things will become much more easier with few approximations here and there things can be further simplified. So, what I told you that it is almost a practical transformer accept a core losses yet to be taken into account where I have considered the winding resistances r 1 r 2, where I have considered the finite magnetizing current and the effects of this are easily seen.

See I can make one comment. So, far I was telling that the moment you apply a certain voltage at the certain frequency the flux level in the core is decided and that is constant, but when the transformer will be operating when the windings are carrying current applied voltage is not creating flux. Flux is created by this voltage and this voltage E 1 is V 1 minus this drop, but the thing is r 1 x l 1 is small. So, E 1 and V 1, I can say magnitude of V 1 will be not exactly equal, but there magnitudes will be very closed by because of what because this elements are dropped.

Similarly, E 2 and V 2 will be also very closed by because r 2 x l 2 are small. Therefore, we can say roughly that the flux level even in a practical transformer it will change as you change the value of I 2 by varying Z 2 I 2 will change. So, this drop now with another value of Z 2 it will be different. Similarly here I 2 dashed will come I 2 dashed plus I m and so on.

So, this drops are small for a well designed transformer. Therefore, it is not very incorrect to say that flux level does change appreciable from no load to full load condition the change in flux level is pretty small because r 1 x small l 1 and r 2 x l 2 what, small.

Anyway in the next class what will do is this, we will tell you about the core loss which is very important. Core loss we will see that it comprises of two components, one is eddy current loss, another is hysteresis loss and when a practical transformer is operated, if you touch the core you will find core is becoming hot ok. Although there is no electrical connection between the conductors and the core. So, that is another interesting topics that we will take up in my next class.

Thank you.