Electrical Machines - I
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Lecture - 32
Equivalent Circuit of Auto Transformer

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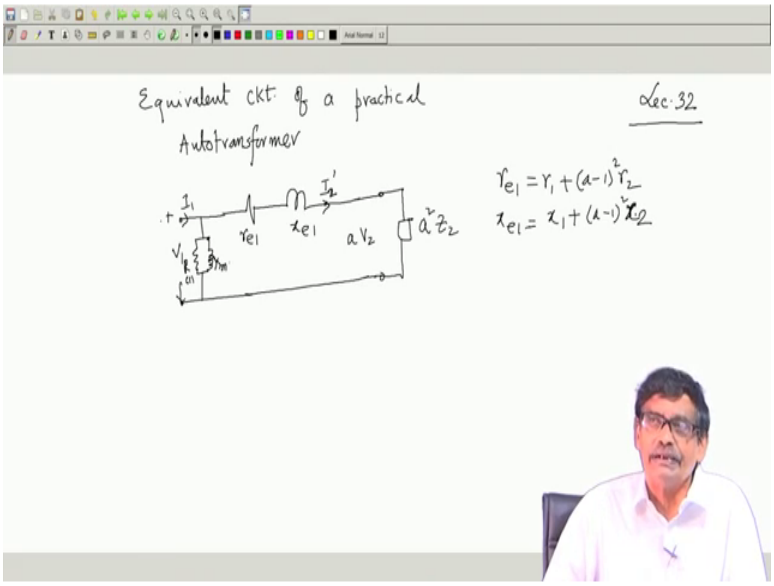

So, welcome to next lecture on Electrical Machines I. And we have been discussing about the Equivalent Circuit of a practical Auto Transformer. And this equivalent circuit when compared to a two windings transformer is somewhat difficult to obtain and that is why uh we were discussing it how to get it you recall from my earlier lecture.

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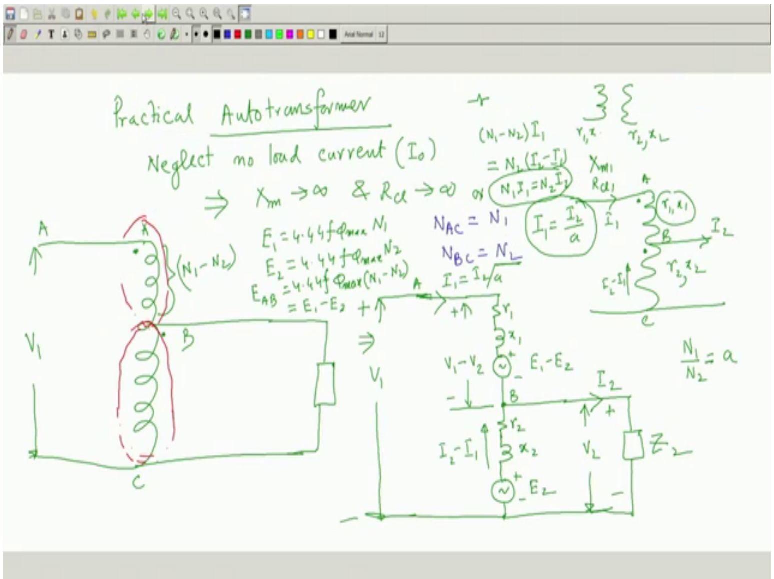

This was the actual auto transformer which is practical and I assume that this these are the visual current distribution I have assumed. Here is I 1 here is I 2. And this part A B which is having N 1 minus N 2 turns. And part B C these are two different coils they have nothing in common between them and this part suppose has got a resistance r 1 and leakage reactance x 1. And similarly this part B C has got a resistance r 2 and x 2 and we know the current distribution and z 2 is the load.

Now, without of course, having an equivalent circuit drawn, this circuit as such is also electrically connected is not by this point. So, it looks like a network problem that way it can be solved that is if you know V 2 if you know I 2 if you know these parameters, then B plus this current into r 2, x 2 these that loop two loops are there two measures these circuit can be handled. But only transformer business which will come in here to note that the voltage induced voltage E 1 minus E 2 here E 2 here this ratio of these voltage is N 1 minus N 2 by N 2 that is the thing, but it can be handled that way.

But we want to find out equivalent circuit and equivalent circuit of this transformer referred to say source side that is this side.

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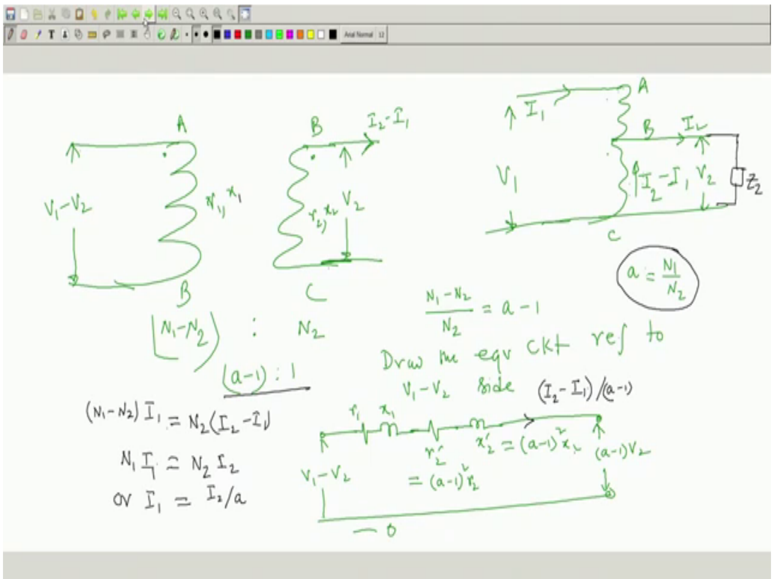

So, to do this next what we did is that portion A B and B C we noted in my last class is that this two windings are separate; this winding has a turns N 1 minus N 2 this winding has a turn N 2 only. Therefore, and this part is having r 1, x 1 I am sorry this is r 1 x 1 this is having r 1 x 1 and this is r 2 x 2; only thing is the as if the voltage applied to this winding is V 1 minus V 2 and this side it is V 2. And the current this winding is delivering is I 2 minus I 1 and not this I 2 mind this we understand. Therefore, between these two windings I can apply all the rules that I have applied for a two winding transformers having trans ratio a minus 1 is to 1, what is a? A is this N 1 by N 2 that we know.

Therefore, it looks like the equivalent circuit referred to V 1 minus V 2 side of these two coils will be like this, V 1 minus V 2 r 1 minus x 1 then these parameters will be referred to their trans ratio is this. So, a minus 1 whole square into x 2 r 2 dash 2 will be a minus 1 whole square into r 2 and here you will get this actual voltage v two a times V 2 means in this case a minus 1 times V 2. And mind you this current here is not I 2 how much will be the current? In case of two winding transformer you know I 2 by a it comes, so it will be I 2 minus I 1 is the actual secondary current that divided by a minus 1 this will be the current. So, what we have got here that I will that will be the starting point here.

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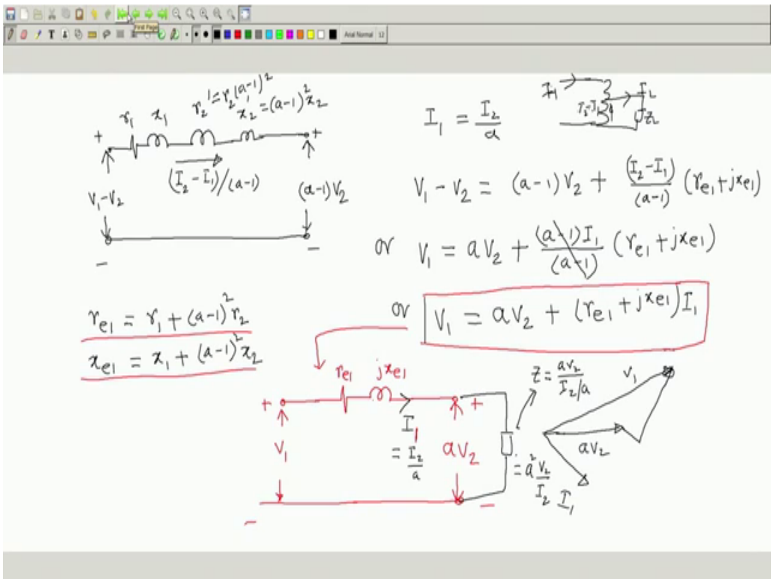

So, I will redraw it on a fresh page that is here is your r 1 x 1 was there, then the reflected value; r 2 dash x 2 dashed is here what is x 2 dashed? It is equal to a minus 1 whole square into x 2 this is how much actual resistance r 2 into a minus 1 whole square is not this is the thing.

Magnetizing branch till now we have neglected that can be easily incorporated later. And this voltage was V 1 minus V 2 and this voltage is how much a minus 1 times, V 2 you see this voltage is a minus 1 times 0 this diagram only I have redrawn there afresh so this is the thing.

Now, in this equivalent circuit this plus minus visual plus minus visual and this current is I 2 minus I 1 divided by a minus 1. But we have seen that I 1 is equal to also I 2 by a that we have already established is not from this MMF balance recall this we will always use. See the MMF of this portion this portion I will do it here in a this MMF in this portion MMF balance, N 1 minus N 2 N 2 I 1 is same as N 2 into I 2 minus I 1 this is the fundamental thing from this minus N 2 I 1 gets cancelled and you are left with N 1 I 1 is equal to N 2 I 2. Or I can say that I 1 can be also written as I 2 by a; a is N 1 divided by N 2.

So, knowing these what is our goal? Goal is to replace this equivalent circuit similar to that of the equivalent circuit of a two widening transformer, that is my input voltage V 1 should be present here alone load site there should be V 2 alone present, current some I 2 dash sort of thing should be present things like that we are trying to do.

Now, what is the importance of doing this? If you do this way then this equation by applying k v l rule I can write down V 1 minus V 2 this voltage is equal to a minus 1 into V 2 plus of this current that is I 2 minus I 1 divided by a minus 1 this current into this whole impedance, if I say that re 1, if I define as r 1 plus a minus 1 whole square x 1 x e 1 as x 1 plus a minus 1 whole square x 2.

If I combine them, then this can be written as this voltage plus the drop here that is a current into re 1 plus jxe 1 this is the thing I can write. And from this if you move this V 2 to this side, then we will see it is equal to V 1 is equal to a V 2 very good, plus I want to have I 1 here in terms of I 1

So, what is I 2? I 2 is a I 1, so it will be a minus 1 I 1 divided by a minus 1. And this is your re 1 plus jxe 1 this will cancel out. And now I am happy ok, I have got an equation which is really we are looking forward that is after getting this equation this equation, I will say that this equation prompts me to draw the equivalent circuit referred to primary from this equation. As if a voltage is there V 1 this side and here is the impedance re 2, re 1, jxe 1 where the description of re 1 is this, description of xe 1 is this and then here is I am having a V 2 and this into I 1 mind you I forgot to write that into I 1 this into in this expression let me put it properly, into I 1 here it is into I 1 is not.

So, this current is I 1 is not this equation suggests that, that this is I 1 therefore, a V 2 plus the drops gives you V 1 in the same way as we draw the equivalent circuit referred to primary of a two winding transformer. But there is an important difference what is that important difference ok, terminal voltage gets multiplied by a V 2 fine, but this r 2 I think I made a made a basic mistake here this should be this should be r 1 plus r 2 not a 1 minus this is r r 2.

And similarly x 1 is x 1 plus x 2 please correct that only basic differences the r 2 and x 2 are to be multiplied by not x square, but a minus 1 whole square got the point, so this is the thing. Then that one has to remember at least with refer to primary if you draw then the equivalent circuits will be like this. And then after that everything is fine that you can draw the phasor diagram start with a V 2 here a is a scalar number this is also direction of V 2 then draw I 1 and then draw this drops at and you get V 1.

So, this is how the equivalents circuit of an auto transformer can be drawn or obtained; and to do that the method there are several other treatment people write lot of equations try to prove it. But what I am telling this can be very quickly drawn provided you apply the rules of two widening transformer for the windings A B and B C because they are separate winding and. So, as if I say that across AB V and V 2 is applied this one, but only thing is its trans ratio is this therefore, it is to be multiplied these voltage will come like that.

And then, defining this r 1 plus a minus 1 whole square r 2 etcetera as re 1 and so on. You will come here then, from this you write down the k v l equation of this and that minus V 2; V 2 cancels there from this side and soon I find o this is the equation this is the reflected current and so on. So, with respect to primary this is the equivalent circuit. In the same way that is from this equation only if you wish that I am not doing mind you. I will be able to draw, the equivalent circuit referred to the load side also got the point I will be getting the equivalent circuit referred to the load side as well.

Starting from this basic equation here, I will be able to do that clear, but that I leave it to you to ponder over, but better do not waste too much time on that is also true because one side you have got that is fine only one point in this diagram. This I 1 also see I 1 is also equal to I 2 by a is it not I 2 by a, I 1 is equal to I 2 by a.

What do you think the impedance connected here it will be this voltage a V 2 by I 2 by a this point is worth mentioning impedance here, load impedance I will at least from this circuit it tells me it is a V 2 divided by I 2 by a, which is equal to a square V 2 by I 2 and what is V 2 by I 2 V 2 by I 2 here it is Z 2, you know V 2 by I 2 is Z 2 mind you, this current these two isolated current is I 2 minus I 1 and I 1 they must balance the MMF the rules of two winding transformer follows.

But I 2 minus I 1 is not your load current that is why that complication comes in, that is if I say across the output terminals of the auto transformer that is here if I draw it to highlight that; if it is Z 2, this is I 2 and this is I 2 minus 1 I 2 minus I 1 and this is I 1 is it? Therefore, the load impedance will be multiplied by a square into a square because of the fact I 2 is not part of this current got the point therefore, this point should be remembered.

So, auto transformer equivalent circuit if you want to draw is slightly difficult means if you are conceptually ok, you can easily develop, but one should be careful. The winding leakage impedance will be multiplied by a minus 1 whole square, but the load impedance should be multiplied by a square where a is N 1 by N 2 is not. So, the that is all I mean equivalent circuit we have completed.

But only thing is I will just now tell you now suppose, I say that in this equivalent circuit you have not talked about the no load current. In any case I will consider the approximate equivalent circuit therefore, the magnetising current and core loss component of resistance that is the loss component of current; can be shown to be connected right across the supply terminals as two components; one is R cl 1, another is X m 1. For example, here I will connect R cl 1 and X m 1 got the point.

So, if I draw it here that I can always do. So, equivalent circuit of an auto transformer, in fact, a lecture 32 I have written here we were at on the verge of completion last lecture itself, but anyway. So, this will be then V 1 re 1 xe 1 and this is V 2, V 2 or a V 2 we got a V 2 I think a V 2. And the load impedance whatever was connected will be multiplied by a square Z 2 and this re 1 do not forget it is r 1 plus a minus 1 whole squared r 2 xe 1 is equal to x 1 plus a minus 1 whole squared into x 2 that is it.

And if you consider this impedance, refer to this side show it here supply side as X m 1 and R cl 1 like the two winding transformer and this is I 1 is the current here clear. So, I 1 then I should tell this one perhaps I will tell some reflected current of these primary side that is, I 2 dashed and once again I 2 dashed is not I 2 by a minus 1 it is I 2 by a.

I think we have spent enough time go through it and try to solve some problems on this auto transformer equivalent circuit. We will also give you some problems in the tutorial or in the hand lecture notes some solve problem, I will try my best to include that, but it is very interesting to study the autotransformer; because autotransformers are all both the two winding transformer and autotransformers are used.

Although you can change the level of voltage from one level to another, for any ratios theoretically it is possible, but there are some advantages of auto autotransformer while the voltage ratios are not deferring too much. Then you choose auto transformer, then also isolation problem we can easily see is not that urgent at the same time economically it will be much attractive. And two winding transformer on the other hand gives you the isolation where it is needed.

[FL] After completing this, our next topic will be a 3 phase transformers. But before 3 phase transformer one small thing I would like to tell you a tidbits of see two winding transformer for example, about one test I will just tell. We have talked about open circuit and short circuit test on a two winding transformer mind you, in auto transformer I am not going to those tests, but if this equivalent circuit is with you can easily find out these parameters by doing similar test this.

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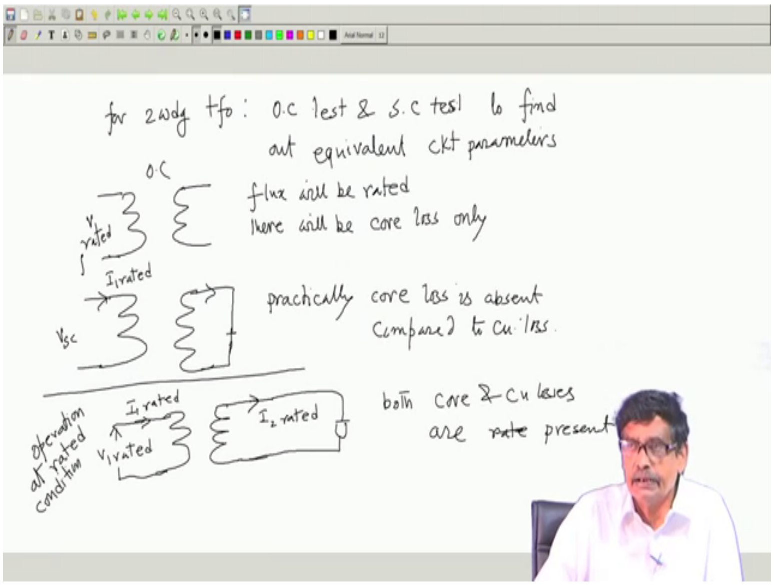

But what I am telling is, for 2 winding transformer you recall for 2 winding transformer, we have done open circuit test and short circuit test, to find out parameters equivalent circuit parameters to find out that we have done. And I told you during open circuit test you recall you apply rated voltage V 1 rated at rated frequency rated frequency secondary is open.

So, for this test open circuit test when you connect like that flux will be rated flux will be rated and there will be core loss only core loss only; because the copper loss is negligibly small secondary winding is not carrying any current and primary current is only two to five percent. So, only core loss takes place during open circuit test.

On the other hand during short circuit test, you keep the secondary shorted, here you apply not rated voltage such that rated current flows current is rated here I 1 rated; since applied voltage is pretty small and flux in the core is directly proportional to the applied voltage. So, flux will be very less, but current will be rated. So, in this test what happens is this practically core lose is can be assumed to be 0 cold loss is absent, as if is absent compared to copper loss all the losses will be copper loss to copper loss ok. And when the transformer will be in use this is during test these I told, but I am once again perhaps repeating, but it is better to repeat keep these points in mind.

When the transformer will be in operation it will be V 1 rated here also and the windings will carry rated current both the windings at full load condition, is not here load is connected rated voltage. And secondary is not silent it is supplying power therefore, during operation this is during operation at rated condition operation at rated condition both the losses are present, both core and copper losses are rated are rated values are rated are present you cannot neglect one from the other that is fine.

Therefore, during open circuit test and short circuit test when you are finding out the parameter values, the temperature rise during this test or that test will never be close to the temperature rise of a transformer which will be put to use at rated condition. Because here both the losses are present temperature rise will be much higher than either of this test and that test. We will continue discussing on a very simple test, I will just mention because that test is so nice and this will also enhance our understanding of transformers. So, I will discuss about sampler test briefly in the next class and then starts topics on 3 phase transformer.

Thank you.