**Electrical Machines - I**
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**Lecture - 17**
**Short Circuit Test**

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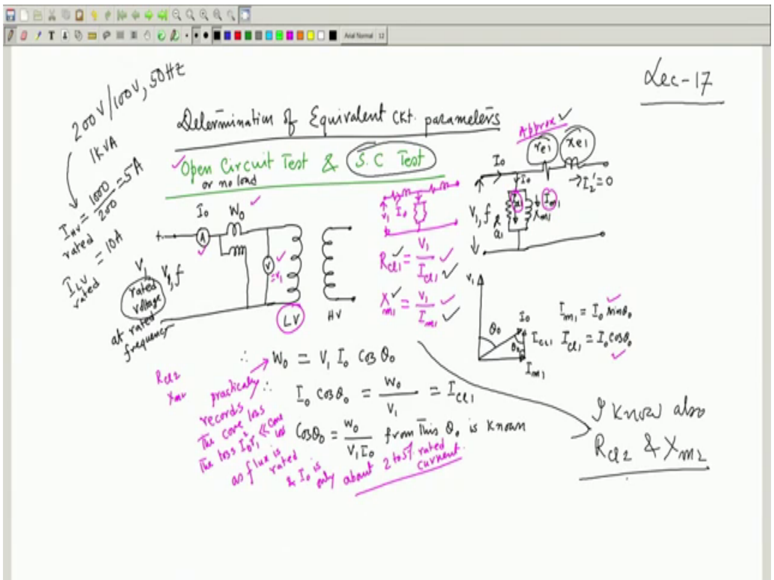

Welcome to lecture number 17 on Electrical Machines-1. And we were discussing about the determination of equivalent circuit parameters. Equivalent circuit for example, has been drawn in this diagram referred to primary side. And you know it is approximate equivalent circuit ok, this is approximate equivalent circuit. And r e 1 is nothing but r 1 plus a square r 2, x e 1 is nothing but x 1 plus a square x 2. Now, the question is this equivalent circuit can be therefore used to analyze a circuit which involves a transformer? And it is easier. So, therefore, equivalent circuit is always drawn referred to a particular side.

So, for example here, now the big question is how to determine the parameters of this equivalent circuit? I will very quickly tell you one of the test open circuit test I discussed in the last class. From that test this parallel branch R cl 1 and X m 1 can be determined. What we did there is this. Generally from the LV side, the open circuit test is carried out, whichever side you energize for testing the parameter values we will get referred to that side. So, referred to LV side, suppose V 1 is the rated voltage you have to apply rated voltage, connect an ammeter, wattmeter and the volt meter and this is the practical transformer. And the other side is kept open no impedance is connected or load is connected across the secondary. And what you all you have to do is you have to take the readings of ammeter, wattmeter and voltmeter ok.

Only thing is that during no load test or open circuit test, if we know the rating of the transformer, we can have some idea about the order of the no load current as I told you 2 to 5 percent of the rated current. So, before doing the test, what do you do from the kvA rating and voltage ratings, calculate the rated current of the LV side and take 5 percent, 7 percent of that. To have some idea that what is the order of the current at the transformer is going to draw during no load test that will help me to decide about the range of the ammeter, and the current coil rating of the wattmeter that is important.

For example, the no load current if you calculate it comes out to be 0.8 ampere expected to be of that order, then you connect an ammeter which can record current up to say 1.5 ampere that will be a good choice. Similarly, current coil of the wattmeter should be of the order of 2 ampere range. Of course, 5 ampere range ammeter and 5 ampere range current coil of the wattmeter will do, but accuracy will be more, if you use lower ranges of ammeter and current coil rating of the wattmeter. Pressure coil rating of the wattmeter is of course the rated voltage of the transformer.

In any case the approximate equivalent circuit is this. So, all the powers the reading of the W naught will practically record the core loss taking place in the transformer. Because no load current is very small there will be some copper loss in the primary of the winding I naught square into r 1 and that will be neglecting, because flux is rated mind you. Rated voltage, rated frequency flux will be rated.

And therefore, referring to this equivalent circuit V 1, I naught you draw theta naught and sometimes it is tempting to represent it in series combination better do not do it although from circuit point of view, it is fine. But whatever resistance real part of this equivalent R cl and X m will not give in ohm the resistance representing core loss, because core loss the flux is constant therefore, it is better you represent in parallel and always talk about this resistance. So, there is a shortcut way, then I naught is known, theta naught is the power factor angle which I can calculate from the wattmeter reading, cos theta naught I will calculate. Then from this triangle I can calculate magnetizing current, this current and this current.

And once this current is known V 1 by I m will give you X m ok. So, here I have written V 1 by I m will give you X m and V 1 by I cl will give you R cl ok, once I know that. Now, if I ask you the question what is wrong, if I carry out the test from the HV side that I will decide slightly later. But what I am telling it, I can after knowing these R cl 1 and X m 1, I can tell you that what will be R cl 2 and X m 2 if you had carried out the test from the HV side.

You simply divide by a square this quantities and we will get R cl 2 X m 2. Therefore, remember always that if you have determined some parameters with respect to a particular side, you need not carry out the test once again from the other side to determine the same parameters, only thing there will be a multiplying or dividing factor of a square depending upon the situation.

So, R cl 1 X m 1 the moment you have calculated what I want to say, I know also R cl 2 and X m 2 I can always calculate by multiplying or dividing with a square as the case may be. Now, today the next test is short circuit test, we will discuss. And in the short circuit test, if you carry out what happens is this you will get these two parameters r e 1 and x e 1 ok, let us see what you have to do. Now, during short circuit test what happens is this, although it suggested always that better you carry out the short circuit test from the high voltage side ok. So, I will first discuss the test, then I will tell you what do I mean by this.

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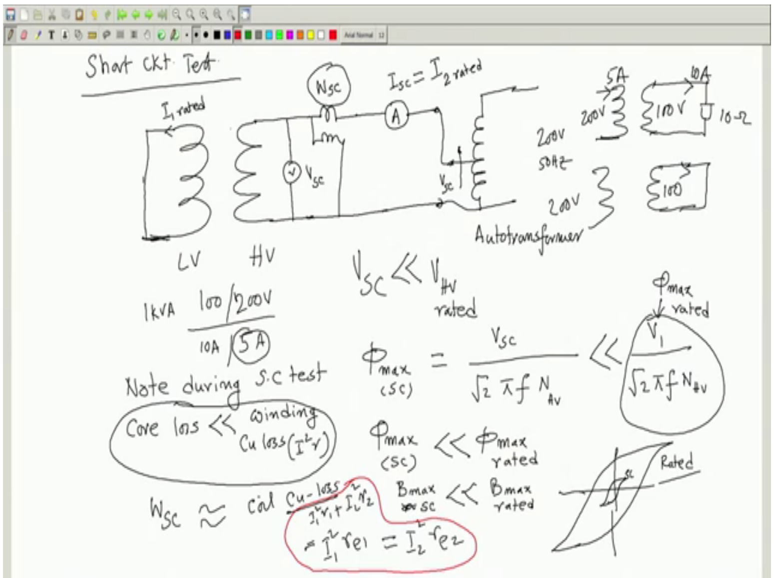


So, this was your transformer ok so, the same transformer that is here it was I should review it like this LV, HV. So, what I will do during short circuit test, I will connect source on the high voltage side and the other side I will just put a short circuit. I will short these two terminals of the of LV side. And here what I will do, I will connect once again those three meters, one is a voltmeter you connect, another is an wattmeter you connect and also connect an ammeter ok. And here I will connect the supply.

Ok, so you give some supply and note down these meter readings that is the wattmeter reading which is W SC I will write ammeter reading I SC I will right and voltmeter reading V sc. Now, the question is how much voltage should I apply during open circuit test which I carried out from the LV side, I applied rated voltage, mind you rated voltage was applied.

Suppose, let us take the same transformer which I am telling that suppose we have a transformer whose rating is 200 volt, 100 volt 50 Hertz and 1 kvA say 1 kvA. Now, the moment this is 1 kvA, then as I told you I can calculate the I HV rated current which is the 1000 by 200 that is 5 ampere is it not, and anyway I LV rated will be how much, 10 ampere. So, let us talk in terms of this transformer then things will be much clearer while doing LV open circuit test, I should apply suppose the rating of the transformer is this. I should apply 100 volt here LV side I have to energize 100 volt and that is all.

Now, what I was telling I HV rated is five ampere therefore, I expect the no load current to be of the order of 5 percent of these that is 5 into 0.5 is 0.25 ampere. So, perhaps in ammeter of range 0 to 0.5 ampere will do. Similarly, the current coil range of this wattmeter I will select as 0 to 1 ampere that will be a good choice and pressure coil will be 100 volt that is what we need.

So, suppose the same transformers; for the same transformer, I am now going to do the short circuit test. So, this time I, so what is the rating of the transformer rated voltage is 100 stroke 200 volt ok, 1 kvA. This rated current is 10 ampere of this side and this side rated current is 5 ampere we have just seen. Now, in this case, how much voltage should I apply here that is the question. So, from the HV side what is the rated voltage of the HV side 200 volt. So, should I apply 200 volt 50 Hertz on the HV side, the answer is a big no, never apply the rated voltage when the other side of the transformer is short circuited.

The answer can be easily understood, recall that in a transformer if you anyway I will draw something here. Suppose, this is the transformer when it will be operated normally this transformer what do you do, you apply suppose 200 volt here, you get 100 volt and then you connect the load. I told you in my previous lectures how much load impedance you will connect is decided by the rated current of the secondary coil. What is the rated current of the secondary coil, LV side 10 ampere.

Therefore, it looks like I should not connect an impedance whose value is less than 10, ohm, if you connect the transformer will be overloaded. But maybe 10 ohm if you connect then this current will be ten ampere that is fine, and then this current will be approximately 5 ampere is not that is this scenario. So, less than 10 ampere if you connect, the rated current will cross its limit.

Now, during short circuit test what you are doing the LV side, if you apply 200 volt, if you get 100 volt here and if you short circuit it this current is going to be pretty high 100 volt by almost 0 resistance, you are short circuiting and that will definitely be many times larger than the rated current. And you are there will be problem, I mean transformer may burned if you have not taken proper precaution that is you are not connected proper fuse these that. So, but during no load test no such problem apply rated voltage rated current and the current drawn from the supply will be only 5 percent of the rated current of the LV side, but here you cannot short circuit it by applying 200 volt you are putting a short circuit.

Then the question is how much voltage should I apply to the HV side, the answer I hope you have got. I can only say this much that I should not apply a voltage across the HV side which will cause the current drawn from the supply to exceed its rated current of 10 ampere. I should not apply a voltage, I will apply such a voltage under this scenario it will be like this. So, you must have an arrangement here in the form of an auto transformer which you must have used. So, this is auto transformer, do not forget to connect an auto transformer ok, where output voltage can be varied starting from 0.

So, what do you do, here your maybe this side here this apply voltage is 200 volt 50 hertz ok. So, set the auto transformer pointer at 0, so that output is 0 here, no current flows even when it is short circuited. Now, gradually increase this pointer, so that you are applying more and more voltage certainly not 200 volt a fraction of that you go on increasing it, but keep a strict watch on the ammeter reading. The moment ammeter reading is 5 ampere, I will stop further increasing this pointer because that is the maximum voltage you can apply ensuring that the currents in the windings will not exceed the rated current that is the whole idea. Therefore, a little voltage is required to do this, got the point.

So, the applied voltage here is less V SC, mind you applied voltage V SC must be much much less voltage than the V HV rated whatever 200 volt is the rate of you do not apply 200 volt under short circuit. But a little voltage as you can see and I have no problem I will connect an auto transformer a variable output voltage I will get and therefore, I will only go up to that voltage which will make this current predicted. Of course, one can go 5 percent, 10 percent I had the rated current that is not a big issue, but certainly not apply 200 volt ok.

So, during short circuit test I am applying a little voltage compared to the rated voltage. Now, during short circuit test the level of flux phi max during short circuit test in the core of the transformer, it will be then V SC divided by root 2 pi f into number of turns of the HV side is it not, that is the thing. And this is certainly much less than the under rated condition whatever flux will be produced root 2 pi f N HV. Therefore, phi max and this quantity is rated flux phi max rated.

So, phi max during short circuit test is much smaller compared to phi max rated. This must be understood because you are applying very little voltage, of course, frequency is high. Which; obviously, then means that B max rated; a B max under short circuit condition is much less compared to B max rated, because you have to divide it with a constant cross sectional area of the code to get B max. It that be the case, so a very little amount of flux will be produced inside the core of the transformer under short circuit test although current in the windings will be rated values.

So, a interesting situation, now during this test, therefore, I will say the core loss will be very small compared to the winding copper loss that is current is I I square into R 2 or R 1 whatever you call plus I 1 square into R 1 the sum of these two winding copper losses that will be high because rated current you are passing. But the core loss as we know eddy current loss depends upon B max square.

And by a large factor you have reduced that B max, frequency same, B max square x square tau is of course, same thickness of the plate. So, eddy current loss, similarly hysteresis loss depends upon the area enclosed by the cores by the by the BH curve of the material area enclosed by the BH curve, but during short circuit test if this is the BH curve during rated I am just trying to give you a pictorial thing. If this is corresponding to rated condition, then BH curve may look like this during short circuit test SC at this is rated condition.

So, both hysteresis and eddy current loss will be less. And also from that empirical formula we know hysteresis loss depends upon B max raise to the power some numbers say 1.6. So, B max itself is quite small, therefore, during short circuit test; note, during it is what writing during SC test core loss will be much much less than the winding copper loss that is I square r loss in the winding I 1 square r 1 plus I 2 square r 2. So, I am not writing that thing got the point. So, this, this is must be understood.

At this I have told you from what is called physical interpretation, why core loss can be neglected during short circuit test. In other words what I am telling, so during the test when this I sc, I will I will apply such a voltage here V SC that I SC become equal to HV side which I am calling as side two compared to my previous thing same transformer I am working with I 2 rated. And also in this the current whatever will flow is I 1 rated, because current ratios are related by that factor A. Therefore, this is the rated current, but flux is not rated it is only a small fraction of the rated flux.

Therefore, this wattmeter reading strictly speaking will record both the core loss and the copper loss in the winding, sum of these two, but because core loss is very much smaller than the winding copper losses. Therefore, we say that W SC is practically equal to the coil or winding copper losses; coil copper losses. You must know I square r loss is copper loss, it is occurring in the copper. Core loss is in the iron, it is occurring that is also some I square r loss, we have seen that, but people do not say oh that is called iron loss fine, everything is fine, because in the iron the eddy current flows.

So copper loss, copper is used to make the primary and secondary so, copper loss is a and copper loss will be I 1 square r 1 plus I 2 square r 2. And you must understand by this time this is same as I 1 square r e 1 if you express everything in terms of I 1, and which is same as I 2 square into r e 2. This portion I think you I told you, you show it you can easily show, so this is the thing; so, this is the situation. Now, I will go to the from the equivalence circuit then what do I get. So, this is the thing I will note this things ok.

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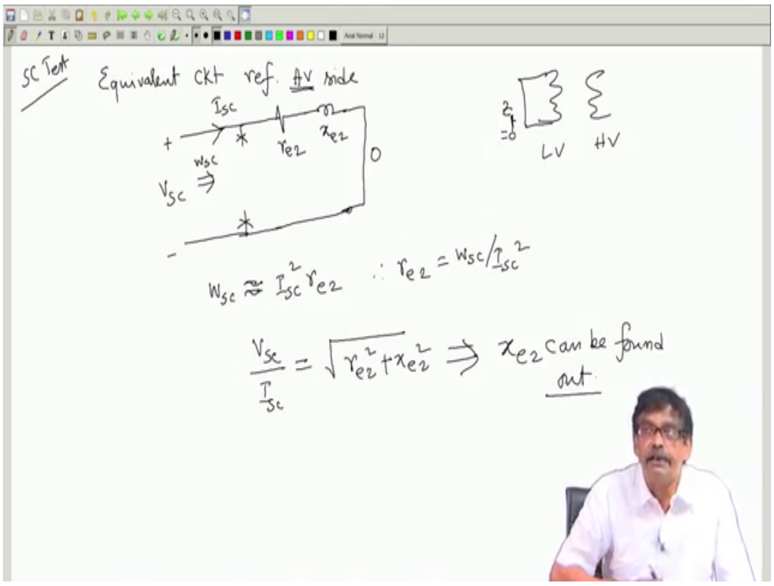


Now, the equivalent circuit referred to the high voltage side will be because I have energized it from the high voltage side. Now, equivalent circuit referred to HV side and I remember we are discussing short circuit test under that condition. What is the equivalent circuit referred to the HV side it will be approximate equivalent circuit, it will be you have applied some voltage on the HV side V SC. And then this parallel branch will be there, is it not, this will be the parallel branch. And then you have if HV side I denote it by r e 2 and x e 2, this will be I have energized the transformer from the HV side mind you. On HV side, load is connected.

Now, what load is connected on the LV side, this is HV, this is LV, I have kept it shorted. So, z 2 is 0 therefore, here also in the equivalent circuit this will be shorted because z 2 is 0 not z 2, z 1 is 0. So, z 1 dashed is 0, is it not, it is shorted. And if I want to write this two, I should write R cl 2 and X m 2 ok. And R cl 1, X m 1 I have found out.

Now, these impedance now coming to the equivalent circuit and trying to establishing the same thing. These r e 2 and x e 2 are quite small compared to R cl 2 and X m 2, these are high here. And also I am telling this core loss power can be neglected power in this resistance is your core loss during short circuit test which is quite small and that is also reflected in the equivalent circuit. What is the eddy current loss now, V SC square by R cl 2, got the point. This voltage square by R cl 2, but this voltage is only a fraction of the rated voltage that is 200 volt for the transformer we have considered maybe 5, 10 voltages, you will find in the laboratory.

Therefore, in essence what I am telling is during short circuit test and this impedance quite small compared to these. So, this branch can be removed approximate. So, what I am telling is this branch as if it is not there, parallel branch can be shown to be not present. Magnetizing current also will be too small v divided by X m 2, but v I am applying only V SC which is much smaller than the rated voltage. So, both I m and I cl are quite small compared to this current, which is now rated current on the HV side for the transformer I have considered I will apply such a voltage such that 5 ampere close now. So, this will be the thing.

Now, therefore, you have this thing you have the short circuit current I SC ok. And this is r e 2, x e 2. Now, what happens is these I will then say the wattmeter reading whatever you have got W SC must be equal to approximately equal to I SC squared into r e 2 straight. And here you note it is series, applied voltage is known, power drawn by the circuit is known, W SC had a voltage V SC I SC. So, I SC squared r e 2, therefore, r e 2 can be calculated.

And similarly the ratio V SC by I SC, VSC applied voltage by this current is this impedance, magnitude of this impedance r e 2 square plus x e 2 square, it will be this; r e 2 is known. So, from this, this will give you x e 2 can be found out. So, from the short circuit test, the value of r e 2 and x e 2can be found out. I will continue with this in the next class.

Thank you.