Electrical Machines - I
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Lecture - 31
Practical Auto Transformer

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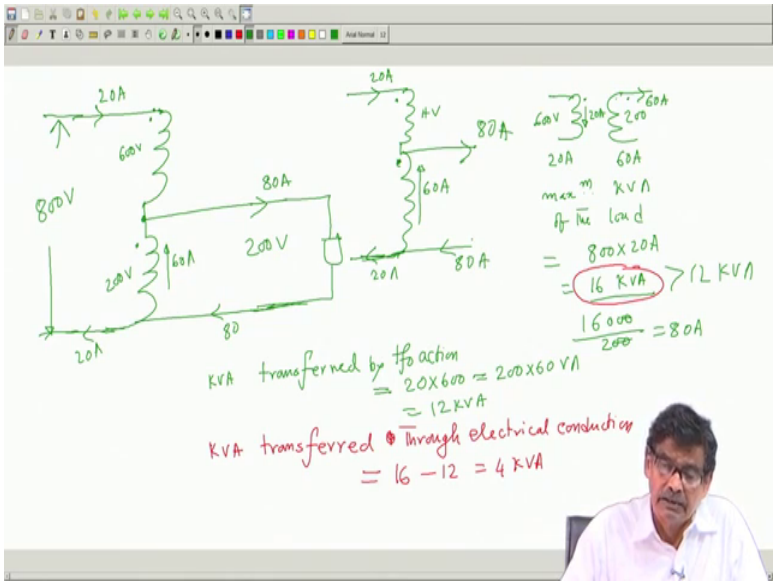

Welcome to 31st lecture on Electrical Machines I. In our last class as you know, we were discussing about how a two winding transformer can be also connected as an auto transformer and for some two connections, interesting connections. We how to calculate the distribution of current in several windings? See, a two winding transformer when you connect in auto transformer form it really this primary and secondary winding is really unaware of the fact that you have connected in this manner or like a two winding transformer; it only knows this much that if it has to deliver 60 ampere. The moment it delivers through the dots here 20 ampere must come in; that is what duties.

Voltages are rated voltages; based on that everything all the calculations go, And as and we have also seen another interesting feature that a two winding transformer whose rating is suppose for the numerical example we have considered 12 KVA. It can be; apparently it looks something very surprising that the KVA handled by this connection is much more than the KVA rating of the two winding transformer and we also told that this is possible in this mode of connection because of the fact that power will be transferred

from source to the load side either by two actions. One is just by transformer action another is by electrical conduction.

It is very easy to calculate how much is transferred by transformer action that I will calculate. And from the total KVA I will subtract that to figure out how much is conducted by conduction that way you just think. And you can do; and of course, these are the only two connections I have discussed; you try on your own how differently you can connect this two coils in, apply voltage appropriate voltage mind you to the windings to get how much KVA? How much current? The interesting thing is whichever winding is left out alone sort of thing you first fix up that current I should not allow more than. And the moment you decide that current the other part of the winding which is which has its own identities separate no common portion of this and this.

Therefore this current can be fixed up and then, the total current. Anyway this you please try solve many problems. Now, in today's lecture I; my plan is to tell you something what is going to happen if it is a practical auto transformer.

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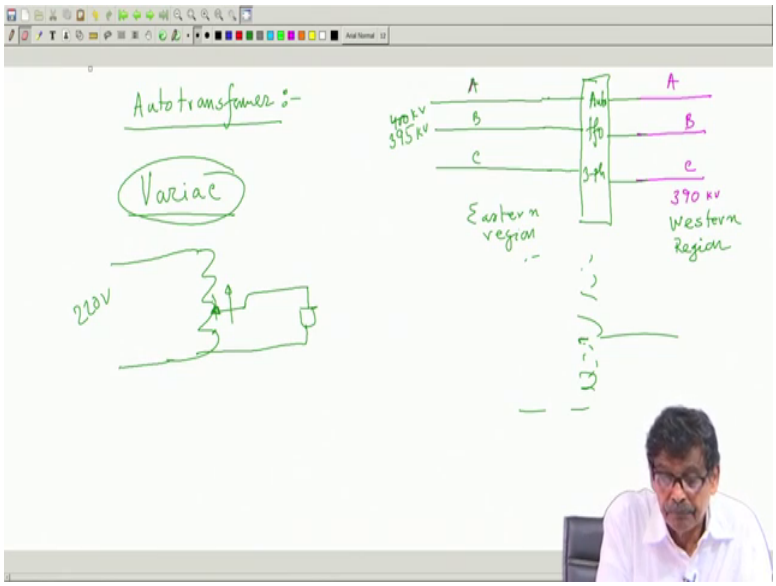

I will discuss that, but before that one point I must tell you; see, auto transformer is the thing. What will be its useful applications auto transformer? It is useful applications will be you must have heard that starting of three phase induction motor; is not? You use an auto transformer start it at a tapings of x then the current drawn from this supply is

reduced. Torque is also of course, reduced by a factor of x square current drawn from the supply is reduced by x square and so on.

Another interesting application of auto transformer will be to connect two power systems. You must understand this point that we have in our country or in all other countries also there common power grid ok; you have several level of voltages ok. Suppose, the 400 KVA is the one line 400 KVA system ok; see, eastern region grid; suppose, there is a grid eastern region 400 KVA. Now, the western region grid also should be supposed to be 400 KVA ok, another grid with different colors I will draw; try to understand. This is supposed to be also 400 KVA.

And you know this power lines will be ultimately connected in parallel that is this is suppose a phase b phase c phase a phase b phase c phase, coming from western region grid; this is coming from eastern region grid and loads are connected in both the system, but I want to make them common member; that is power may go when, there is deficiency in power generation in western grid. Perhaps, this grid will supply power or there and vice versa.

So, grids, common grids if you want to make all over the country; all the grids are to be connected in parallel. Suppose, this level of voltage should be also 400 KVA then, only this two can be; suppose this is A phase; this is B phase; this is C phase and these are corresponding phases here ABC. This is supposed eastern region, eastern region grid; this is western region. Who have kept this lines a live? Several generators. They are connected in parallel you get the voltage. Here also several generators connected in parallel as generated this grid. Now suppose, you want to make it more flexible that I will connect them also in parallel and if due to some reason Western Region some generators fail. So, the eastern region can help to pump power into this side or vice versa that is what I am telling.

Now, what happens is this? This is 400 when you connect this to in; if you want to short this you cannot just do just like that because of the fact the level of the voltage must be same. It may so happen; it is absolutely this side voltage is suppose not 400 KV because of some practical reason or otherwise, it is suppose 390 KV; are you getting? Because loads here also it is not 400 KV; may be 402 KV or say 395 KV because you will be loading. These systems are loaded; this volt bus voltage may not exactly match. Suppose

it is 395 KV, but I want to connect them in parallel. So that flexibility increases this side can fit power; this side can fit power and what not.

So, in such situations these two systems can be connected. If you connect an auto transformer in between, three phase auto transformer I will tell what this auto transformer. Three phase through an auto transformer you will be able to parallel; two winding transformer can be also used to parallel them, but I will not do that why? Because I see that the ratio of the voltage is so small; 395 to 390 KV I have to connect. This side is 395 KV; this side 395 KV, nothing better than auto transformer you should think about because trans ratio or the voltage ratio is close to 1.

You will be saving more or very large amount of copper; size of the auto transformer will be less. So, this is one very practical use of an auto transformer, three phase auto transformer. Now, what is a three phase auto transformer? I will just this I will take up when I will take three phase transformer; right now you just try to understand. Here is a case, where the voltage ratios will be close to 1 and I have to connect these two.

So that I can parallel them not directly because if I connect them directly without transformer 5 KV difference will cause large current to flow almost like short circuit. So, this is one case or maybe you can start connect an auto transformer to start an induction, three phase induction motor. Of course, I must add one remark. Now to start an induction motor using a bulky auto transformer that to I mean is not a good solution; there are very good solutions because of the use of invertors power electronics there, but earlier it was very much used.

So, auto transformer is an natural choice when, the voltage of the two sides you require voltage levels are of this same order ok you really save money copper that is there. Now, another thing you have used in the laboratory which is called variac sorry variac. In the laboratory you must have used to carry out experiments and I also was telling that is it is drawn like this and this stepping point you can move you can adjust to anywhere you like and you can supply your load at various level of voltage.

Suppose, there is 220 volt you want to do some experiments to find out the characteristics of the load starting from 0 voltages up to 220 volt. So, there is a pointer there which you can vary by rotating a shaft through a carbon brass this is connected.

You touch different segments of the turns and gradually you can increase voltage to the load.

But it is called variac. It will be same the current distribution etcetera we have to find out from the whatever analysis we have done like that you have to do no doubt about it, but here while doing this, while making this variac do you think the cross sectional area of this portion is less than the cross sectional area of this portion no because you do not know where he will be operating; so, this must be understood.

Variac is strictly not an auto transformer in this sense we design the auto transformer get some economic advantage. Well, here nothing like that you should be prepared. So, the gauge of the wire here throughout is fixed; you must understand this distinction in a variac laboratory equipment that is why you will find variac is too heavy mean there is no savings this side. Its KVA rating is known; maximum current it can draw and so on. This point I must bring out to you. So that you distinguish between an auto transformer dedicated auto transformer like this where it will be used; it will have a fixed tapping; is not?

This is thinner wire. I drew with different colors, fixed tapping over. Nothing like that this can be moved this way that way. If you do it between taking lot of risk you do not know what is the current rating, mixed up current rating of the turns? I hope you have got the point. So, this must be kept in mind.

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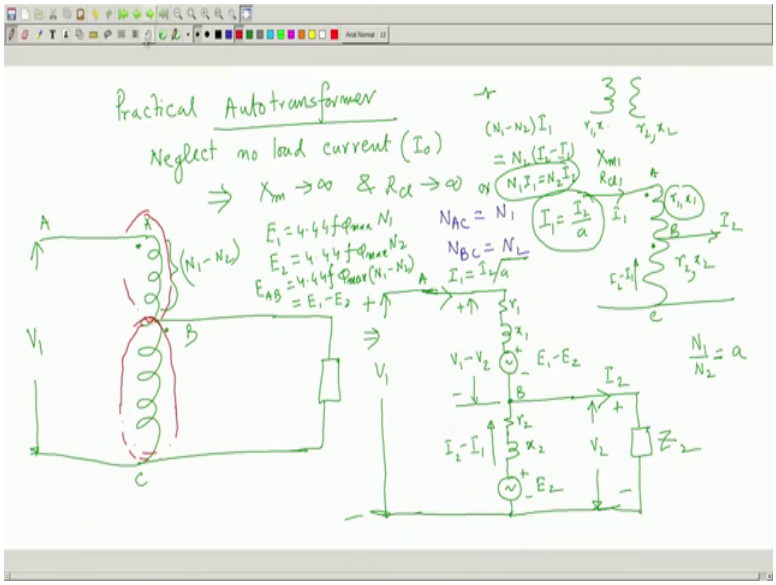

Now, I will discuss what to do if the auto transformer; how to analyze a circuit involving an auto transformer, but which is not ideal, non ideal auto transformer, a practical auto transformer; what should I do? Practical auto transformer not variac; a practical two winding transformer we; you have to take then r 1, x 1; r 2, x 2 and then, magnetizing reactance X m 1; R cl 1 core loss component of resistance; all these things we have to bring here.

So, similarly in the auto transformer since there is a core; there is time varying field therefore, there will be core losses and not only that there will be this is the auto transformer thing where a fixed tapping is taken. So, this portion of the winding will have r 1, x 1; this portion of the winding will have r 2, x 2 and so on. Similarly, the magnetizing branch and no load current; first what will do is this I will assume that windings will have some resistance and leakage reactance because leakage flux will be there and this portion and this portion of the windings have their own electrical identity no mixed up between them.

So, I will say the resistance of this portion of the winding is r 2 and leakage reactance is x 2 and this portion of the winding is r 1 and x 1; I can very well define that ok. So long when there was this things were and magnetizing and no load current first neglect. I will tell you how to take no load current, neglect no load current; that means, I naught which implies that I am telling that X m is tending to infinity and R cl is tending to infinity it means that we shall see [FL]. Now, and I will first draw as usual; this is my transformer and I use this nomenclature A C and this is B C. And I will say that N AC is equal to N 1 and N BC is equal to N 2 and this two are my output where, I will connect load; is not? This is the thing.

Now, I am saying that this portion A B has a resistance r 1 x 1 and this portion BC is having a resistance r 2 and leakage reactance x 2 and here I am applying a voltage V 1. Earlier, when this things were not present B 1 is equal to the induced voltage here; V2 was equal to induced voltage here. Therefore, we can easily see that if I want to show this resistance and leakage reactance I must draw it like this. A point I will draw it slightly higher place. So, I will draw it in this way. A; I start from a point; V 1 is the supply voltage A. Then, there will be just like two winding transformer r 1 x 1; it will only cause extra voltage drop and then, we will come your v 1 and this two were dots, E 1; I am not sure whether it will be E 1. I will write what it will begin.

Now, I reach up to point B. So, it will be; this is the point B and then, I will draw r 2; I will draw I mean j x 2 I am not writing you understand it is j x 2 r 2 x 2 and then, there will be another induced e m f in this portion. This induced emf, I can write it has E 2 no problem why? Because this is the voltage you have applied; flux is same. So, voltage induced N BC is N 2. So, 4.44 a phi max N 2. So, this is the induced voltage correctly I have drawn and voltage per turn is fixed; how much it is? It is approximately B 1 by N 1, total number of turns

Number of turns here is N 1 minus N 2. So, what will be the induced voltage here? It will be E 1 minus E 2. Are you with me? Because induced voltage in N 1 turns; if I call it as E 1 induced voltage in N 1 minus N 2 turns will be N 1 minus N 2. So, I let me write E 1 is equal to 4.44 f phi max into N 1 whatever it is total; between these two terms E 2 is equal to 4.44 f phi max N 2 and if I say what is the induced voltage between A and B; here, what will be the induced voltage? It will be equal to 4.44 f phi max into number of turns between these two points which is nothing, but N 1 minus N 2 and which will give me E 1 minus E 2 got the point.

So, this is the thing and here will be one load. So, immediately we see that there will be; it is not as simple as that of a two winding transformer where, the equivalent circuit was r 1 x 1 and. so on E 1 E 2. Here this, this is what it should look like and there will be a distinction between V 1 and see, if you start from this to this in so for as induced voltage is concerned it is fine; E 2 E 2 will cancel and E 1 induced voltage, but there is a mix up now.

I will tell that this current is I 2 first thing is; first thing first I 2 and suppose, I say that this current is I 1. I do not know what are the relationships that I will find out, but I am sure about one point that is if this is I 2; if this is I 1 no matter whether r 1 x 2 or r 2 x 2 is present; the current here has to be I 2 minus I 1 and this current has to be I 1 it does not debar me or does not confuse me that r 1 x 1 is there; can I write these? Yes; k c l I have simply applied.

But only argument is interesting argument; see, the portion AB and portion BC they are two individual coils as if and these voltage I will call V 2 terminal voltage which is not same as E 2 because r 2 x 2 is there, but r 2 x 2 is not carrying same current as the load it is different. So, this current is I 2 minus I 1; is not? So, therefore, the moment load is

connected some I 2 is flowing it will draw some current I 2 and this time r 1 x 1 r 2 x 2 is present I cannot easily say how much current it will draw by balancing output power and input power because there will be power loss in this element; in this element as well; is not? It is slightly complicated, but one thing is clear, the mmf balance that rule must prevent. If this portion carries winding, this portion cannot remain silent.

Therefore, I will say and this two are dots. So, N 1 minus N 2 into I 1 must be balanced of this current through the dot this current is I 2 minus I 1; it must be equal to N 2 into I 2 minus I 1 that remains there is no doubt about that and odd this means minus N 2 I 1 cancels off from both sides; is not? This is I 2. So, this also means N 1 I 1 is equal to N 2 I 2. See, the point is I should not start from this I must establish it. So, happens that like a two winding transformer I mean N 1 I 1 is equal to N 2 I 2. I have derived that I will define N 1 by N 2 as a I will define that.

Then, I will say that I 1 is equal to I 2 by a; this much I am I can confidently say. If this current you record it so much ampere N 1x total turns N 2 this turn. Then, this current will be I 2 by a. This I am sure off; got the point; this is the thing [FL]. Now, this voltage is V 2 and this voltage is V 1, applied voltage; terminal voltage, induced voltage they are not now same there will be a little drop here, but this tells me that the voltage here across so called across A B portion of the winding, this must be V 1 minus V 2 it has to be this voltage minus this voltage is V 1 minus V 2 with this side plus this side minus.

Now, look at this; today, I will only tell this much look at this portion this coil and this coil. These two coils are separate; is not magnetically coupled? Therefore, I can say that I mean what I am trying to tell in the next page I will draw.

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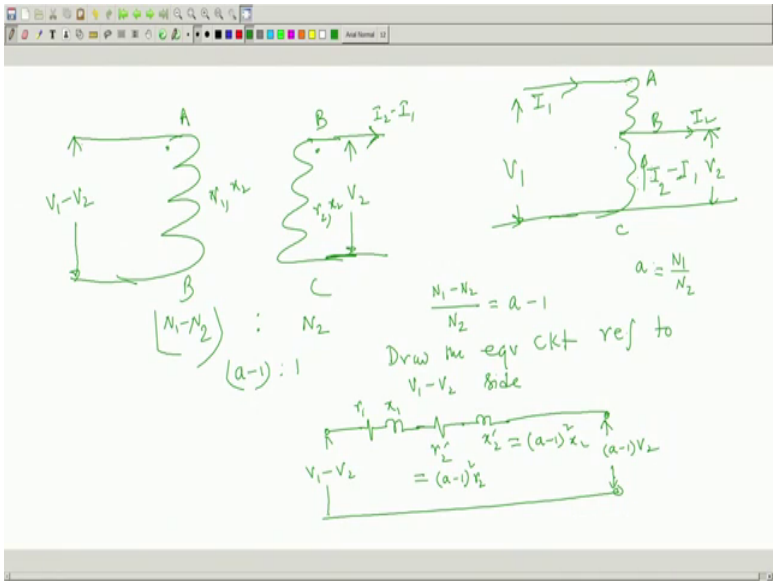

What I am telling is A B is a coil and I will write B C is another coil; this two coils and I find that A B has been supplied with a voltage of V 1 minus V 2 terminal voltage; is not? V 1 minus V 2 and this fellow across V 2 it is V 2 I am not showing the load yet because the problem here is this coil current and load current as different, but can say this much. See, this winding is delivering a current f I 2 minus I 1; this much I am certain.

What things is to be connected to achieve this? Let us not bother right now, but this is what I can think of ok. So, I will draw once again here. So that we can easily refer to A B and C. What I am telling this current is I 2 minus I 1 and this current is I 1 and this voltage is V 1 and this terminal voltage is V 2; these are all fine V 2; this current is I 2 that is there, but if you look at this two separate coils it is telling me as if I can draw this diagram and say that it is a at least these two portions are a two winding transformer across the primary of which I have applied V 1 minus V 2 and secondary is loaded such that it delivers a current of I 2 minus I 1 this much I can say.

And then, I will say; so for as this transformer is concerned what is the number of turns of this A B N 1 minus N 2 is not very interesting, N 1 minus N 2 is the number of turns and what is the number of turns of this N 2? I will say that this is a transformer whose trans ratio is N 1 minus N 2 by N 2.

I will say whose trans ratio is this N 1 minus N 2 by N 2 and this one is equal to then, a minus 1 because I have defined a to be N 1 by N 2. Now, please be with me, what I have

done; this to are separate windings. This fellow is carrying a current I 2 minus I 1; this portion is carrying a current I 1. So, it is just like a two winding transformer having applied voltage to this coil A B V 1 minus V 2 and this as V 2, but delivering a current of I 2 minus I 1; not I 2 then, you will be doing mistake because as I told you this coils are really unaware of the fact that is whether it is connected like an auto transformer or like a two winding transformer.

So, this is the thing and if that be the case then, I will say that this is a transformer of ratio a minus 1 is to 1. Then I will go another step ahead and today, I will stop it here. Then draw the equivalent circuit; equivalent circuit of this thing circuit refer to source; refer to I will not say source to V 1 minus V 2 side because this winding will see it across it has been applied a voltage of V 1 minus V 2 and what will be the equivalent circuit? V 1 minus V 2 is the applied voltage; is not? Then there is r 1; there is x 1 will be there, it is winding; this winding r 1 x 1. This winding B C I have assumed that to x 2; so, this will be r 1 x 1 and this will be your what? R 2 dashed and x 2 dashed.

Now, the big question is what is this r 2 dashed in terms of r 2? Trans ratio is this. So, a; this must be a minus 1 whole square into r 2, not s square into r 2. Similarly, this x 2 dashed should be equal to a minus 1 square into x 2; is not? What voltage should I write? Here, this V 2 a times V 2. So, I must write it here a minus 1 into V 2, actual voltage V 2 a times this. See, what I have drawn; I have this two windings I have drawn separately, they are doing this.

So that I can invoke whatever I have learned from two winding transformer those simple, but important principles I will straightaway apply and say this is the thing. We will continue with this in the next class; it will take some time, but up to this point be absolutely clear ok; try to understand it is very logical and interesting. In autotransformer the equivalent circuit drawing is slightly; I will not say the word tricky, but rather I will say you have to apply your own minds correctly. So that correct equivalent circuit you can draw refer to a particular side.

Thank you.