Electrical Machines - I
Prof. Tapas Kumar Bhattacharya
Department of Electrical Engineering
Indian Institute of Technology, Kharagpur

Lecture - 27
Auto Transformer Versus Two winding Transformer

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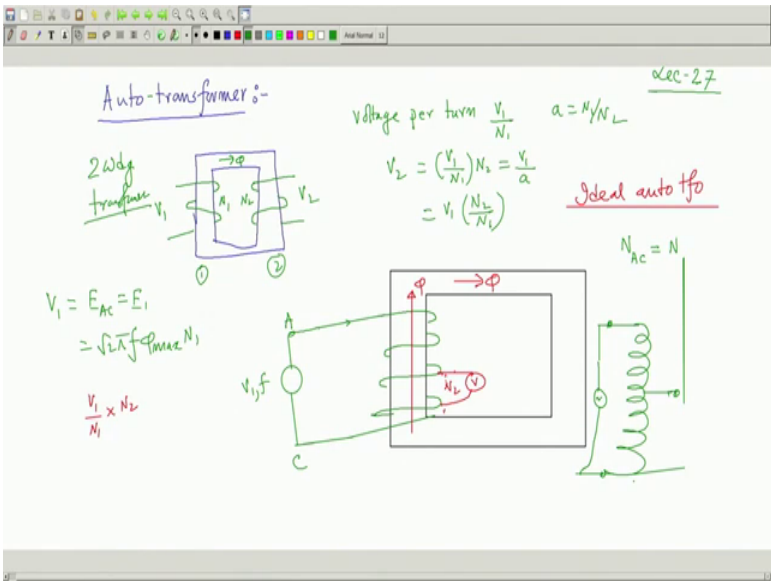

Welcome, to lecture number 27 our earlier classes were very important we derived the expressions for efficiency and regulations. And we then told at the end that our next topic will be Auto Transformer. Now auto transformer also does the same thing, it changes voltage from one level to another keeping the frequency same. So, this was two winding transformer of course, the basic working principle remain same as we will see now.

What is done is in auto transformer instead of using a, instead of using two separate coils a single coil is used the idea is where like this. For example, you say that, your the code is like this; and you use single a number of turns ok. I am showing it to be wound on one limp, but it may be distributed over the whole core length.

So, suppose N number of turns are wound ok, these are the two terminals; A and say C where I will apply first get the idea how it works? I will apply some rated voltage at rated frequency. The moment you apply a known voltage at a known frequency what gets fixed, the flux in the core gets fixed. And first I will tell about ideal auto transformer, ideal auto transformer that is all flux are confined to the core little magnetizing current is required all these things. In another words I will neglect magnetizing current, no load current no eddy current is trace is loss in the core.

Therefore, as the current flows little magnetizing current alternating flux will be produced and it will move like this. And let me say that, number of turns of this N AC is equal to N 1 total number of turns. So, you know the applied voltage and induced voltage it between these two points will be V 1 is equal to E AC induced voltage that is E 1 say. And this is equal to root 2 pi f phi max into N 1 we know this is what happens and that is it.

Now, this flux mind you will link all the all the turns. Suppose I take a voltmeter then, let us resume there is a ohmic contact I can make so I connect a voltmeter here. Now this voltmeter if I connect between these two points will it read yes it will read why not? What will be the magnitude of the voltage here if you applied V 1 here? You will then tell how many turns are there between these two points? If the number of turns are 4, then you will be able to calculate because voltage per turn remain same multiply with N 2.

So, if there are N 2 turns here between these two tappings, the voltage induced will be V 1 by N 1 into N 2; voltage per turn is V 1 by N 1 and that into N 2 will give you the voltage here .

Suppose the number of turns is 100 N 1 and you have taken tappings at 50 percent midpoint tappings then there will be 50 turns there. So, if you have applied 200 volt you will get 100 volt there is not? Step down will take place. And therefore, between this tappings, I will connect the load after changing this available voltage to a voltage level which is required for the load.

So, so I will not use to separate coils single coil and have suitable tappings from the secondary and it looks like I can get then any level of voltage. For example, so this diagram, hence forth I will draw it simply like this; this whole thing core I will not draw I will simply draw a coil, here you have applied voltage and here you have taken tappings suppose these two points. So, these two is your input terminal and these two is your output terminal. And let us draw a nice picture here, so that we know what is happening.

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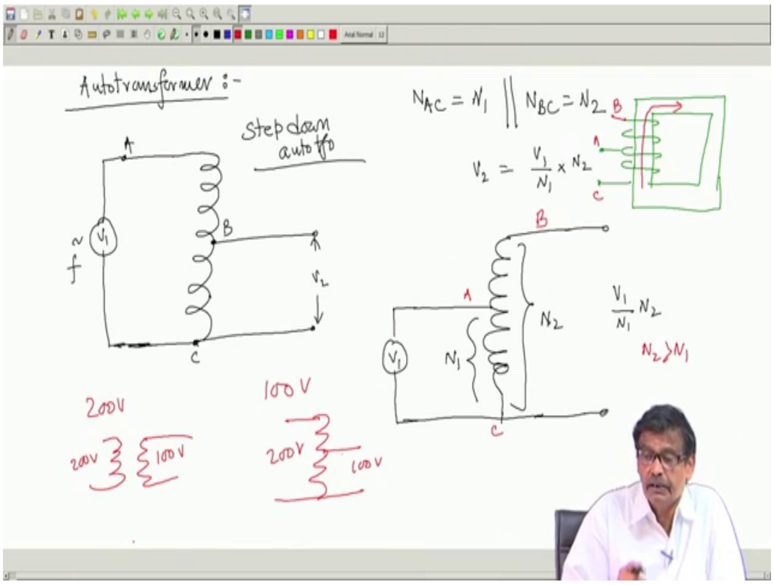

So, autotransformer it is like this, this is the coil I will draw this way. And here is your tappings taken, I will say this terminal as A this terminal is C indicating common between primary and secondary. And I will say that N AC is equal to N 1 and here I will apply voltage of frequency f.

And this point let me call this point to be B and N BC I will say it is N 2. Then, voltage available here I will call it V 2 V 2 will be V 1 by N 1 that is the voltage per turn decided by this V 1 and whole number of turns N 1 into N 2 and that is it. So, so by changing N 2, I will be getting output voltage. So, in this arrangement if B is very low at this point if N 2 is very low you get high voltage to low voltage very low voltage transformation is possible.

So, in a two winding transformer this is precisely we do we want to change the level of voltage can we step down step up the voltage? Here it is step stepping down the voltage yes you can step up the voltage. For example, this is step down autotransformer step up autotransformer will look like this what do? You do you give input voltage here, V 1 this you call your N 1 ok.

And here from you will take the output, voltage per turn will remain same this is N 2 N 2 number of turns. So, available voltage here on the secondary side will be V 1 by N 1 into N 2, but since N 2 is greater than N 1 you will get higher voltage on the secondary side. That is this is the if I draw it here like this, this is suppose the transformer core it is like this. In this case what I do single winding no two separate coils; you give supply voltage to this number of turns, flux will be linking all the turns mind you.

So, this is your A in this case this is your C this is your B and this is your A C and B. So, N BC that is N 2 turns is more than N 1 and you can also step up the voltage. Therefore, it looks like one can use a single coil like this instead of two winding transformer, where you are using two coils therefore, it is natural then that is I now have two option, suppose somebody says me that I have 200 volt supply and my load requires 100 volt.

Then, I will the solution now two options what are the two options? I will use a two winding transformer 200 volt and 100 volt this will be the thing. Or I can also use an auto transformer, where the number of tappings here will be high half of this full number of turns here so a 200 here, 100 there. So, either of them you can then use to supply your volt at 100 voltage when 200 volt supply is there.

That the now the moments two options come in we must examine which one to choose should I choose a two winding transformer or should I choose a an auto transformer? Here realize the question. Same thing can be done apparently by both the options ok. So, we will see examine that thing right now.

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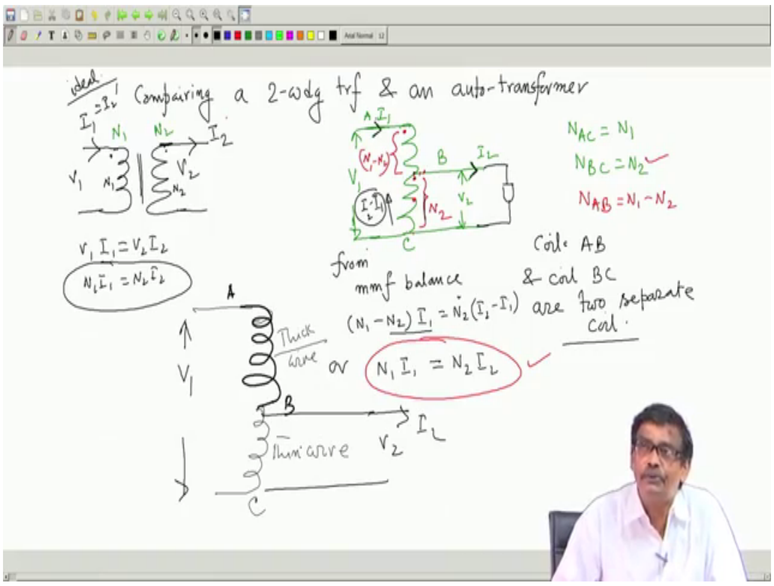

Therefore comparing I will use different color, comparing a 2 winding transformer, and an auto transformer. Now the moment you say I will compare two transformers, their ratings must be same then only you can compare two things at same level.

So, what is the ratings? I demand that your 2 winding transformer should do like this V 1 it must transform it to a voltage V 2. And you will neglect the no load current that is pretty small ideal conditions to understand the what is the implications of this which one to choose. So, I want to transform an available voltage V 1 to a level V 2 and I must see that the current deliver to the load is I 2 that is k VA rating I must also specify of this k VA so the transformer will deliver V 2 I.

So, V 1 I 1 equal to V 2 I 2 that is what I want to do got the point. And this is your 2 winding transformer. Now the same thing I want to do with an auto transformer. So, I will draw the auto transformer like this, suppose it is a step down case. So, V 1 you apply and you take a tapping here and this terminal is A this terminal is C and this terminal is B. So, V 1 I will apply I should get here V 2 and your load should get same current I 2 got the point; flux in the core should be same.

So, how the flux in the core should can be same? If this is N 1 turns this is N 2 turns then I will demand that N AC is equal to N 1 hm. And N BC here is equal to N 2 is it not? This is what I will do. Therefore, when this current is delivered here also the current should be I 1; output volt ampere must match with the input volt ampere that is what is this so this V 1.

Now, the number of turns present here in this portion it is N 1 minus N 2, no number of turns present here is N 2 that is what I have assumed N 2 N BC is N 2. Number of turns present here is N 1 minus N 2 is not? N 1 minus N 2; these the number of turns present here between A and B. So, N AB is equal to N 1 minus N 2 mind you, the dots are here this is dot this is dot.

Now, if you look at this connection very critically you will immediately see that this two coils this coil and this coil that is coil existing between terminals A and B. And coil B C there is no common turns present their separate coils like this. For example, as a whole in this particular configuration, which one to call primary you have applied between A and C A voltage V 1 perhaps this is primary where the whole number of turns is N 1.

Where is secondary, between B and C how many turns are there? N 2, but this N 2 turns also a member of the primary coil number of turns N AC is not this is common to both primary and secondary this causes problem [laugher] I mean initially oh what to do then. So, first thing is I say that coil no coil A, B and coil B C are two separate coils totally separate are two separate coils, this and this portion this must be understood that is very important point to be noted. And they are linking same flux therefore, MMF and voltage ratios will follow the rules of a two winding transformer what else, flux is common same flux is not? Previous diagram is the core flux is common to both the parts. So, same flux and I have identified coil A B and coil B C ok, if you connect some load on the secondary primary you apply voltage this coil is supposed to carry some current coil B C coil AB is also supposed to carry some current.

But I am sure about one thing these two coils will carry current and they have to follow the rule of a two winding transformer what else. In other words what I am telling if this I 1, suppose current is I 1 current delivered to the load here load is connected delivered is I 2 then this is I 1 this is I 2 then apply KCL at this point, this current I will write I 2 minus I 1 is not? I 2 minus I 1 plus I 1 I one will cancel and it will give you I 2 KCL I have applied this is the situation.

In a two winding transformer remember this two are dots here, if current delivered is I 2 and this is having N 2 turns and if your primary is N 1. Then what I told you that if it is an ideal transformer I 1 is nothing, but I 2 dashed I 2 by A MMF must be balance whenever you show current coming out from the dot, then only transformer primary will invite current from the source through the dot terminal such that N 2 I 2 is equal to N 1 I 1.

Ideal transformer no load current you neglect that is only 2 to 5 percent forget about that and this must prevail. In this transformer also the moment you have applied a certain voltage V 1 at certain frequency f across the turns N AC then the flux level gets fixed. In the core KBL is to be satisfied here the same arguments therefore, for any reason if this two parts of the windings carry current their MMFs must cancel out, so that the net MMF remains because of that N 1 into small magnetizing current, which is negligibly small.

Therefore the moment I do this I will say that look here this is I 2 minus I 1 coming out from the dot this is the direction very important. So, I will write that MMF balance from

MMF balance I will write N 1 minus N 2 into I 1 through the dot current coming in. And through the dot this direction current is I 2 minus 1 what is the number of turns? N 2, this must be equal to N 2 into I 2 minus I 1.

This must prevail no way, that is I 1 is the moment you are trying to draw a current I 2 in the load some current I 1 will follow will flow in the primary coil through A and if this is I 2 and this is I 1 this current is I can correctly show as I 2 minus I 1 phases these are from bottom to top. And these two MMFs must cancel them out so that this will remain there.

Now, in this case N 1, I 1 is equal to N 2, I 2 we have seen same ratings. See, I will compare a 2 winding transformer with an auto transformer with same ratings once again what do I mean by same ratings? I will change the voltage level from V 1 to V 2 total number of turns N 1 here secondary turns N 2 here. And I will delivered if current I 2 to the load here also I will deliver a current to the load I 2. But incidentally this current deliver to be load is not the current flowing through this portion of the coil that is different issue. Overall, as a black box I must be able to deliver I 2 current as I am doing it here.

So, N 1 N 2 for both this transformers the number are same because flux level is same and N 1, I 1 equal to N 2. But in the case of an auto transformer I get this relation or I will say that N 1, I 1 minus N 2, I 1 N 2 I 2. So, minus N 2 into I 1 this term and this N minus N 2 I 1 will cancel out once again giving you this relationship same as this fellow. But the reason that this will be true I must get it by balancing the MMFs of the two separate portions of this coil that I have identified as AB and BC. Then only I can invoke all the things I did for 2 winding I can do it here also thinking that these two coils are separate coils common flux induced voltage there induced voltage there and so on.

So, this is the relationship which will hold good ok. What is the k VA? k VA rating is V 2 I 2 or same as V 1, I 1 same k VA we must compare it that is there. Now after getting this, the interesting thing is that if you look at this portion of the winding BC whatever current will flow is not equal to I 2 current secondary current it is not it is in fact, the difference of these two currents. Unlike this thing in the secondary of these two winding transformer whatever is the load current I 2 that flows through the winding all along primary of course, I 1 current.

But here it is not like that current in the load is I 2, but current in the portion BC is the difference of I 2 and I 1. Therefore, it looks like the sectional area of this portion of the coil copper section required will be less compared to the copper sectional area here because more current I 2 mind you I 1 I 2 all will be in phase. Therefore, their difference will be real difference when you take the even the phase are difference because I 2, I 1 will be in phase.

Therefore the difference of current only flows, suppose I 2 is the rated current I 1 will be rated current no doubt this will be high whatever it is. But in this portion magnitude of the current will be quite small. And therefore, the sectional area of copper whatever copper you are using for N 2 number of turns it will be much thinner compared to the sectional area of this portion. That is what I am telling is, if I draw it like this suppose I use a bigger this one.

Suppose this is the copper wire I am using for this portion B I am sorry thicker wire it is like this. And for this portion, that is this is your A and this point is B. Now for this portion BC you use a thinner wire getting thin wire this is crucial to understand, this should we thick unlike a 2 winding transformer I 2 whatever load current you are delivering that we will decide what it is if it is well beside this sectional area will be more that is all there. But here in this portion the sectional area of the upper portion will be same as the sectional area of this 2 winding transformer here.

But for this portion I can make it thinner, so it looks like this point is C thin wire this will be thick wire. Therefore, it looks like I will be transmitting a voltage V 1 to a voltage V 2 and it will deliver a current I 2 no doubt it will deliver same volt ampere it is handling. But it looks like you will be able to save some copper volume I will continue with this in the next lecture.

Thank you.