Electrical Machines-I
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Lecture – 29
Numerical Problems on Ideal Auto Transformer

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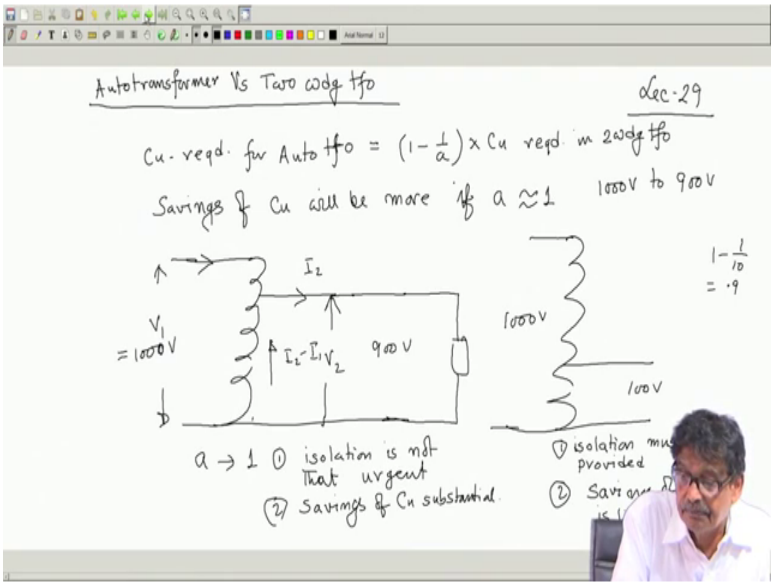

Welcome to lecture number 29 on Electrical Machines I and we have been discussing Auto Transformer. In fact, we have been comparing auto transformer versus two winding transformer, two winding transformer.

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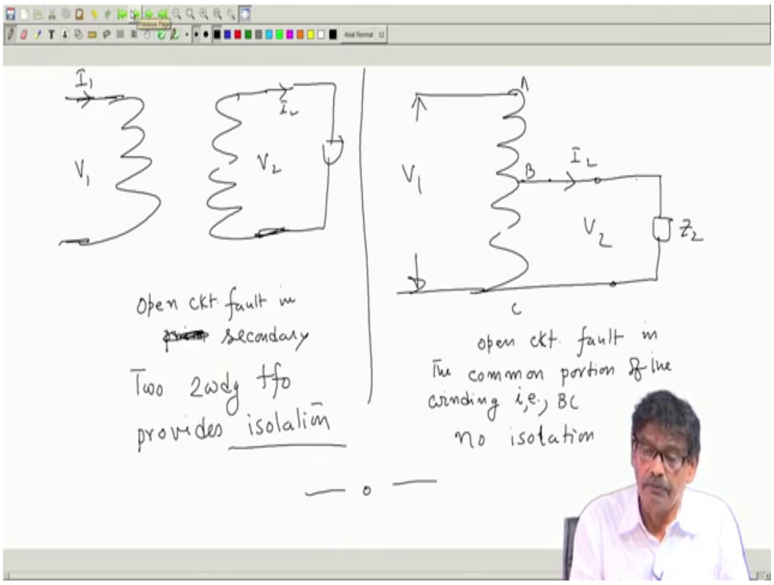

Recall in the last class I told, because if you want to change a transfer a certain amount of kva from primary source site to the load side, you can at a two fixed voltage levels V 1 V 2.

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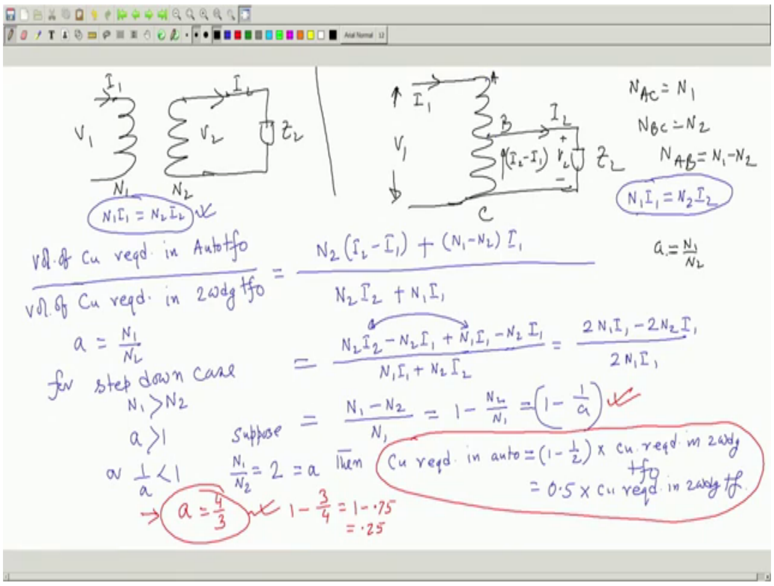

You can do that by using either a two winding transformer or also by an auto transformer. Now therefore, there were now we will find that there are two options I can do the same thing change the level of voltage from V 1 to V 2 and transmit the same kva.

Now, which one to choose? Two options are there it looks like either of them can be done, but I told you that if you use an auto transformer then copper required will be less compared to the copper required in a two winding transformer always less. So, savings of copper will be can be easily found out subtracting these two. But, the point is that this ratio is 1 minus 1 minus a copper required in an auto transformer is 1 minus 1 by a where, a is N 1 by N 2; a is N 1 by N 2. And, we also showed with some numerical examples, that as the turns ratio is close to 1 savings of copper will be more and more, but nonetheless no matter what is this ratio either large or small there will be always savings of copper.

Then we argued that if that be the case then it should be all the autotransformer all along the winding transformer should not be used, what is the fun? Because you will be always saving copper to transmit same kva from this source to the load side at to fix different voltages, same job can be done by an auto transformer. But, there were further issues then I told you that look a two winding transformer is a better option, if you require isolation, some critical load is present, if there is an open circuit on the secondary of the of the two winding transformer ok. No problem at best at most the load will not get any supply there ends the matter, but that is not to be the case if an open circuit fault occurs in the N 2 turns that is common portion of this windings of an auto transformer.

Even if it becomes open primary energized this voltage this high voltage may appear across these of course, these voltage minus whatever is the drop here that will appear across the load. Therefore, on the load side there may be a sudden rise of voltage if such a fault that is open circuit in the secondary that is in the BC part of the winding takes place and auto transformer does not provide isolation. Therefore, where isolation is a must no, two winding transformer should be preferred I mean, autotransformer should not be used the loads may be critical. That is why two winding transformer is also there, because it provides that isolation that is what I told in my last class.

Now, the question is then when to use auto transformer? Auto transformers can be used see the I write this thing copper required for auto transformer the previous result only auto transformer is we found, 1 minus 1 by a into copper required in two winding transformer of same rating otherwise, what is the fun of writing this two winding transformer this we have found. And, we have observed that savings will be more, savings of copper will be more if a is close to 1.

In fact, if a equal to 1 and this mathematical expression gives in you autotransformer does not require any copper, what does that that is a critical point forget about that, but I will use an autotransformer. It simply means, that no transformer is necessary then supply voltage the same voltage in one, but there may be situations when for example, you want to step down the voltage from 1000 volt to say 900 volt, here this ratio is close to 1 is not 1000 to 900.

In this type of transformation we find savings of copper will be more that is what we established here in our last class, Turn's ratio closed 4 by 3 savings of copper required is only 25 percent, Turn's ratio is half then that is 2 1 by 2 and savings of copper is only 50 percent. So, closer you go to a equal to 1 savings of copper will be more and more. If that be the case, then I will say better go for an auto transformer that is when this voltage V 1 and this voltage V 2 their orders are nearly same transformation ratio for example, 1000 volt to 900 volt then savings of copper will be quite large.

Because for this portion you require thinner, where I to minus I 1 and for this you recall this is I 1 this is I 2 and this is I 2 minus I 1 savings of copper will be much more. But, then the problem of isolation still remains, the problem of isolation you cannot avoid that is there. But, look if this is of the order of 1000 volt and your load requires 900 volt and now, an open circuit takes place here in the common fault of the winding then the voltage which will be coming across the load, which will be coming across the load will certainly not be 900 volt; it will shoot up by a this path, supply will come here by a this path. But that voltage rise will be not too high, because it is already these two are of the same order we must understand that.

So, not only the savings of copper will be more, but also isolation is not a big issue in the sense, that when this voltage and this voltage are at comparable level same level then voltage will shoot up from 900 to at best maximum 2000 volt only, what percentage of increase it is 10 percent is it. Therefore, but imagine I am using an autotransformer 1000 volt to say 100 volt, I want to get 100 volt here and I have decided I will use an auto transformer. Now, first of all in this case this ratio being too high savings of copper will be there compared to a two winding transformer, but savings of copper compared to this configuration will be much less.

Because, a is here 10 so, 1 minus 1 by 10 so, it will be 0.9 only. So, copper required in auto transformer will be 90 percent of what? Of the copper required for making it two winding transformer, but nonetheless is having little saving is there. But, here the issue is if there is a open circuit here then you see the load side gets connected to this high voltage side. It will not shoot up to 1000 volt, but it may shoot up to 600, 700 volt. Why not 1000 volt? That will be a drop here in this case.

But nonetheless this the so, far as the load on this side is concerned it will fill that rising voltage or the personnel whoever is working here on this side they might get shock, if there is a open circuit takes place here and no isolation is provided by auto transformer. I think you have understood this point therefore, for the safety of the personnel who expects always here 100 volt he will suddenly see it has gone up to 800 volt, this is dangerous and also it may be dangerous to the load, load may not cannot accept that large voltage.

But in this case 900 volt, load working whoever is working here, 900 volt it will go up to he must have taken enough precaution to work at this voltage length, but voltage you will only shoot up a little maybe by 10 percent, 5 percent like that if there is a open circuit occurs. So, isolation problem when a tends to 1 isolation is not that urgent; is not that urgent this is one and second thing is savings of copper is substantial; savings of copper substantial. Whereas, in this case in this ratio I will say isolation is urgent, isolation must be provided, under what condition? Open circuit in the common and secondly, savings of copper is also not very high.

Savings of copper is little, savings of copper with respect to whom? With respect to it winding transformer therefore, for such a large transformation ratio of voltages you better go for a two winding transformer, where isolation will be there I think you have understood this point ok. So, this is the thing. Now, before I proceed further that is see to understand what is going on in an auto transformer. So, far I have taken an ideal case that is transformers are having no leakage impedance this that and so on [FL] ok.

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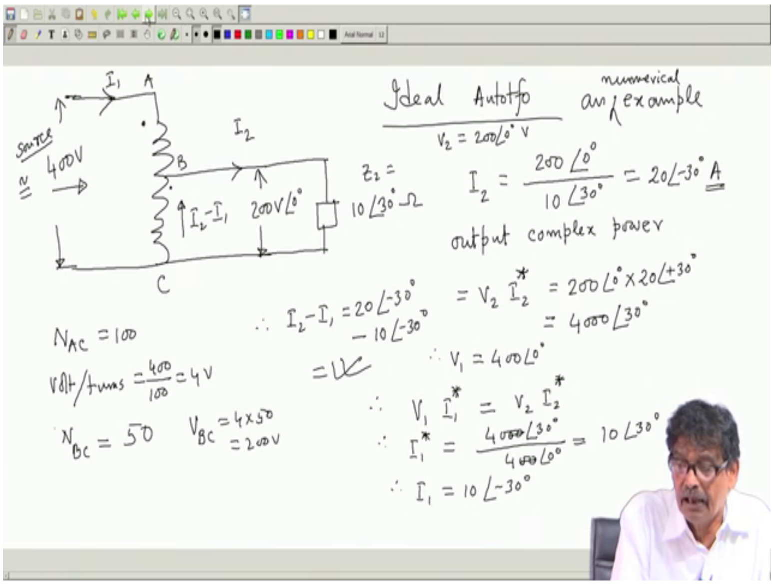

I will just point out, one thing that that suppose yeah in the form of a problem so, that you understand what I am trying to tell. Suppose you have an auto transformer ok, here is and it is stepping down, it could also step out. See I have done all the derivation assuming it to be stepping down the voltages. Now, the same sort of equation I can write and come to the same conclusion even if it is step up, when the ratio will be I better do not do it things like that ok, that I leave it as an exercise.

Suppose, I say that derive whatever things I have done if I apply a voltage here and secondary voltage is V 2 whether steel copper savings; why not copper savings will be there anyway primary and secondary can be interchanged that way you can always anyway that is the thing ok. So, you know it is there. So, this is the thing now suppose, let me solve one problem ideal autotransformer, how you should be handling this problem ideal auto transformer.

An example, numerical problems; so, winding impedances are neglected cold losses are not there, we will discuss this little later. Suppose I say it is 400 volt I will apply here, a problem is given it is 400 volt and suppose it is 200 volt I say. I tell that the transformation ratio is such that 400 to 200 volt and I say that you have connected an impedance here of value say 10, 30 degree inductive impedance, I have connected z 2. I ask you to find out calculate currents in all the branches of the circuit, a very straight forward problem but, you should do it like this.

One way of doing this because this is 200, this is 400 given otherwise number of turns could have been given suppose, I say that this is a this is C N AC suppose I say it is 100. Then immediately I will calculate volt per turn, volt per turn which will be equal to 400 by 100, 4 volt per turn. And, suppose I say that N BC is equal to say 50 turns, then I will say this voltage V BC must be equal to 4 into 50 that is 200 volt is not, that is how I got the voltages.

Now, I have been asked to calculate currents in all the parts of the auto transformer and mind you this is dot, this is dot here. First thing what I can see, that I can calculate this current I 2. So, I 2 will be 200 all voltages will be in phase, because same flux links all the voltages and there is no distinction between V 2 and e 2, no distinction between V 1 and e 1 they are 1 and the same and all the voltages are in time phase. Why? Because common flux all these part of these coils same flux is crossing, only thing number of turns are different. Therefore, I 2 will be taking this voltage in reference I 2 I will calculate simply like this.

And which will be equal to 20 minus 30 degree ampere, I will get I 2; now I will argue you as I did in case of a two winding ideal transformer that the this is I 2 and this is so, V 2 first I write V 2 is equal to 200 0 degree volt I 2 is this. Then output power output complex power is equal to V 2 I 2 star that is what we will be doing. So, this will be 200 0 degree into I 2 star is 20 plus 30 degree is not. So, this will be 4000 Watt plus 30 degree that is the output complex power. And this must come in from this input, because there is only one source of power where I am feeding supply 400 volt AC rms value is 400 volt.

Therefore, if I assume this current to be I 1 which is still now unknown I will say and mind you V 2 is this therefore, V 1 is also known 400 0 degree, but I do not know I 1. So, what I will do is I will say that V 1 I 1 star must be equal to V 2 I 2 star, whatever you dump on the load must be drawn in from this source side this is source, it must be like that. Therefore, I 1 star will be equal to V 2 I 2 star V 2 I 2 star is this. So, I put those 4000 30 degree divided by V 1 which is 400 0 degree and this becomes how much? 10 ampere 10, 30 degree.

But mind you this is I 1 star therefore, I 1 will be 10 minus 30 degree. Therefore, balancing the power on the load side and that is the power drawn from the source, you can avoid several physical things what is going on that is I know I 1 now. The moment I know I 1 then I can calculate this current, this current better show in this way, this current then will be I 2 minus I 1 that is how we are specifying I 2 is known I 1 is known. Therefore, current in this portion in this direction it must can be calculated.

So, I 2 was here there is no star so, 20 minus 30 degree minus I 1 which is 10 minus 30 degree, whatever it comes. So, the current distribution of various parts of this circuit can be easily calculated, provided of course, the transformer is ideal, winding resistances not there, leakage reactants are not there, such that V 1 becomes e 1 V 2 becomes e 2 and so, on. Another example I will ask you to do is this one.

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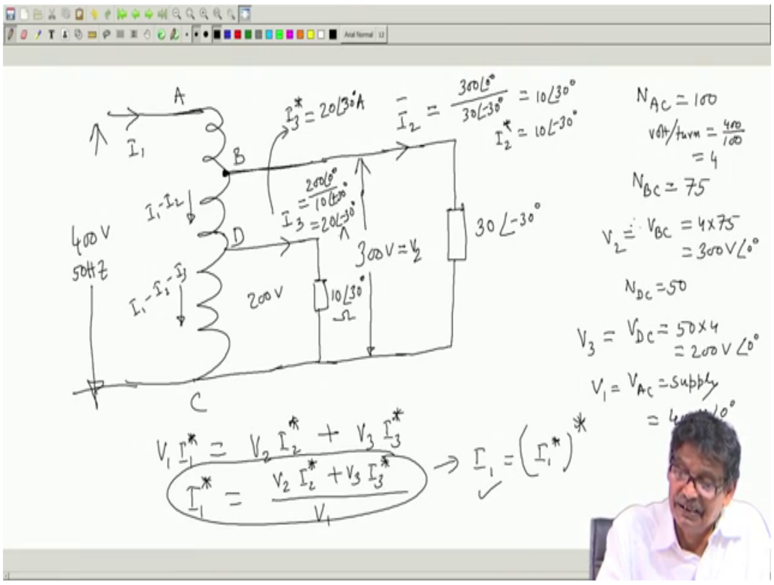

Suppose you have same problem sort of thing, suppose here I have applied 400 volt 50 Hertz and once again, I say that N AC is equal to 100 N AC, then immediately I will calculate volt per turn is 400 by 100 is equal to 4. Now, what I am doing is I am taking a tapping from point B, such that N BC is equal to suppose 75. Therefore, I will immediately calculate V BC voltage available between these two is this was 4. So, 4 into 75 that is 300 volt, I will be getting and suppose I have two loads. So, one requires 300 volt supply another requires 200 volt supply.

So, from the same sort of auto transformer suppose, you have another tapping say at point D such that N DC I say it is 50. Then therefore, V DC will be equal to 50 into 4 is equal to 200 volt. And, mind you all these voltages are in phase this is 0 degree, this is 0 degree and your supply voltage V AC is the supply, that is also 400 volt 0 degree you know that is the thing. Now, I say that I will connect here load. So, here you will get 200 volt and here you will get 300 volt. And suppose, 200 volt I terminate it on a load whose impedance is say 10 30degree ohm like the previous one.

And between these two points I supply another load where you are getting this and suppose, I connect here an impedance of 30 minus 30 degree like this that is from the same auto transformer by two tappings at B and D C, being the common terminals I will supply two loads which requires two different voltage levels. Then the question is this show the current distribution in various parts of the coils and this way. One way of doing this is going by physical argument trying to balance the MMF, but there is a shortcut method, what is that? This is the only source of input power and power are consumed only here and there transformer being ideal so, these two must match. So, this is your V 1 supply voltage.

Therefore I will first say that let this be I 2, let this be I 3 and let this be I 1. So, I will say that V 1 I 1 star total complex power absorbed by through the terminal say C is V 1 I 1 star must be equal to suppose, this I say as V 2 must be equal to V 2 I 2 star plus V DC; suppose, I call it as V 3 V 3 I 3 star this is the thing. And, I 2 and I 3 are known. What will be I 2? I 2 will be V 2 that is 300 0 degree divided by 30 minus 30, it is capacitive loading and this will come out to be 10 plus 30 degree and I 3 will become 200 0 degree divided by 10 minus 30, 10 plus 30; if you do it will become 20 minus 30 V 2 V 3.

Of course, if this is I 2 then do not forget to calculate I 2 star that is 10 minus 30 degree. If this is I 3 calculate I 3 star which will be equal to 20 plus 30 degree ampere put it here, everything is known including V 1. Then you calculate I 1 star which I am not going to calculate put the values, all are phasors plus V 3 I 3 star divided by V 1. Of course, after getting this I 1 will be equal to I 1 star star another complex, do not forget to take this complex along with it.

Anyway this is how no matter how many tappings you have taken, what different kinds of load you have connected very easily it can be done. And, after I get this I 1 I 2 after I get I 1 I 2 all the things, what I will do? I will go on applying this KCL here at B and also do not forget about these this way or that way it does not matter. So, far you are correctly writing the KCL, you can show this current to be I 1 minus I 2 I 1 coming I 2 going I 1 minus I 2; here, I 1 minus I 2 coming then another I 3 is going I 1 minus I 2 minus I 3.

Interesting thing you will observe the MMF of this portion, whatever turns A B E MMF these are the isolated coils, this portion, this portion, this portion. So, some of this MMF will vanish to 0, it will be automatically taken care of. Anyway, we will continue with this next class.

Thank you.