Electrical Machines – I
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Lecture – 34
3 Phase Transformer Using 3 Single Phase Transformers

Welcome to lecture 34 on Electrical Machines I and we will start today 3 Phase Transformers.

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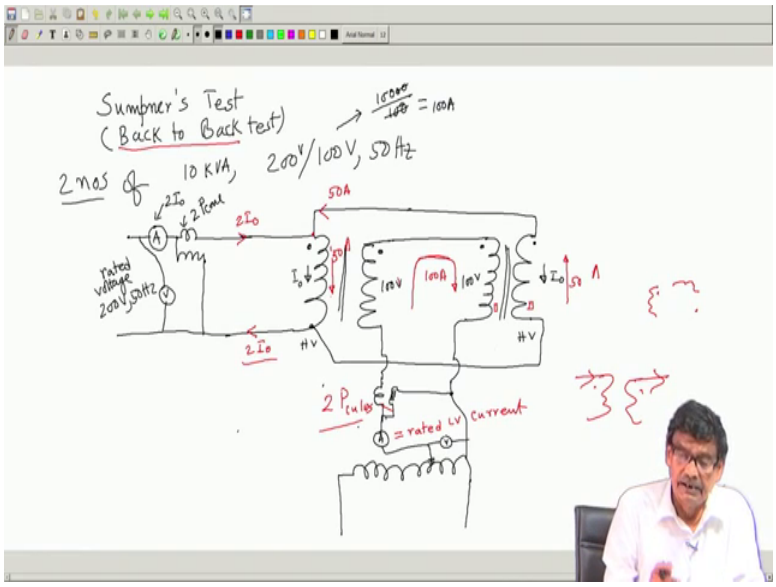

And just in my last lecture I told you about one very important test called Sumpner test or back to back test and this was the picture. So, here the beauty is the transformer under the condition of the test will have rated flux as well as rated current. And if you wish you can find out the equivalent circuit parameters as well, because you know the no load current of each transformers you know the watt meter reading or core loss of each transformer from which the parallel branch RCL and XM can be calculated. And from this side also you know what is the voltage needed to supply the rated current, half of that will be actually appearing if you measure the voltage here if you connect also a voltmeter.

I mean suppose you connect also a voltmeter. This is the rated voltage similarly here you connect a load and voltmeter. So, once again you have generated the short circuit test data 1, test as we carried out from the HV side in this particular example another from

the LV side and equivalent circuit parameters once again can be estimated. And these parameters values will be corresponding to at rated temperature for example, while carrying out the test you energize the transformer for a long time maybe hours, so that the steady state temperature is reached, but it is an interesting test.

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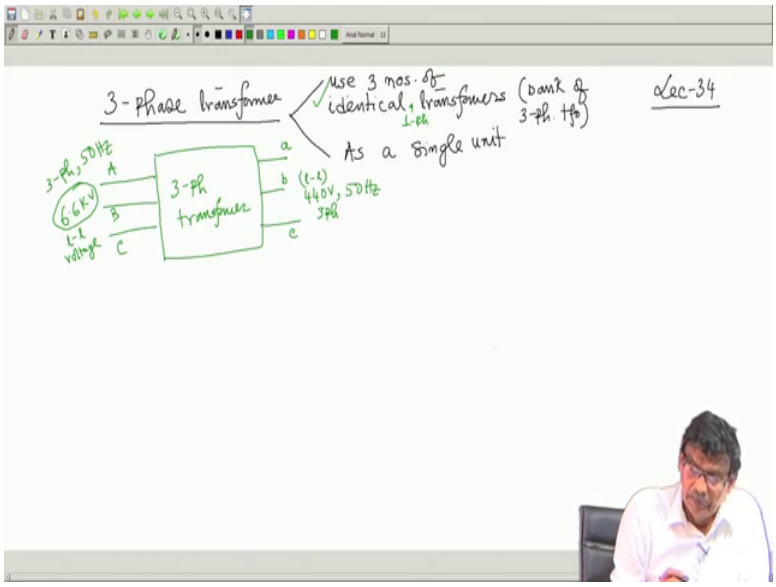

Now, today we will start 3 phase transformers ok; 3 phase transformers. They 3 phase transformers can be up to type so, one not two types one is use 3 numbers of; 3 numbers of identical transformers. And in this case when you use 3 numbers of identical transformers to be used in a 3 phase voltage transformation, it is called a bank of 3 phase transformers a bank of 3 phase transformer. Or a 3 phase transformer can be manufactured as a single unit ok, 3 phase transformer as a single unit ok.

So, we will actually first examine this one that is 3 numbers of identical transformers I will take. And the problem is to because of our system power system is of 3 phase and in 3 phase I have 3 phase voltages and those voltages will be assumed to be balanced. And if you require to change that voltage to some high or low 3 phase voltage, then we will be using 3 phase transformers that is the idea, that is suppose you have 3 phase system like this which is suppose 6.6 K V on one side.

Then connect a 3 phase transformer and at the output you will get suppose 440 volt 3 phase this is 3 phase 6.6 K V this is 440 volt 3 phase of course, 3 phase 50 Hertz in our

country and this will be also 50 Hertz because frequency remains same. And all these voltages here whatever I have written is line to line voltage.

A typical distribution transformer will have and of course, it will have a KVA rating associated with it. So, 440 volt 50 Hertz 3 phase and this 440 volt once again is line to line voltage. So, the supply here is A B C and here this apply I may call on the secondary side A B C. So, this box will contain a 3 phase transformer, which may use 3 number of identical 3 numbers of identical single phase transformer I must write it like this single phase 3 numbers of single phase transformer. Or a 3 phase transformer as a single unit when it 3 single phase transformers you use it is called the bank of 3 phase transformers.

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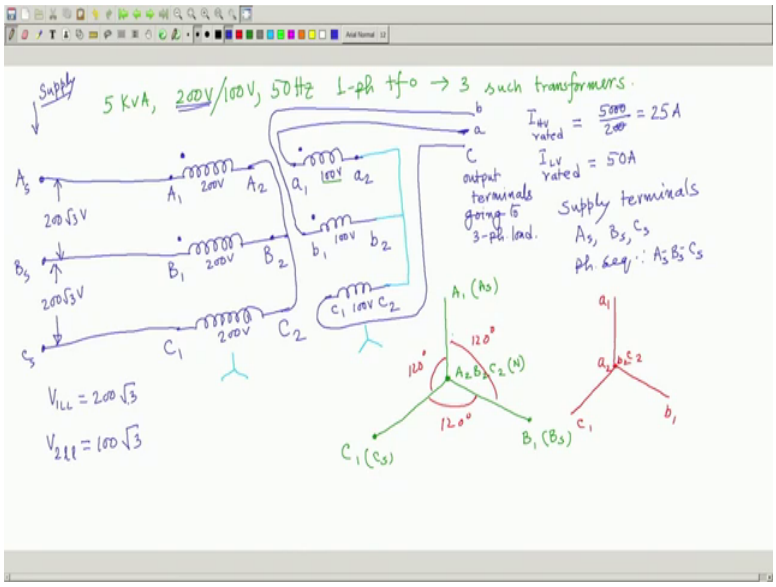

So, let us start with this. Now suppose let us assume that, I have 3 numbers of single phase transformer each of rating say 5 KVA 200 volt, stroke 100 volt 50 Hertz single phase transformer; this is the rating of each of the 3 transformers I have used ok.

Therefore, each transformer will have its primary and corresponding secondary. For example, so there are 3 three such transformers you take 3 numbers, 3 such transformers; 3 such transformers. Now the moment there are 3 transformers for identifying the primary and secondary coils so far in single phase there was one primary one secondary.

So, terminal markings was not that important although I could do it is only HV side LV side that is all, but in case of 3 transformers there will be 6 number of coils, each

transformer will have two coils one primary one secondary, one high voltage one low voltage. Therefore, it is essential to mark the terminals of the transformer appropriately. So, what I will do is this suppose this is the transformer one, its primary and this time for convenience I am sketching the secondary of one transformers like this.

And I will mark the terminals as A 1 and A 2 generally capital letters are used for the high voltage side and small letters I will tell it is a 1 small a 2 lowercase letter and this is capital letters so this is one transformer. And also I will assume that this terminal capital A 1 and small a 1 are dot and that I know how to ascertain by doing some test.

So, polarity test I will do put the markings so this is one transformer and this transformer I will call transformer a. In the same way I will have the second transformer which I am drawing below, B 1 and B 2 you understand now and its secondary small b 1 and small b 2.

And similarly these two fellows are dots, so 1 1 are dots and the third transformer in the same way it will be C 1 capital C 1 capital C 2 and small c 1 small c 2. Therefore, I have very clearly identified the terminals it looks like I named the transformers in A B C and I will assume it will be supplied from supply A B C that is why a phase b phase c phase like that [FL] this polarity marking is essential I am telling you.

Now suppose what I will be doing, so the rating of this winding is 200 volt, this winding also 200 volt rated voltage. And similarly rated voltage of this secondary coils are also 100 volt, these I know and also I know the rated current of this side as you know 5000 by 200 I write it here I HV rated is equal to 5000 by 200 25 ampere.

Similarly, ILV rated will be is equal to 50 ampere we can calculate. So, rated current of these transformers are also known rated voltages are known and I have the mark the terminals. Now what I will do is this suppose I want to connect the primary coils in star ok, individually I know there each one these; these; these are individual transformers. But as I told you my supply is A B and C A s, B s, C s and I will assume the supply phase sequence to be supply terminals, which is a 3 phase system I will marked as A s, B s, C s and phase sequence is phase sequence is A B C you understand this.

So, this is about the supply so this is supply. Now these 3 terminals A 2 B 2 C 2 suppose I short them, then it becomes a star connected primary star connection means 3 coils are

there 3 terminals of each of them you short ok, so this is how you shot it. And I will give supply like this AS I will connect to A 1, BS I will connect to B 1 and CS I will connect to C 1.

Now, since it is star connected, the supply voltage whatever it is line to line that divided by root 3 will appear here ok; since the rated voltage of the transformer is 200 volt therefore, I can apply a line to line voltage of 200 and root 3 safely is not line to line voltage 200 root 3 volt.

Because after all these transformers are identical transformers they will have equal parameters, so root 3 times less voltage we will come across the primary windings of each of these 3 transformers. If it is two because transformer rating was 200, 100 volt 200, 100 therefore, I can apply a voltage of 200 into root 3.

So, that rated voltage will then be applied across the these coils primary, secondary coil I have not done anything they are separate now nothing has been done. Therefore, this is the thing now let us see what is the phasor diagram of this applied voltage and let us assume this is the thing now let us see. Suppose the phasor diagram of this side is mind you I have shorted A 2 B 2 C 2.

So, this is the point A 2 B 2 and C 2 they are shorted they will be at same potential let this be called A 1, which has been connected to A s this is same as A s supply A s; this point is B 1 which is connected to supply B s and this point is C 1 which is connected to supply C s s stands for supply therefore, this point is the neutral point I can say.

So, A 1 A 2 is the voltage phasor here, the moment and each length here it is 200 volt that is why this length is 200 root 3 line to line. Now the moment you apply like that this transformer see the rules of the single phase transformers only we will be using to understand what is going to happen if you connect in a either star or delta we will see those things.

But I am sure about one thing, that the voltage phasor if it is 200 here it must be 100 volt and induced voltages are in phase. Therefore, the secondary voltages if I draw with a different color it will be half of this length although I am just drawing a 1, a 2 and it will be parallel to capital A 1, A 2 because induced voltages or applied voltages are all in phase.

So, for this single phase transformer, this is what is going to happen you will get a voltage like this. Similarly for the second transformer and mind you a 3 phase balance system means they are 120 degree apart is not it lengths are same supply voltages these are 120 degree apart. Therefore, B 1 B 2 the second transformer what is the applied voltage which phasor is the applied voltage B 1 B 2 what will be the induced voltage in small b 1 b 2 a line parallel to this and since b 1 is dot so it will be just parallel to this like this.

Although since I have not connected any of this they are allowed to leave alone therefore, they there will be a voltage parallel to b 1 b 2. Similarly there will be another voltage available parallel to this c phase voltage which will be c 1, c 2 then this will be the same secondary coils I have not collected if you connect volt meters or c in the oscilloscope you will find 3 voltages existing across the secondary terminals which 120 degree apart.

Because b 1, b 2 is parallel to this and c 1 c 2 parallel to this angle between these two is 120 degree here also the angle between these two is 120 degree and so on [FL]. Now what I will be doing is these three terminals, I will short you imagine this three are shorted the moment you short this 3 secondary also gets connected in star.

So, this is star connection and then the secondary also becomes star connected and the moment A 2, B 2, C 2 are shorted this 3 phasor cannot live in isolation because A 2, B 2, C 2 I have forced to these three terminals to be at equal potential their potentials cannot be different if it is connected by a piece of wire like this therefore, these 3 phasors this and this cannot now remain in isolation, but what will happen is, it will be like this that b 1, a 2 is connected to b 2 and c 1, c 2 are you getting a 2, b 2, c 2 I have forced them to be at equipotential these 3 phasors where in isolation they cannot be. So, it will be like this.

So, what I have done I have applied 200 root 3 line to line voltage here, which will ensure that across each of the primaries of these three individual transformers 200 volt appear of course, these 200 volt, 200 volt, 200 volt are fine, but they will be displaced by time because of the supply is balanced. And but I know if this is 200 it cannot be it must be 100 because of the rating of individual transformer being known 100 is known.

And then I draw the primary phasor diagram, then I have told you a 2, b 2, c 2 a shorted so do not leave this 3 phasors in isolation as for your connection you put them in. But one thing is clear a 1, a 2 will be parallel to small a 1 a 2 b 1, b 2 parallel to this one and this length is 200 this is 100 and so on that will be maintained single phase only. See, although we have connected it in a particular fashion rules of single phase transformers will only I will apply to carry on further.

So, this will be the phasor diagram and then I will say this is a 3 phase transformer which is connected in star; star that I will write like this. And where are the output terminals output terminals are here, if you bring it in this way these will be the output terminals and I will write here perhaps small a output 3 phase terminal a this one is b and this was in to c this is output terminals going to load going to 3 phase loads.

So, it will be like this therefore, I have applied 200 root 3 line to line voltage here what will be line to line voltage across a 1 b 1? It is this length line to line voltage once again will be balanced 3 phase. And the line to line voltage on the secondary side so if I write it like this V 1 line to line if it is 200 root 3 I will say V 2 line to line small letters for the low voltage side this will be equal to each one is 100, 100 into root 3.

So, I have been able to change the level of a balanced 3 phase voltage, which is 200 root 3 volt to a level 100 root 3 volts that is how I have been able to make is that clear. [FL] Now the second thing is we will discuss I mean I will be going a bit slowly do not worry about that. So, this is the thing so there I will now draw a bit faster to say about loading of this transformer.

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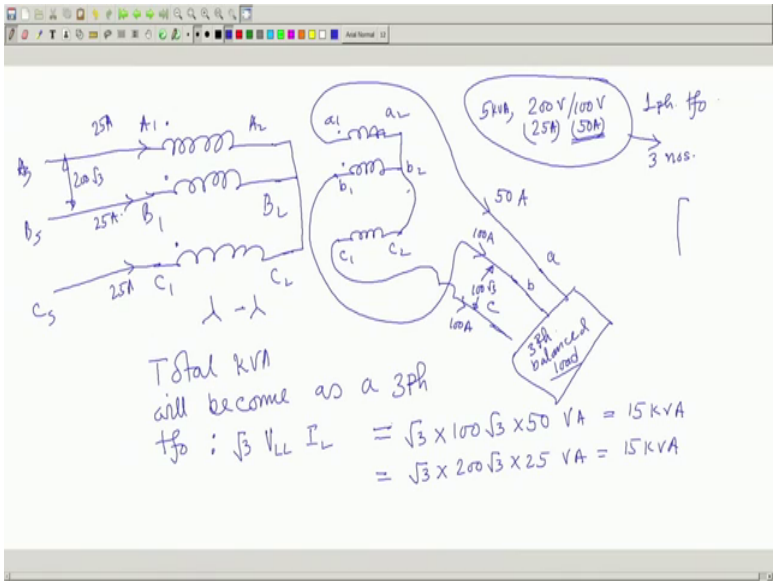

For example what I have done this is A 1 A 2 this is corresponding small a 1, a 2 these are dots similarly, this is B 1, B 2 the previous diagram only I am drawing c 1, c 2 these are dots and this is the third phase C 1, C 2 and this is small c 1, c 2 is it not. And what connection I have made? I have made this a star connection and here I have connected 200 root 3 volt three-phase supply A s, B s, C s and here the line to line voltage applied is 200 root 3 y 200 root 3 because rating of each of the transformer was 200 volt each one is single phase 200 volt 100 volt 5 KVA single phase transformer.

And rated current of the HV side was 25 ampere this was 25 ampere rated current and this rated dell V side will be higher 50 ampere two times and what I have done is I have shorted this and I have taken output here a I am so sorry, here I made a mistake, this is b so a, b and c these are my output terminal a, b, c who had 100 into root 3 you will get line to line that is what I have told I am just repeating this repeating this pins.

Now, the question is this supply I will connect a balanced 3 phase load ok, here I will connect a 3 phase balanced load if you connect a balanced 3 phase load which may be start or delta connected I do not mind. But the only restriction I will put what is the maximum current I can what is the maximum line current on the secondary side will be the LV side rated current is 50 ampere and it so happens that this current the line current because it is star connected happens to be same as the winding current LV side winding current.

Therefore maximum current I will allow to flow here is 100 ampere here also 100 ampere here also 100 ampere ok. And b raised assume the moment through the dot 100 ampere goes in for this transformer, this fellow will draw 50 ampere. Similarly this fellow will also drop 50 ampere this is also 50 ampere will these currents be in phase no not at all they will be in time phase difference depending upon the power factor of the load etcetera, but magnitude of the currents will be same. Each one will start drawing.

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Sorry this one is LV side I will allow 50 amperes thank you. So, this is 50 amperes is not rated current is 50 LV side LV side is this so 50 and if it is 50 it will be 25 thank you for pointing out this. So, this is 25 please correct that. So, this is how it will be 25 this is also 25 this is also 25 ampere.

So, I have taken 3 numbers of single phase transformer whose rating is this. Now what is the total k VA total k VA will become then will become as a 3 phase transformer; as a 3 phase transformer is any side you can calculate for example, if you calculate from this side you must be knowing that in a 3 phase system if the line to line voltage is VLL.

If the line current is IL for balanced thing the total k VA is root 3 VLL, IL irrespective it takes care of both star and delta that is why people love to use this formula so often, forget about start delta tell me what is the line to line voltage? only thing load is balanced so that is a condition line to line voltage is VLL line current is IL total k VA will be root 3 VLL IL.

So, if you calculate from the secondary side the total k VA then will become root 3, VLL is how much? 100 into root 3 and IL is 50 is not so much volt ampere which becomes 15 k VA, which of course, will be same if you calculate from this side which tells you root 3 line to line voltage is 200 root 3 line current is 25 so much volt ampere which will also become equal to 15 k VA, nothing surprising each transformer was rated at 5 k VA.

So, you have connected it as a 3 phase transformer with star; star connection, then total k VA will become 15 k VA anyway we will continue with this in the next class.

Thank you.