**Electrical Machines - I**
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**Lecture - 47**
**3 Phase to 6 phase Conversion**
**O.C/S.T Test on 3 Phase Transformer**

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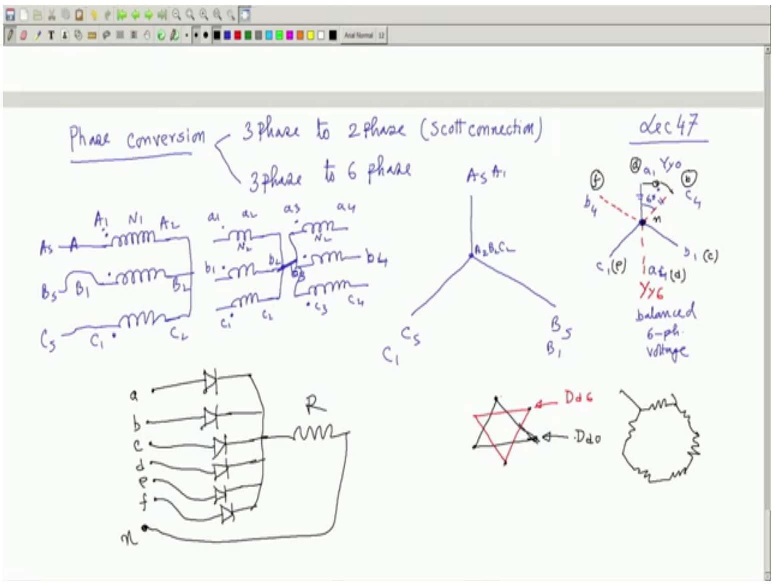


Welcome to 47th lecture. We have been discussing in general actually it should come under the topic phase conversion. And we have studied 3 phase to 2 phase, and we have completed this and this is called Scott Connection, got the point. Similarly, these connections another connection is there 3 phase to say 6 phase conversion. 3 phase supply is there you require a 6 phase supply.

Anyway, there are as such you know motors which are 6 phases, 6 phase balanced 3 phase balance to 6 phase balance system. 6 phase balance system will be what? There will be 6 voltage phasors which will be 60 degree apart. 3 phase system 3 voltage phasors of equal magnitude 120 degree apart. Now, 3 plus to 6 phase conversion were used very much at certain point of time. For example, we have a 3 phase to DC conversion by using a diode bridge. 3 phase supply you give you will get a DC supply.

But if you increase the number of phases of that AC to DC conversion using diodes 6 phase will be always better, you will get better DC there, is not. The ripples available is not 120 degree apart, every 60 degree something you will get. Anyway, I will just tell you how to suppose 3 phase to 6 phase I want to do. What I will do? I will take two 3 phase transformer, not two 3 phase transformer, one 3 phase transformer with two secondary coils, ok, identical secondary coils. For example, these are the primaries we now know, so, I will draw.

This is quite simple, I mean to understand. This is suppose dot dot etcetera. So, every time I am drawing dot, so that you also see it is importance, it is necessary to put the dots A 1, A 2 and then this a 1, a 2, a 3, a 4,. But and these two coils are identical, ok. These are all N 1 turns, these are N 2, N 2 turns B 1, B 2, C 1, C 2. Then this is b 1, b 2, c 1, c 2 and no b 3, b 4 and this c 1, c 2, c 3, c 4 here. And what you do is this you connect this in star. So, I know the phasor diagram. So, phasor diagram will be primary side it will be supply is A S, B S, C S. So, A S here supply, B S, A S.

And A S is nothing but A 1, B 1, C 1 and this is A 2, B 2, C 2. Now, what you do is this you connect these secondaries, these two groups in stars, but one connection you make Y y 0 and the other as Y y 6 and you are done. Why? Because if you join these 3 then you get Y y 0, is not and your this voltage will be this say a 1, b 1 and c 1. And the other group what you do? That also you connect in star, but this time join this dot terminals a 3, b 3, c 3 then its phasor diagram will come out to be this one Y y 6. So, this is primary was Y y 6 this primary is y blue I will write this is Y y 0.

Then what? The naming of the terminals will be this is a 2, is not, this is b 2, not a 2, a 4, b 4, c 4. And then you join these two neutrals these two you short. Then this point becomes a global neutral on the secondary side where a 3, b 3, c 3 and a 2, b 2, c 2 are shorted. So, if you see this voltage waveform of this terminal this terminal they will be 60 degree apart of same magnitude. So, you have been able to generate 6 voltages on the secondary side which are of equal magnitude and 60 degree phase difference. So, balance 6 phase voltage, 6 phase voltage.

We will not discuss much more, but what I am telling is what happens is this in the see diode bridge and this may be the names of this may be changed the bit. So, that what I will tell; what I am telling is you name this output terminals a 1 to be a suppose, ok, this c 4 you say b b phase of the secondary side, this is c phase, this is d phase, this is a b c d e and this is f phase. I could rename them then I have got these 6 voltages a, b, c, d, e, f whose magnitudes are same and so on. So, what I will do is this I will connect it and it has also got a neutral.

So, I have a supply system now whose terminals are a, b, c, d, e, f and also neutral, got the point. What you do now? You connects diodes one of the applications I am telling you connect diodes and then connect the resistance, load, where you want to get the c and this point connect it to neutral things will work, ok. So, anyway, so phase conversion 3 phase to 6 phase can be done this way. Another way you can do, I hope you have now got the idea. Can I do it by using some delta connection?

Yes, connect one group as Dd 0 another as Dd 6. I will not do that, but I will tell you the end results. One group this you connect in delta Dd 0 and Dd 6 this group. So, the output phasors will be like this then. Suppose, this is Dd 6, you work out that on your own and this is black color. This black one is Dd 0. Then also these terminals of course, there is no scope for connecting neutral now, this is delta, this is delta, where is its neutral nothing to be joined here as I have joined here.

So, if you connect a voltmeter for example, here even one no load is connected voltmeter will read this much, this voltmeter will read. But here if you connect the voltmeter here circuit is not completed because two apparently other thing. So, what is to be done, you will get balanced voltages there provided load is connected, so connect a balanced 6 phase load clear. So, return path will be obtained. 6 rheostat you can show it in, I should not call it delta like a polygon it will look like 1 2 I mean equivalent resistance 3 4 5 6, suppose this is my impedance load impedance these 6 terminals you join there then the circuit will be completed balanced 6 phase voltage you have been able to applied.

Anyway see this 3 phase transformer connection is a very nice subjects and lot of further more connections are there using many small-small windings, doing these adding that phasors. For example, one of such examples were traditional zigzag connection as I told you. But it is in nutshell whatever knowledge you have acquired, I hope you if you read those things some advanced topics on transformer winding connections, in-corporating more coils into it you can do several other things that is there, but these are the main things, ok. And you will be able to I think solve simple numerical problems on this.

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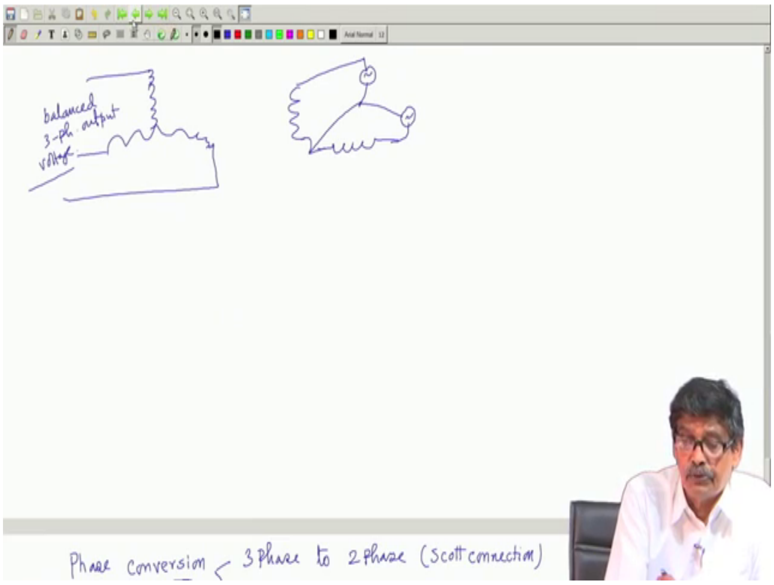


So, this is the phase conversion thing. 3 phase to 2 phase, then 3 phase to 6 phase and so on. One can go on doing like this.

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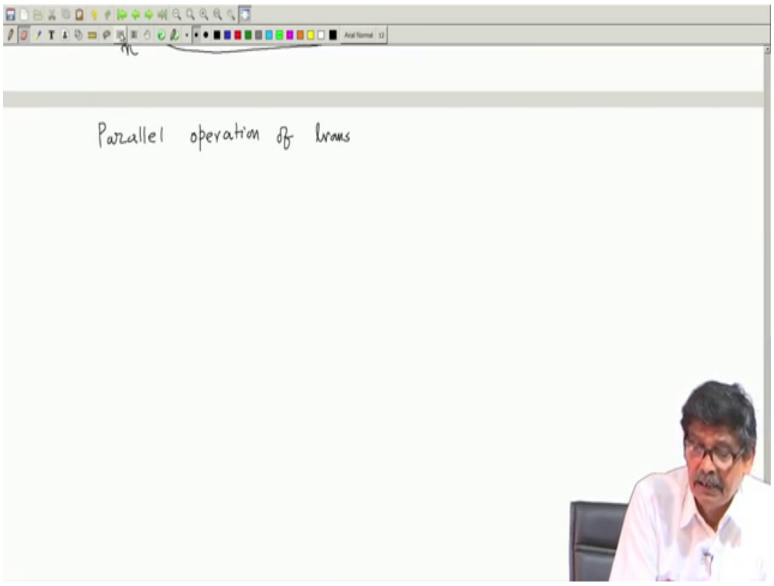


Now, our next topic will be the parallel operation of transformers, that is another important topic, ok. Our next new topics is parallel operation of transformer [FL]. Before I do the parallel operation of transformer, I am sorry let me tell you one thing. What is that thing? That is look here if it is a single phase transformer, I must know the equivalent circuit parameters and this can be measured by doing some simple experiments like open circuit and short circuit test. Now, what do I do for a 3 phase transformer? And how to find out the equivalent circuit parameters of a 3 phase transformers? Suppose, I say the transformer rating is known, what I, let me write some rating.

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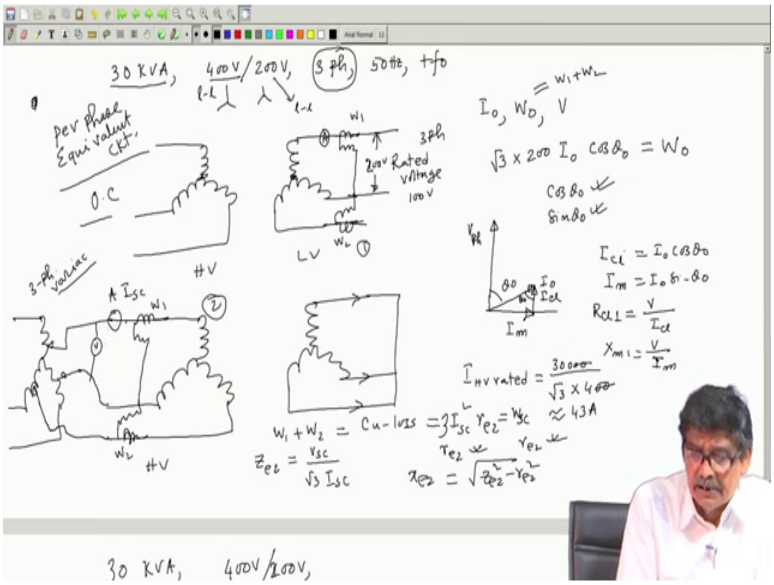


Suppose, say 30 kVA, 30 kVA, just writing some numbers say 400 volt stroke 200 volt, 3 phase, 50 Hertz. Calculator [FL]. 50 Hertz transformer anyway calculator is not needed, ok. Now, and I say that the transformer is star star connected, it is given, star star connected. And it is a 3 phase transformer, not a bank of 3 single phase transformers put together. So, what do I know about these things? About these things I know that this is the total kVA, this is line to line voltage mind you of the HV side, this is line to line voltage.

So, in the same way you carry out the, carried out the open circuit and short circuit test here also you should do the same thing. So, what do you do? The transformer you connect generally as I told you from the LV side you carry out the no load test. So, suppose this side is LV, this side is HV, therefore to carry out the no load test what I will be doing is this I will apply rated voltage, apply rated voltage. What is the rated voltage? 100 volt. Where it should be applied? Between line to lines; see that is what I am telling this is line to line voltage, so it does not tell you the 200 volt. You applied rated voltage, and 200 volt is the line to line voltage.

This 200 volt never tells you that this LV side voltage rating is 200 volt. 200 by root 3 is the rated voltage of the LV side, but anyway 200 volt you apply. You connect 3 phase 200 volt and you connect ammeter, and also wattmeter and better connect two wattmeters because it is a 3 phase system. So, note down I naught and W naught wattmeter reading and this one.

Secondary side open circuit, open circuit, and applied voltage of course, must be rate, so you have a voltmeter as well connected here. So, you know applied voltage. Now, then what you do? You calculate the parameters in this way on the per phase basis. How it is calculated? First thing is root 3 vll, this ammeter rating, I naught, no load current it will draw into cosine theta naught.

And during open circuit test it is only cold loss matters, is not, copper loss we neglect because no load current is very small may be 2 to 5 percent the rated current. How much is the rated current? As I told you always do this HV, so rated current of HV side this I will come. So, no load current will be small and you calculate this and this must be W naught, and from this you will be able to calculate cosine theta naught, from that you will be able to calculate sin theta naught then you will be able to, so per phase voltage if you have applied per phase equivalent circuit, so V phase and this will be your no load current. Then this is theta naught, just like single phase.

Then break it up into two component and that is magnetizing and I cl and then calculate I cl. This is theta naught, this is theta naught, I cl is equal to I naught cosine theta naught is not, I naught cosine theta naught and I m is I naught sin theta naught. And once you do that you will be able to calculate R cl 1, suppose you say LV side is 1. So, R cl 1 will be the applied voltage V divided by I cl and X m 1 will be equal to be V by I m that is all.

Similarly, while doing short circuit test what should I do? Generally, from the HV side the short circuit test is done HV side and LV side is kept shorted. Of course, for this rating it does not really matter from because it is only 200 volt 400 volt in the laboratory all the voltages are available and hopefully the meters required will be also available there.

So, so there what you do? This LV side you can short them. The moment you short the LV side can I apply rated voltage 400 volt here? Never, because it will then draw very large current. Current will be only limited by its leakage impedance. So, here you must have a 3 phase auto transformer to apply rather small voltage. Oh sorry, and auto transformer it is not autotransformer I should call it variac, 3 phase variac. Because you must be knowing the difference between a variac and then autotransformer. Autotransformer means these winding you are using different section of wires you get advantage. Anyway. So, so you measure the voltmeter reading here V sc. You record the current. You connect 2 wattmeters. See this W naught is equal to W 1 plus W 2, algebraic sum. So, this is W 1 plus W 2.

And while using the wattmeters, it is better because during open circuit test power factor is rather small use a low power factor wattmeter. Anyway those are details of the experiment, but you somehow note down this total reading W naught. Here also connect better 3 phase transformer, 2 wattmeters, current coil and pressure coil. Note down ammeter reading and call this current I sc. How much voltage should I apply so that rated current flows? What is the rated current on the HV side? I HV rated. It will be how much 30, 1, 2, 3; 30,000 kVA by root 3 into 400, 400, is not. Approximately, how much it will come?

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Student: 43.

40?

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43 ampere say. 43 ampere. So, you have to choose an ammeter which can read 50 ampere say and similarly wattmeter current coil. But line to line voltage voltmeter rating should be very small, may be 5, 10 percent of 400 volt. 5 percent of 400 volt is only 20 volt. Voltage required will be pretty small, so that current rated current will be circulated.

Secondary, will be also carry rated current primary, so that copper loss will be there. So, wattmeter once again will (Refer Time: 23:44) this W 1, W 2, sum of these two, W 1 plus W 2. We will give you the copper loss at rated current. We neglect the cold loss. Why? Because rated voltage applied is very small. Flux is only a few percentage of the rated flux, so when you apply rated voltage rated frequency. Therefore, copper loss we assume this and then this I sc square into this side I have called 1, this side is 2, so I sc square r e 2 will be this, from which r e 2 is known, r e 2 is known.

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Into 3, ok, total copper loss. Similarly, once you get r e 2, you have to calculate z e 2, z e 2 will be this impedance. So, what is the impedance? Per phase it will be applied voltage V sc line to line you have measured by root 3 divided by I sc. And once you get. So, from this r e 2 is known, from this W sc. So, r e 2 known, then x e 2 can be separated which is equal to root over z e, z e 2 square minus r e 2 square.

But only thing you should careful that per phase equivalent circuit the moment you carry out test, one test from LV side, another test from HV side, and it is your duty now to choose from which side you will draw the equivalent circuit. This I told you in this earlier class. Therefore, if I want draw the equivalent circuit refer to the LV side then you have to transform these parameters in that sense. What is the turns ratio here? Turns ratio of the winding if the connections are the same star to star or delta to delta, then the turns ratio will be the line to line voltage ratios, is not. So, that is the thing.

Now, the question is what happens? So, per phase equivalent circuit you have to draw, per phase. See worked out problems from books as well as in my notes I have included some problems you go through that. Per phase equivalent circuit we refer to.

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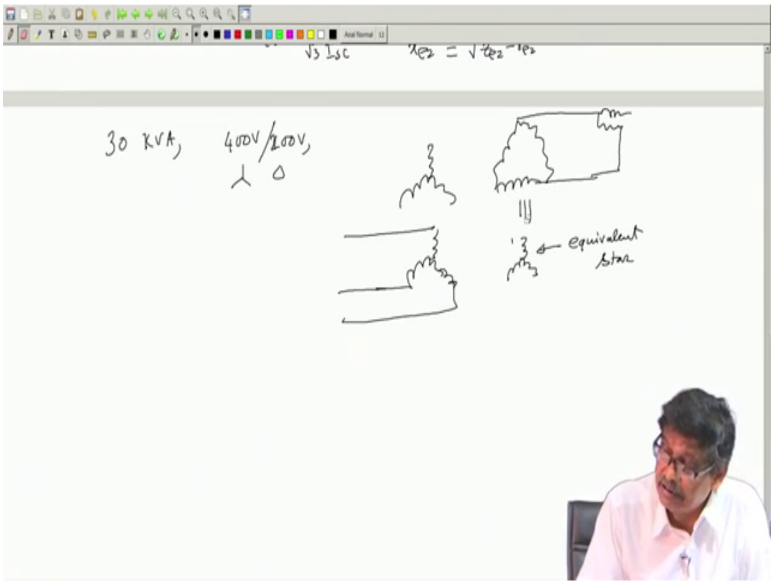


Now, suppose I say that the transformer is star delta, ok. Same rating what I told 30 kVA. Suppose, I say that 30 kVA, 400 volt, 200 volt, and the connection is star delta then what do I do? How to draw the equivalent circuit like that? Ok. You have to carry out the open circuit and short circuit test. Because the readings we are taking are only the line readings, is not. We are while carrying out the test I am measuring the line quantities.

In fact, you do not need that information whether inside this is star or delta connected, is not. We have connected everything in line, ammeter, line to line voltage I measured. I never ask where the neutral is I will measure this phase voltage, got the point. So, one type, one way of looking at the thing is carry out the test in the same way as you have done and imagine as if it is star star connected and tell that per phase equivalent circuit. Listen to me carefully what I am telling, is not.

See the transformer is now star and this side is delta. I can always imagine that no it is so far as measurement is concerned, it does not matter, oh. It you can equivalent to this side, you can consider it to be some equivalent star and then calculate the parameters in the same way because what you are doing, you are measuring total power drawn by that 3 phase connection which is star shown here during the no load test. Suppose, I carry out the no load test what do I do? This is your actual transformer I will connect 2 wattmeters here. Let me slightly clean this thing. Try to get the idea, I will not tell. It is in fact not needed so much of pointing out, but it should be understood what we are doing.

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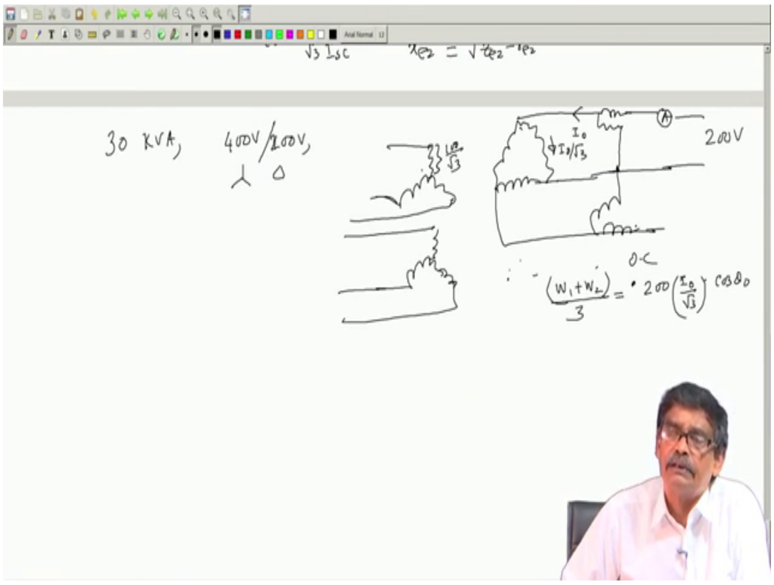


Ammeter you connect, rated voltage you apply, 200 volt while doing open circuit test this side is open, who bothers. That is fine. But what I am telling you can always imagine this to be star connected while calculating the parameters and leave with them. Another way of doing it that is looks like more appropriate, it is like this. That is I will carry out the test no doubt, I will say that look this is the no load current you are carrying. I will start calculating per phase what I will do? Per phase voltage applied to this winding is how much? 200 volt.

I will say this is I naught by root 3, if it is delta connection I know that. So, through the winding I naught by 3 root 3 is going, ok. This total wattmeter reading during open circuit test will be this sum of the cold losses of all the 3 phases, is not. Therefore, this voltage and this W 1 plus W 2 by 3 I will do and leave here, ok. It is a single phase transformer, this is its primary, this one is secondary, whatever it is one of the coils and power absorbed by this is this one and whatever is the power factor angle, I will calculate. So, in that case I will do it like this that is this by 3, I will say 3 not 3, V naught into I naught by root 3, this is this is this current.

I naught by root 3 I will take whatever it is that number, I mean I should not translate to I naught be I naught and cosine theta naught, and calculate cosine theta naught. And, then I will calculate I naught by root 3 sin theta naught to get magnetizing current and this one. And, I will while drawing the equivalent circuit referred to this side 200 volt. Only thing is in that case turns ratio will be 200 by 100 by root 3, that you must understand.

Anyway, solve some problems on open circuit, short circuit test because it is per phase basis the analysis is done, regulation problem, this, that, will be all similar because single phase transformer it can be considered to be a single phase transformer 3 such units, ok. Think about it and we will continue in my next lecture the parallel operation as I told you.

Thank you.