Electrical Machines - I
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Lecture - 45
Phase Conversion Using Transformer: Scott Connection

Welcome to lecture 45 on Electrical Machines-1 and we were discussing various connections of 3 phase transformers and give you a sort of guideline owing to select what connections ok; star delta, delta star or zigzag.

And zigzag connection as I told you is essentially a star connections and in my last class I told you because with delta connection, I just view 1 digit 0 and it was like this and I told you if you know the input line to line voltage and the turns of each primary and each secondary coils, then you will be able to calculate what will be the phase voltages of these zigzag connections between the neutral. And one of the phases of the output at the this goes to load a, b and c and what is the line to line voltage and phase voltage, how to calculate you can easily relate them ok.

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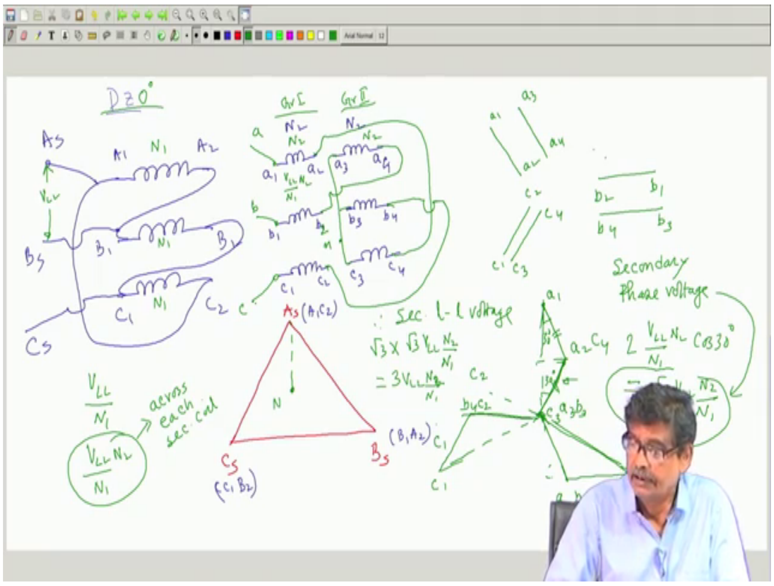

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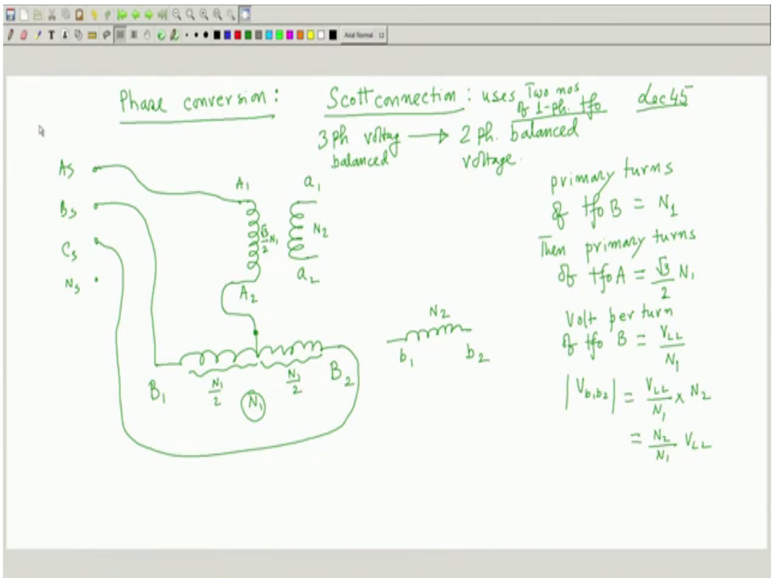

Now, another interesting thing with transformers is that using transformers it will be possible to convert a given polyphase system to another poly phase system. That is called phase conversion. We will briefly discuss that phase conversion, of which one very popular connection is called Scott connection; which changes a given 3 phase voltage. It converts to a 3 phase balanced voltage of course, to a 2 phase balanced voltage. See our supply system is all 3 phase; generation; distribution; transmission.

Then of course, you get single phase voltage you can get between 1 line and neutral. Like that that is there, but sometimes 2 phase balance voltage may be needed. For example, if you have a 2 phase induction motor ok, then you must supply the stator coils by it 2 phase supply instead of a 3 phase balanced supply, because the motor is 2 phase and 2 phase induction motors are also used in control system and other applications.

There similarly there maybe 2 phase electric furnaces, where 2 phase supply is necessary, but the problem is first understand the problem; problem is you have a 3 phase supply available to you As, Bs, Cs may be with a neutral Ns supply is available, and you have a 2 phase load this side. So, how to convert this 3-phase supply to a balanced 2 phase supply voltage system and then feed your load that is the problem.

So, the connection is called Scott connection and it uses 2 single phase transformers. Two numbers of single-phase transformer; that is 3 phase to 2 conversion requires 2 single phase transformer, separate transformers and you can show that it will give you a balance two phase voltage; the idea is very simple ok. So, let us start what is done is this you have one transformer, whose primary coil I will say, because transformers are to be named, in case of 3 phase case 3 isolated transformers can be used and there were 6 coil, so proper naming is required.

So, in this case of course, two transformers are there, and let us call these transformer to be transformer A with terminal say 1 A2 and its secondary is having B1 sorry small letters b1, b2, a1, a2 sorry, small a1 like the 3 phase, a1, a2 and you have another transformers which I am drawing horizontally the reason will be clear and its secondary is this one ok. This is suppose B1, B2 and this is also b1, b2.

Now, we required two transformer; one transformer is transformer A another transformer is transformer B. Now, are this two transformers are identical? Really not. What happens is this you select this two transformers in such a way that the secondary turns are equal N2, N2 and primary turns of this transformer is B transformer is N1. So, secondary turns are same, primary turns of transformer B is equal to suppose N2 then, primary turns of transformer A should be this is let me write why I have written N2, N1 primary turns N1 and this two are N2 N2 secondary.

So, N1 and then this primary turns are selected at root 3 by N1. That is the primary turns of these is root 3 by 2N1, it secondary turns N2, primary turns of this transformer is N1 and its secondary turns is N2. That is how the transformer turns we have to select of this two transformers and not only that then in transformer B primary at the 50 percent you must have a tapping such that this turns become then N1 by 2 and this turns becomes N1 by 2; so, total turns is N1. So, at 50 percent there will be a tapping ok.

Now what you will be doing is this A2 you join it here with this 50 percent tapping and these three, I will connect it to supply A1 say this I connect to B1 and this I connect to B2. Suppose I connect like that and secondary I have not connected anything it is just isolated and leaving like that.

Now, first of all you can see that what is the voltage applied to the primary of transformer B. The voltage applied is line to line voltage is not and total number of turns is N1. Mind you this transformer has its own magnetic circuit separate; this transformer has its own magnetic circuit. So, volt per turn of transformer B is equal to VLL by N2

N1. Total turns is N1 VLL voltage per turn. Therefore, what will be the induced voltage between in the secondary of the transformer B.

So, voltage magnitude b1 b2 it will be volt per turn of transformer A into N2 what else. So, this voltage will be N2 by N1 into VLL clear ok. Now, you see I will draw here so, that I do not have to or shall I go to next page. I will select this one, this diagram is needed. So, select this so that I do not have to draw, copy and I go to next page, paste it here. So, that is the thing. Now I will erase this things, so this was the thing [FL].

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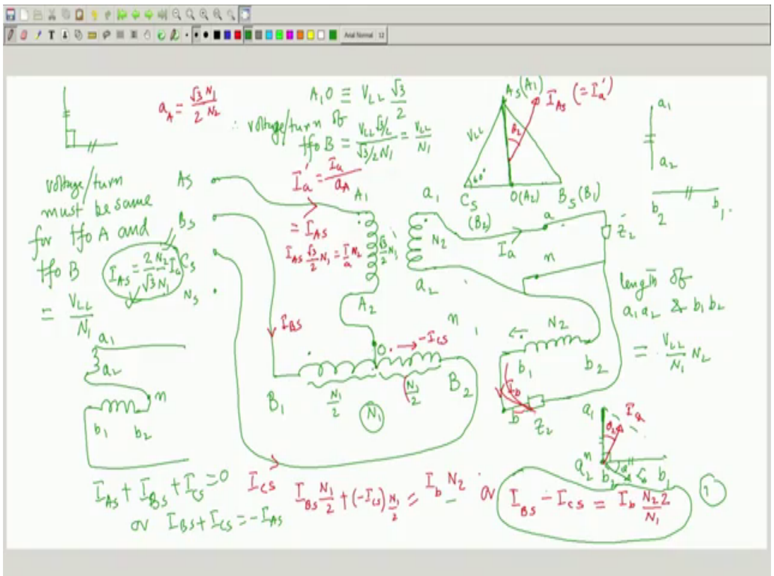

Now and we have examined what is now, suppose I want to see in phasor term so, what are the voltage I have applied on the primary side. Since the supply voltage is balanced like the previous one in transformer connections, I can draw this voltage triangle and supply is phase sequenced as A S, B S, C S. So, first I will draw this, this is A S, this is B S, and this is C S I will draw and A S is A1, A S and A1 same B S and B1 is same and C S with B2, it is also same, it is like this. So, what is the voltage applied across the primary of the transformer B? It is this one; B1 B2.

Therefore, if we say that like the previous one, this one ones are dots this one one are dots suppose I say then, on the secondary coil I will have this induced voltage, which will be b1 b2. We have done much more complicated case in case of 3 phase ok. Now, here it will be like this what else. So, this will be the secondary this voltage phasor parallel to b1 b2 of course, I have not correctly named, this must be b2 is connected to

CS. So, it should be I am sorry you know this is B1 is connected to BS and CS is connected to B2. So, voltage applied across this is B1 B2. So, the secondary induced voltage b1 b2. So, I should name it accordingly nah B1 is here so, it must be B1 and B2, now it is correct.

So, this is the available voltage, if any mistake please point out this is the thing. Like this several times we have done in case of 3 phase. [FL] Now, the question is what is the voltage applied and this point I will call O where that 50 percent tapping has been taken. Now the question is where this point O is in this phasor diagram? It must be at the middle point. O lies here because half of the voltage if you move from here you get O, is not this total voltage is this VLL by 2 VLL by 2 will come here. So, this point is O.

The moment I get this O point is a nothing but also your A2 point, because you have connected like that and what is the voltage applied and this is A1. So, voltage applied across the primary of transformer A is this vertical line; is not this is the voltage applied across the primary of transformer A. If line to line voltage is VLL, what is the magnitude of the voltage applied across A1, A2? It will be this length this is 60 degree.

So, length A1 O is nothing, but VLL sin 60 degree nah root 3 by 2. See my goal is to get at the secondary 2 voltages which will be 90 degree apart. What is balance two phase voltage? Balance 2 phase voltage is like this phase voltages will be equal and there will be 90 degree apart. Maybe 1 phase is A, another phase is B; that is what I want to get.

So, 1 voltage phasor is like this to the primary of transformer A, I have applied this voltage whose magnitude is VLL by root 3 therefore, induced voltage on the secondary will be also parallel to this. That is A1 A2. I want this length to be same as this length. What is the voltage per turn? This voltage divided by number of turns of the primary. So, voltage since secondary turns I have said to be same, I must ensure that the voltage per turn of transformer B and voltage per turn of transformer A they must be same.

So, I write that; so, voltage per turn must be same for transformer A and B and transformer B. They must be same then only the secondary voltage magnitudes will be same. I will simply multiplied with N2 to get the secondary voltage for this transformer. What was the voltage per turn? VLL by N1 which must be VLL by N1. Now, this voltage I have right now seen it is VLL into root 3 by 2. Therefore, its number of turns if you set it to capital N 1 as before, it voltage per turn would have been then VLL root 3 by 2 divided by N 1 and its secondary voltage would have been VLL by root 3 by 2 by N 1 into N 2 and that will not be same as this one.

So, to make the voltage per turns saying that is why its number of turns of transformer A primary is chosen to be root 3 by 2 into N 1, then I will write you see voltage per turn of transformer B must be VLL root 3 by 2 divided by root 3 by 2 into N 1. And that will tell me this is VLL by N 1 as the transformer B therefore, the length of this phasor length of a 1, a 2 and b1, b2 will be then VLL by N 1 into N2 there will be same. So, you see at the secondary coils of this two transformers there exist 2 voltages whose magnitudes are same and which are 90 degree apart.

So, it was a balance 3 phase voltage and on the secondary coils although I have not connected them yet, I get a balanced 2 phase voltage, is that correct no confusion fine. [FL]. If that be the case then what I will tell is this I will now join a 2 and b2 to create the neutral of the two phase system and I will take output 3 terminals I will take one will be marked as a another will be marked as b another will be neutral. So, the moment you join this 2 phasors cannot remain in isolation a 2 b 2 what I have joined a 2 with b 1, therefore, I must place this as a 1 a 2 and I have joined a 2 with b 2 so, it should be placed here.

It will be like this or what you could do is this if you want to make the a phase voltage leads the b phase voltage you can join a 2 with b 2. Are you getting me? What I will do is I will join a 2 with b 2 to create the neutral. In that case what how it will look like please be with me what I am telling this is fine balance two phase system you will get and a phase voltage will like the b phase voltage and neutral is here. Another way you could do connect the secondary coils this was the thing this was a 1 a 2, this was b 1 b 2 is not and a 1 a 2 voltage is here.

So, I could join a 2 with b 2. Did I not join that? No, why I did not join; a 2 with b 2 I could short. So, in this case a 2 with b 2 I will short and get the output from this, get in the neutral. Therefore, let me clear this I will do like that. So, let me slightly modified this, but you get the idea that will also work no problem.

So, what I am telling is this is b 1 b 2 I have drawn these are the voltage phasors like this. So, what I will do now? I will join a 2 and b 2 together that is and call this to be by neutral and I will take output from this as a phase and take output from this for b phase.

And if you do like that a 2 b 2 you join then your phasor diagram will look like look like a 1 b 1, a 1 a 2 and I have joined b 2 with b 1 and this is my neutral. That is what I made. the earlier one will also do. But any way let us draw like that.

So, that a 1 b 1 supply comes out like that and this is your balance 2 phase voltage. In case of balance 2 phase voltage and this I will say as the line to line voltage; line to line voltage will be route 2 times the phase voltage. You can easily understand; so far so, good. So, this is what is Scott connection is. So, this two transformers in terms of number of turns, they are not identical.

Secondary turns are must be same, N2 N2, but primary turns of transformer a which is just drawn vertically, this vertical drawing has nothing to do with really 90 degree, this access that access; no on the table you draw. I have drawn it so, that I understand this phasors much more easily. So, this is transformer B having N1 turns and also I will demand a 50 percent tapping available from the primary of transformer B and then I will connect like this connect it to a balanced 3 phase system and the number of turns of primary of transformer A is not N 1 has that of B, but it must be root 3 by 2 into N1 and secondaries are connected like this. Is that clear? So, that is the thing.

Now, the question is that I will connect a balance 2 phase load on the secondary side. So, I have got a balance 2 phase voltage, the magnitude of the voltage also I know. So, I will connect a balance 2 phase load here on the secondary side so, some balanced current will flow. Then how to estimate the current which will be drawn from the supply 3 phase supply? That is important; is not I must examine, because after all you see you are connecting a balance 2 phase load here is a 3 phase system; 3 phase voltage supply system here.

We like that it also supplies the balance 3 phase current, not a unbalanced current like that. So, if you connect a balance 2 phase load on the secondary side, does the primary side current which is drawn from a 3 phase supply remain as a balance 3 phase current and how the magnitudes of this secondary current and primary current will be related to? That will be the next thing.

Suppose you have connected a balance two phase load; so, between a and n. So, this is the balance 2 phase load of same magnitude of impedance ok. If it is z 2 this is also z 2 per phase impedance, got the point. Now, suppose it supplies a current Ia direction of the current I have assumed. So, Ia here depending upon the power factor angle of z 2 it will be positioned. So, Ia maybe there, this is I secondary. What is this angle? Is the power factor angle of the load, is not a phase current Ia. But the moment it supplies a current these are transformer so, rules of transformer must be satisfied what is that voltage ratios are in the ratios of turns.

Similarly, if through the dot a current comes out its primary will draw additional current through the dot whose magnitude will be Ia by turns ratio of this transformer, for transformer a i am telling. So, it must draw an additional current Ia dot, whose value will be Ia divided by what is the turns ratio say turns ratio of transformer a is how much root 3 by 2 N 1 by N 2. So, Ia by a A turns ratio of the transformer b so, that is how it will be reflected upon ok.

So, so, this is Ia and this is Ia dashed which is the line current of a phase happens to be. So, a phase current will be also in phase with these, that is what we have learnt. So, primary side a phase current if I show it will like I mean it will be in same phase. I am just drawing here. It has it does not mean any connection etcetera current I am drawing, this is your I AS which is same as which I am calling it as Ia dashed this will be thing and this angle will be theta 2.

So, the line current of the primary side I have drawn, but there are two other line currents. Let this line current be IBS, that is how in a 3 phase system I show, let this be ICS ok. Now, I must find out in terms of the secondary current what will be the value of IBS and ICS. So, same rule that is MMF must be balanced. Now, in this case it will be slightly tricky; in the sense that this current suppose the this current I say this is I small b secondary line current through the dot Ib current is coming out.

Therefore, there will be reflected current here on the primary side and that reflected current in terms of I BS and I CS if I write, I will balance the MMF. Here also I could do like this I AS will be such that; see this is I have followed, but I could write it like this I AS, the value of I AS I could calculate the MMF produced by primary root 3 by 2 into N1 must be equal to Ia into N2. Same thing I will get this is I AS is Ia dash, if you bring it down here the same thing you will be getting. Got the point? This one N 2 root 3 by 2 N1 by N2 is a.

Similarly, I will balance the MMF of the secondary and primary for transformer B. Now, let me write only on this page let it be clumsy; so that we do not miss the point. What is the MMF produced by transformer b, current coming out from transformer b is how much Ib. So, Ib into N2; Ib into N2 therefore, through the dots currents will go in, but you see here there are two half's of this N 1 having the primary having total N 1 turns of which N 1 by 2 turns is carrying IBS current entering through the dot.

Therefore, these MMF must be equal to let me write here only so, that you understand. So, this must be IBS into N1 by 2 that is the thing. But this portion is N 1 by 2, but it is carrying current see if this is dot this is dot. So, this plus so, current flowing into the dot of this part is minus I CS into N 1 by 2 and this should be equal to Ib into N 2. See this is crucial see secondary MMF through the dot Ib current is coming out.

Student: Sir.

So,.

Student: (Refer Time: 36:16).

I am just telling. So, through the dot current is coming out. So, Ib into N2, this is the direction of Ib I have assumed. So, through the dot if current comes out in its primary through the dot current will be invited as here was small Ia through the dot if there was no complication only, but here these two parts carrying different currents.

So, I have to calculate. So, through the dot current coming out is Ib therefore, I must expect through the dot what is the current flowing. IBS by virtue of its direction enters through the dot, but that IBS last for only N1 by 2 turns. So, it is IBS by N1 by 2 I have done. Through this portion of the coil I have assumed I CS flowing like this, that is what we assume for 3 phase circuit analysis and if this is dot this is dot we have learned in auto transformer this that. So, current flowing in this direction is minus I CS.

So, this plus minus I CS into N1 by 2 and that must be equal to Ib into N2 or this is equal to I BS minus I CS is equal to Ib into N2 by into N2 by N1 into 2 is not this is crucial. This is the thing we get. See what my problem what is the statement of the problem statement of the problem is you get a balance 2 phase voltage, connect a balance 2 phase load. Secondary currents which are balanced this will be Ia where will be Ib, I will make it more clumsy on the same paper so, that you understand. Ib will be here of same magnitude lagging the b phase voltage by theta, this two I know.

What I am trying to do now, then for this loading what should be my IAS, IBS, ICS? Deductions I have assumed in accordance with the 3 phase circuit directions. Then what should I do? I must balance the MMF. I will neglect the no load current etcetera. So, write the MMF equation here, what is the current coming out through the dot Ia? What will be the current coming in through the dot? It is IAS, it has to be. So, these two MMF's are same because they will nullify the flux.

So, that is the first equation, IAS into root 3 by 2 into N1 is equal to Ia into N2 over. But for this portion it is slightly you have to be careful the current direction Ib I have assumed like this, coming out from the dot Ib like this. So, Ib into N2 that is the secondary side, then through the dots must current enter and that MMF I have to calculate. Now, I BS enters through the dot, so I BS, but this IBS is up to this point N1 by 2; so IBS into N1 b 2.

Now, what about this portion, you have assume this current to be I CS so, I can always presume minus I CS is flowing and this is dot. So, this MMF plus this MMF must be equal to this. So, this is one equation. I AS in terms of secondary current so, I have already calculated. I AS was how much, I have calculated. See I AS already I have got 2 by root 3 into N2 by N1 into Ia. So, I have to find out the 3 phase side current in terms of secondary current of which I AS already obtained.

Now, I have to find out I BS and I CS in terms of secondary currents, that is what we are planning to do. To do that I find another equation is missing, because I must have 2 equations in order to express I BS and I CS in terms of secondary currents ok. This is one equation. So, where is the third equation? Third equation is it is a 3 phase system, I AS plus I BS plus I CS must vanish to 0 or the other equation is I BS plus I CS is equal to minus I AS; right hand side is known IAS has already been obtained. I will put it here then I have two equations I will just simply solve them. We will continue this discussion in the next class.

Thank you very much.