Electrical Machines - I
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Lecture - 37
Vector Group of 3 Phase Transformer

Welcome to lecture number 37 on Electrical Machines I and we have started discussing about 3 Phase Transformer connections. And I have told you a 3 phase transformer can be constituted by using 3 identical single phase transformers or as a single unit of 3 phase transformers. So, to begin with I have started of taking 3 identical single phase transformers and connected trying to connect them externally. So, that a balanced 3 phase voltage can be transformed into another balanced 3 phase voltage in the secondary.

But while doing so, we should be knowing the a dot markings or polarities of the transformers and we should be systematic in describing the current. In my last lecture we just we were seeing that the there is a shift in the secondary voltage with respect to the primary voltage. And how that shifting by what angle the voltage is shift that is called the and that is generally written on the nameplate of a 3 phase transformer and that is called vector grouping. So, we were up to that, but recall that; so this was the thing.

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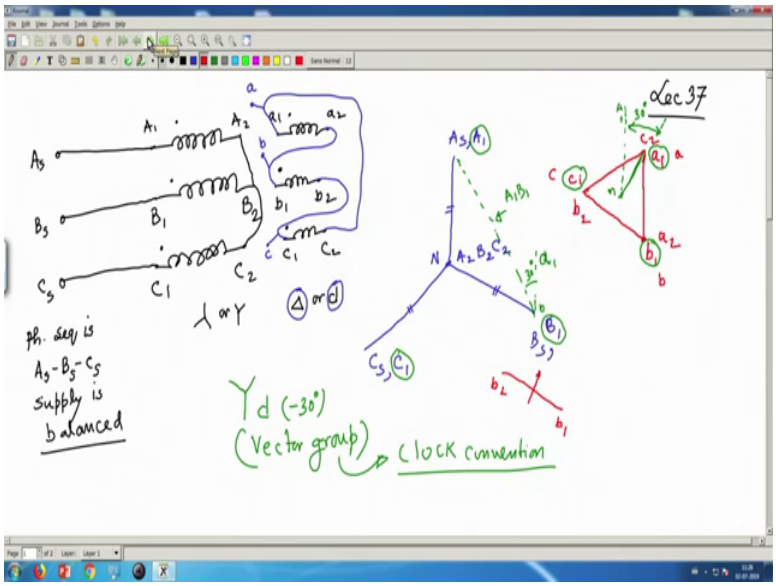

So, you have a 3 phase transformer and once again very quickly I will tell these are suppose the this is one transformer A, it has got a primary terminals A 1 A 2 and this is

small a 1 a 2 is the secondary terminal. Similarly you have the second transformer B and it has got its primary B 1 B 2 and correspondingly it secondary and c 1 c 2 and this is small c 1 c 2. And then you have the supply 3 terminals that is A s, B s and C s.

Now, I have to connect the supply and connect this primary and secondary in a particular fashion has desired and I told you that while connecting the transformers in star windings in star either A 2, B 2, C 2 should be shorted or A 1, B 1, C 1 can be shorted valid star connections. And also remember these one terminals are dots like polarities at any given instant of time similarly for the transformer B and transformer C. And these how do I get? I will test for polarity to this individual transformers put the dots and mark the terminals accordingly. Anyway this is how the thing is.

So, suppose I say that I will connect the transformer primary in star, I would like to connect these in star or Y. And secondary I would like to connect it in delta or in later it is small d and I will of course, make valid connections. So, what I do is this I make a valid star connection A 2, B 2, C 2 shorted and I will connect A 1 with A s, B 1 with B s and C 1 with C s. And suppose the phase sequence of supply phase sequence is A s, B s, C s ABC A stands for supply.

Now, the easier way of connecting this I will going to tell you now we have seen the interesting features, if somebody connects differently what is going to happen and things like that. Now, today's lecture is all valid connections we will be doing ok.

The moment you do this then what you say a phase sequence is this and supply is balanced; supply is balanced. If the supply is balanced, then it is best thing to do is draw the supply voltage first. So, I draw the supply voltage which will be equal to like this 120 degree apart equal lengths and this is suppose A s, B s and C s all lengths are equals here balanced.

And note that A s is connecting to A 1, then I will write it is also A 1 is not this point. Similarly B s is connected to B 1, so comma B 1 and C s is connected to C 1 commas C 1 and since A 1, B 2, C 2 are shorted. So, A 2 is here, B 2 is there, C 2 is there they are shorted, so their potentials are same and this. In fact, is the neutral of the side, fine?

Now, suppose the secondary side I would like to connect it in delta and there are two possible deltas delta connect two possible delta connections are there. So, first of all I

will connect it suppose like this; like this series and closed and output I will take from A 1 wherever A 1 is there B 1 and C 1. Let the secondary output be a, b and small c, I am not writing s because it will go to load.

Now, based on these you can easily see, the secondary voltages will be since voltage applied across the primary of transformer A is A 1 A 2. Therefore, this side you have the secondary voltage small a 1 a 2 which will be parallel to this length. So, I write it like this a 1 a 2 got the point parallel to capital A 1 A 2.

Similarly, small b 1 b 2 the induced voltage in the secondary will be parallel to this B 1 B 2 and B 2 A 2 are shorted therefore, how to place these? So, b 1 b 2 and b 1 is connected to a 2. So, so b 1 b 2 will be like this here I am just drawing b 1 b 2 parallel to this it is available, but I have joined a 2 with b 1. So, I will shift this fellow parallelly and bring it here like this such that it a 2 and b 2, b 1 are joined. So, I must write it here b 1. So, b 1 a 2 is this point.

So, b 1 b 2 got the point parallel to this similarly c 1 c 2 and c 1 is joined with b 2 therefore, this phasor should be parallelly shifted and it must be this that is b 2 is connected to c 1. So, c 1 c 2 got the point and this is absolutely fine.

Now, output see this is a input A 1 is connected to A s, B 1 is connected to B s, C 1 C s. Similarly, I would like to take the output from small a 1, b 1 and c 1. So, I circle them just this will be my output a 1, b 1 and c 1 although b 2 is connected, but I will call it my a, this 1, a 1 and c 2 are joined from this I am taking the output I am calling this a to be consistent with the primary side. So, that is the thing.

Now, the question is if you connect like this I should write it as star, secondary is delta. Now, what is the phase angle, what should I write? Now, while doing the phase angle you can find out first where is the artificial neutral of the secondary side got the point. So, so this is the neutral.

So, you see that this will be the. So, this triangle we have identified A 1, B 1, C 1, similarly you circle the primaries A 1 with respect to this will be talking. Now, I will examine with respect to neutral on the primary side there is A 1 voltage, similarly with respect to this artificial neutral which is centroid of this equilateral triangle and with respect to that neutral the a phase voltage is this phasor A 1 n.

Then you draw these a capital A 1 n here suppose thing, this primary a phase voltage with respect to its neutral is here A 1 you should not make confusion that capital N and small n is connected no small n is not there in fact,, but anyway that is the A 1 phase vector if I that is vertical. So, I find that the this voltage lags the a phase voltage with respect to the neutral on the a phase side by 30 degree and this is the thing.

And I then write it as it is lagging, so may be minus 30 degree I will be telling it. But one important thing also you note that it is not only the phase voltages that A 1 with respect to neutral that maintains 30 degree. What about the line to line voltage? For example, primary side line to line voltage A 1 B 1 because phase sequence is this. So, this voltage is A 1 B 1 which happens to be equal to A s B s this is the line to line voltage.

On the secondary side, what is the line to line voltage? It is this vertical line and this line to line voltage two this is a 1 b 1 if you just that is also 30 degree lagging. Not only the phase voltage with respect to the neutral or artificial neutral that will lag which also means that line to line voltage is too will be lagging by the same amount this point you must understand because this is A 1 B 1 line to line voltage on the primary side your small a one b one becomes vertical ab voltage of the same line to line voltage that lags it will be true as you can see for bc and ca phase as well. So, examine only the lag or lead with respect to a particular set of line to line voltage that is the thing I wanted to tell. So, this is the connection then Yd minus 30 degree [FL].

Now, sometimes this vector grouping this is the vector group is also expressed in terms of a clock minute and hour hand positions angle between them that is how. So, I will first explain that then explore more interesting connections after that. So, first clock convention vector group which is can be also expressed instead of showing the angles by clock conventions; clock convention.

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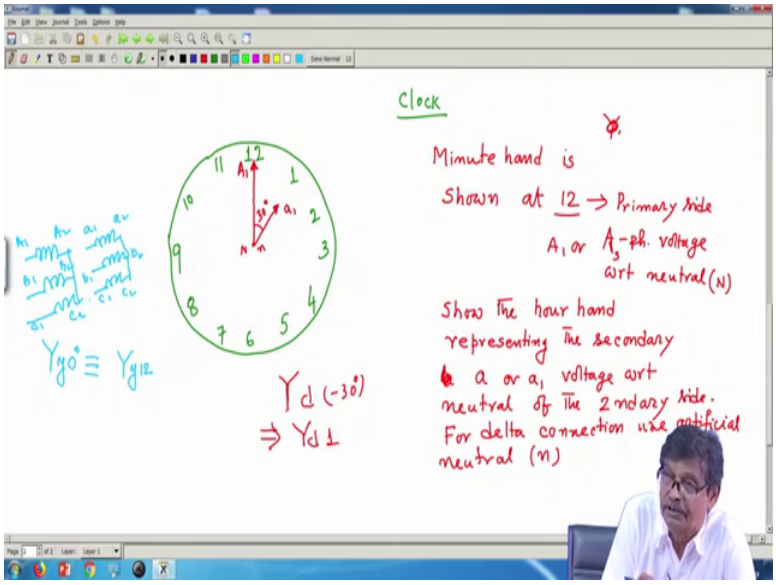

So, you let us let me go to next page and you see you have a clock here let me explain that then I will go there. Suppose you have a clock of course, you have got all the markings here 1, 3, 6 here and 9 ok; 1 3 6 9. And of course, no it is 12; 12, 3, 6, 9, then you have in between of course, 1 and 2, 3, 4 and 5 and 7 and 8 and 9, 10 and 11 this is usual clock our familiar clock.

And there will be two hands hour hands and minute hand; minute hand is longer. So, minute hand is suppose in the position of 12, hour hand could be anywhere in our usual clock I mean that will I mean minute and hour hand both can be anywhere and you get the time. But here while following this clock convention to describe what is the vector group of the transformer you note that the angle between two consecutive numbers on the dial of the clock is 30 degree that is known that is this angle is 30 consecutive to any numbers you take 30 degree.

Now, what is done is this the minute hand; minute hand is shown at 12 always you will show it and let this minute hand represents the primary side. Say A phase voltage with respect to neutral that is this voltage A s N or A 1 N that is the primary side neutral voltage that voltage I will place in the minute hand and always show it in the twelfth position of the clock this is the primary voltage.

And secondary voltage I will once again this is suppose A s, A 1 or A s either of them with respect to neutral. Similarly, show the draw or show the show the hour hand; show the hour hand representing; representing the secondary a or a 1 voltage with respect to

neutral; neutral of the secondary side; of the secondary side. For delta connection use artificial neutral that is small n this is capital N you have got the point.

For example the previous connection; in the previous connection minute hand is a 12 vertical A 1 capital N and secondary a phase voltage this a 1 is once again a which is going to load you. So, this is a, a or a 1 with respect to neutral this is my b, this is my c therefore, this a phase voltage. Now, this angle been 30 degree, where do you think in the clock should I show this secondary voltage at one is not.

Because we have seen that secondary voltage is doing this. So, this minute hand which is bigger it is capital A 1 N and this is small a 1 n I should not write this, but I am writing you should not be under the impression that if I write like this I meaning capital N and small n are shorted no it is just separate two things. Because two neutrals are located at different positions and they are not connected electrically, but just to indicate what does this mean.

Anyway this is the thing, then I will write it as primary is star connected Y, secondary is delta connected delta. Earlier I wrote it minus 30 degree in the previous page this is same as Y d 1 that is the time is 1 then only this connection I mean this is the connection Y d 1 it simply means that the with respect to neutral of a particular phase primary side voltage and secondary voltage how they are dispersed. But since hour hand I will always represent to indicate the secondary voltage therefore, secondary voltage lags the primary voltage by 30 degree ok

So, this is the vector group. For example, this I will just write for example, Y we have seen that Y; Y with different color let me write so much space is there. For example, this connection I will not redraw you know Yy 0 degree we have seen. What does this mean? It means these are the primaries you short these are the secondaries, this is A 1 A 2 a 1 a 2, B 1 B 2 etcetera C 1 C 2 small c 1 c 2 and b 1 b 2 and suppose you make star, then this connection indicates it is Yy 0 degree means I will write it as what, then this these voltage a 1 n both minute and hour hand will be together. So, I will write it as Y 12 time is 12, then only I will say this is Yy 0 degree.

Similarly, if you short these I should have written Yy 6 because secondary voltage should have been with respect to neutral here primary voltage is there they would have been 180

degree out of phase. I hope you have understood this one.Now, let us try some more connections.

Another connection is a see previously let me draw another one, so that with delta connections you become comfortable. Suppose there are two ways of delta connections either this way or other ways that is a cyclically you go this or it could be connected like this. So, the second connection let me try, what is this?

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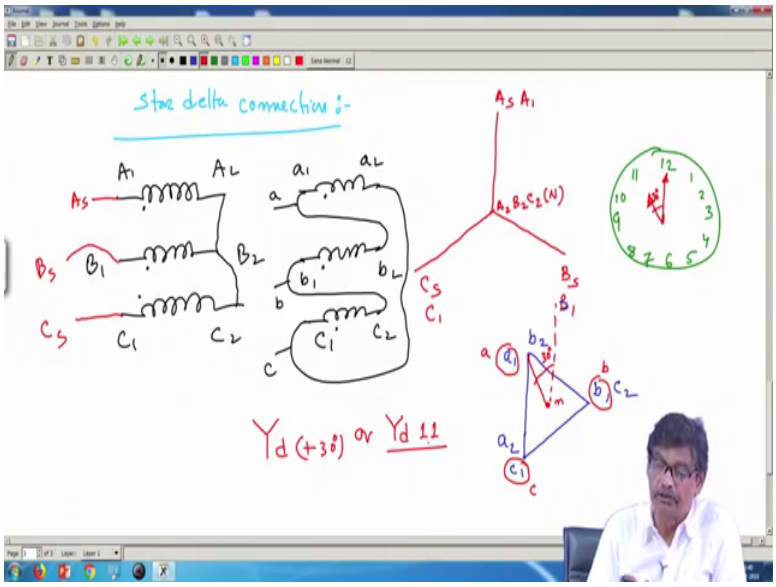

So, once again star delta connection ok. So, these are the primaries A 1 A 2, B 1 these are the primaries B 2, C 1 C 2s and these are the secondaries small a 1 a 2, small b 1 b 2 and small c 1 c 2 and suppose I have shorted these.

So, I get the primary voltages as supply voltages are this is A s, this is B s easier way of drawing I am telling C s. So, supply voltage is balanced draw A s, B s, C s first 120 degree apart and this is A s, B s, C s you draw and this will become the neutral and where A 2, B 2, C 2 are joined this is capital N this is over.

Then you know you connect it suppose like this you joined other way now and mind you these are dots do not forget to show that which I have already told you that is important. So, you connect this closed circuit there will be no circulating current because I have been very meticulous very careful about polarity marking and that is why I am

connecting and this is my output terminals small a, small b which will go to load 3 phase load like that.

Now, in this case the secondary voltage I am now drawing. Secondary voltage will be mind you this A s is nothing, but your A 1 is not; is nothing, but A 1, B s is nothing, but B 1 and C s is nothing, but C 1.

Now, I will sketch the secondary voltage now you see there is the voltage a 1 a 2 which will be parallel to a 1 a 2. So, I draw it here a space is there this is suppose a 1 a 2, it must be like that this is B (Refer Time: 30:35) this is b [FL] then B 1 B 2 parallel to that the secondary voltage has been induced that I get from single phase funda that is induced voltages in each transformers will be co phasor with the primary voltage that we have we know from.

So, b 1 b 2, but this time I have joined b 2 with b 1. So, move this b 2 with b 1, so it must be like this. I first write this a 1 a 2 here this side a 1 a 2 fine with this then b 1 b 2 I will draw like this with a little practice you will become conversant with this, this is the thing a 1 b 2 I have joined. So, there must be at some potential and then c 1 c 2 and c 1 is joined with a 2. So, is like this c 1 c 2 is not`

So, it is a valid delta connection and then I am telling mark this please follow the instructions carefully. So, that you will never make mistake while working with a 3 phase transformer in the laboratory or in the site.

So, a 1 b 1 c 1 these are the thing this is a this is my b this is c. So, balanced 3 phase voltage will be obtained. So, here is the artificial neutral because delta connection no neutral. So, a phase voltage with respect to this neutral and a phase voltage of the primary is this the vertical line therefore, it is 30 degree. So, in terms of clock it will become this 12, 6, 3, 9, 10, 11 etcetera 1, 2, 4, 5, 7, 8.

So, primary voltage with the minute hand I will always show, so that was this and secondary voltage with respect to same a phase voltage with respect to neutral is now ahead of this. So, it must be shown here hour hand this is the secondary voltage and this is 30 degree. So, this connection I should say it is Y d plus 30 degree or you show Y d 11 like that ok. We will continue with this try to understand very interesting, but at the same time people often make confuse confusion I mean.

Thank you.