Electrical Machines - I
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Lecture – 44
Choosing Transformer Connection (Contd.)

Welcome to 44th lecture and we have been discussing the effect of third harmonic flux and third harmonic currents in particularly 3 phase transformers. Star star connection without neutral always causes problem, including single phase loading is not possible because secondary neutral becomes oscillating and so, on.

So, the, but if it is a delta connection, if exists either in primary or secondary at least one is delta connected, then in the lines there will be there is no possibility of any third harmonic current to exist if it is that side is delta connected because they are co phrasal and so, on. But nonetheless there will be induced voltage then in the coils itself and this coils are close to itself therefore, the magnitude of the third harmonic current circulating third harmonic current will be then, they are co phrasal 3 E 3rd 3 times of that divided by the leakage impedance of suppose the secondary side is delta.

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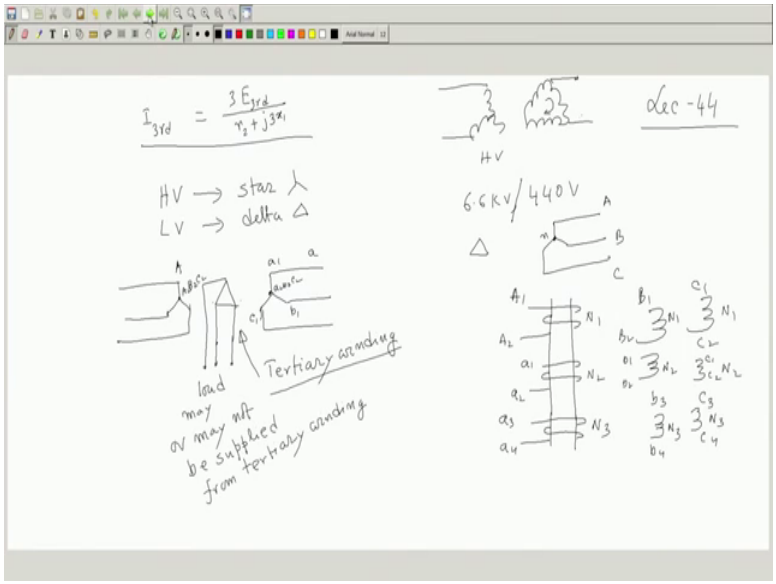

This 3rd harmonic current will circulate like this. So, 3 times E 3rd divided by the leakage impedance of this side, but if the at the fundamental frequency leakage impedance is x 1 it should be j 3 x 1. So, impedance also increases and there will be

circulating current little bit and this may cause extra heating no doubt because of this circulating current, there will be copper loss, extra copper loss and so, on. But nonetheless that major problem of getting at the output a voltage which will also have third harmonic component is avoided that is what is important. So, it causes extra heating slight extra heating will be caused. In any case now the question is what is the I will tell only general guidelines. For example, generally HV site. So, it looks like one of the site better be having delta connection.

So generally HV site is chosen as star star connection. Why? Because the voltage per phase will be less, so insulation level etcetera will be lesser. And LV site since the coils will be delta connected this will be low voltage, this is high voltage site this voltage will be also less because of this one and let this be delta connected that is the guideline delta.

But this is not all in fact, there are situations other reasons will override this that is may be the low voltage side is star, primary side is delta. For example, a distribution transformer typical rating is 6.6kv and 440 volt, what is done? Because this site it is a distribution transformer you must have the 3 phases as well as neutral. So, this must be of star connection and this must be this can be selected as delta because of the fact one of the windings I want to be delta that is the idea.

And from this I will be able to supply A phase with neutral to a group of consumers from B phase and neutral to another group and C phase to neutral to another group 220 volt supply etcetera can be done and everything is fine. So, depending upon the situations general guideline is high voltage side better select star, low voltage side delta as perhaps. So, one of the windings be delta connected is always preferable and sometimes if the voltages are high, what people do? They use star star high voltage on both the sides relatively high voltages. So, then select star star, but with star star there are problems we have seen, but what people will be doing they will also put another coil which will be delta connected.

That is there will be 2 secondary's because it is always preferable to have a delta and you suppose you require star star nothing doing high voltage this side high voltage this side, I will take advantage of lower insulation level this that. So, it is like this and you connect it and another additional windings therefore, for each phase then if I draw the limb of say A phase it will be like this A 1 A 2 and then small a 1 a 2 and another a 3 a 4. Two separate

secondary's are there for a for each primary similarly for B phase and C phase. Now, in this case we have seen and these two turns may not be same. In case of zig zag connection we saw this type of secondary's present, but those two secondary's were identical same having same number of turns you recall that. So, here it is N 1 may be this is N 2 this is N 3. Now, what I am telling is this is star connection A1 A 2, B 1 B 2 like that.

And perhaps this is the main secondary, this is main primary which is star connected may be this is A 1 this is A 2 B 2 C 2 etcetera and this is also star connected this is say a 1, this is b 1 correct b 1 and this is say c 1 correct way I have connected and this is the neutral a 2 b 2 c 2 I have connected. And this will go to the load and this one I have connected in delta this a 3 a 4, similarly you will have b 3 b 4 I think you are understanding what I am telling and you will have c 3 c 4 like the other two limbs and these I will connect in delta got the point.

So, you connect them in delta and 3 terminals will come out, here this winding which is connected in delta is called tertiary winding which is primarily added so, that third harmonic current about that problem you need not worry about circulating third harmonic current will flow. Not only that you can get then two different level of voltages and supply it two different loads also ok. Suppose some people use primary star secondary main secondary star and also here whatever voltage you get you supply another three phase load.

That is which two secondary's then, but sometimes no load is connected it is merely it is present because you provide the flow of the third harmonic magnetizing current in this winding. So, depending upon the turns ratio two levels of voltage you will be load may or may not be connected load may or may not be supplied; may not be supplied from tertiary winding.

I think you have got the idea. So, high voltage high voltage star star then delta, since I was telling you it is always better you have a delta connection somewhere and all this windings are wound on the same magnetic circuit. So, like a phase you have b phase c phase like here. So, that you B 1 B 2 here also small b 1 b 2 and C 1 C 2 small c 1 c 2 and then c 3 c 4. So, you have two secondary coils and they need not be of same turns

depending upon your voltage requirement, you can decide what should be your N 2 this is N 1, this is N 1, this is N 2, this is N 2 and this is N 3 is not this is the thing.

So we now understand that the things goes 3 phase transformer connection we have learned that is if I ask you make a 3 phase transformer connection star delta, delta star without first really questioning where should I use it that first I discussed confidently how can you do it do polarity test do that. And then we have pretty qualitatively of course, discussed about the third harmonic importance of third harmonic magnetizing current we present in the transformer in order to make the flux sinusoidal, hence the load voltage will be sinusoidal.

I do not know whether I have a previous one is there no. Let me tell you one interesting thing; for example, zig zag connection also we have done apart from star delta and this one, let me try today to do another zig zag connection just to telling you.

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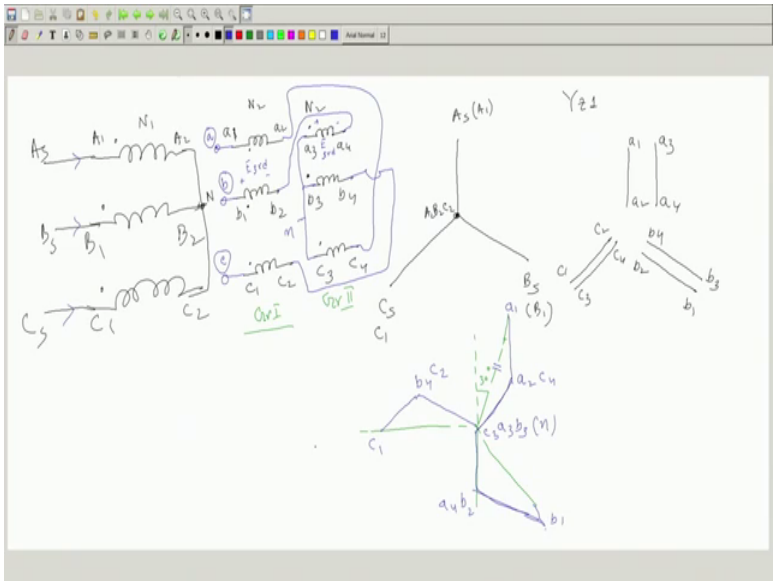

See suppose I want to make a delta zig zag connection ok. Why I am coming back to zig zag once again is because of the fact in star star zig zag connection if you recall 2 phases of on the secondary site belonging to two different groups they are connected in series ok. And the polarity dot polarity of this one we discussed about Y z 1 for example, let me tell that once again so, that you also have a practice and for example, suppose I want to do Y z 1, what should I do?.

Primary it will have two identical secondary's, this time it is identical not tertiary or secondary this is N 2 this is N 2 this is N 1 and this is A 1, A 2, let me do first a 1 a 2 and a 3 a 4 is not, then B 1 B 2 this is small b 1 b 2 this is b 3 b 4 and finally, you have C phase C 1 C 2 and small c 1 c 2 c 3 c 4. And all this odd numbers are dots relative to its primary this is one set, this is another set and this is another set and suppose I connect this two in star because primary is to be connected in star, then the I will connect this to supply A s B s and C s and your primary phrasal diagram will be very simple like this.

This is suppose A s B s because supply voltage is balanced C s and A s mean A 1 only this is B 1 and this is C 1 and this are A 2 B 2 C 2 this is the neutral of the transformer N. Now, on the secondary you know you have got this voltages a 1 a 2 and a 3 a 4 I am not explaining because we know this and this is 120 degree apart b 1 b 2 and b 3 b 4 and finally, you are also having parallel to c phase and this is c 1 c 2 and c 3 c 4 is not in this way it is there. Now, suppose I because zig zag connection is essentially star connection we know this is group 1 and this is group 2 ok.

So, I want to get y z 1 means this is the primary voltage primary voltage with respect to the secondary voltage will be lagging a line voltage with respect to secondary neutral will be lagging by 30 degree, is not? These will be the phase voltages, this we have done I will do very quickly. So, this is the thing. Now, while getting this voltage I want to get a 1 generally here. So, your output voltages will be this and this and as you can see it is a 1 a 2 and this is parallel to c phase and this I will take c 3 c 4 is not.

Similarly, this fellow can be broken up into this 2 phasors and this is b 1 b 2 and this is a 3 a 4 and this can be broken up into this 2 phasor's this one parallel to b 3 b 4 b 3 b 4 and this is parallel to c 3 c 4 c 1 c 2 is not then based on this I come here and connect accordingly. For example, a 1 a 2 is connected to c 4. So, take a piece of wire connect it and which 3 are shorted a 3 b 3 c 3 short them is not short them and I connect. So, ones will be the output terminals a 1 b 1 c 1 these will be my output terminals then b 2 is connected to a 4. So, b 2 is connected to a 4 and c 2 is connected to b 4 and your connection is over.

Now, only one point why I have redrawn once again is that only one point I want to tell. So, it is effectively a star connection there is a neutral point solid neutral point a 3 b 3 c 3 and there are 3 lines only thing is between the neutral secondary neutral that is n to one

of the lines, if you start your journey from neutral you will come across two coils belonging to two different phases that is a phase and b phase in this case if you start n from n traverse a 3 a 4 then traverse b 2 b 1 and get your supply b this is supply a load supply side this is c.

So, two coils are in series, now suppose in this connection neutral is not connected therefore, and there is no delta connection. Therefore, I am sure the current no third harmonic current exists here only 50 Hertz component of current will flow and in the core of the transformer third harmonic flux must exist. And that third harmonic flux is going to induced voltage both in the primary and the secondary coils is not and the polarity of those voltages are shown here.

Now so, far as the third harmonic voltage is concerned you see they are co phrasal. If this is plus this is minus E 3rd fundamental I am not showing and then this is also third harmonic E 3rd in all the coils third harmonic voltage will be induced and so, plus to minus and then minus to plus and you reach the neutral. So, what is the third harmonic voltage present across the phases? 0. Although in each coil third harmonic voltage exists, but in the phases no third harmonic voltage.

So, it is a superior thing compared to simple star star, but I take a zig zag coil which will at least ensure that there will be no third harmonic voltage in the phases that is this voltage, it will be RMS value only in the phases neutral to any of the lines and between the line of course, it will not be there therefore, it is a better proposition that way is not. So, zig zag connection has another interesting connection that perhaps, I will tell later or in your course of power system you will learn very easily now after you have understood this that, it can be used as a grounding transformer a better choice for a 3 phase transformer anyway that I am deferring now. So, far example this connection we have understood.

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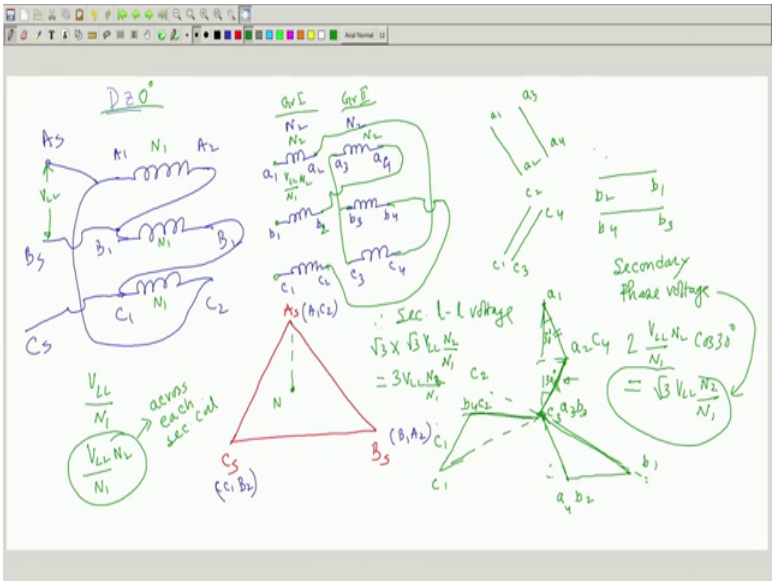

Another small connection as I was telling with D suppose I want to do a delta zig zag which I have not told, but let me do it. Suppose the primary winding is no delta connected zig zag winding I have done. So, that is why I am doing so, that you become more confident B 1 B 2 and C 1 C 2 and delta connections and it has got 2 secondary's identical N 2 N 2 turns mind you it is not tertiary one of them and this is N 2 N 2 turns and what is the point of writing. These are all same turns this is also N 2, this is also N 2 two secondary's corresponding to each phase. It is essential to make a successful connection to mark the terminals meticulously I mean you cannot do arbitrarily something b 3 b 4 and c 1 c 2 small c 1 c 2 small c 3 c 4.

Now, suppose I have decided I will connect it like this a delta like this and I will give supply A s here supply B s there in the B phase and supply C phase that is how I will give supply. Now, this side is delta delta connected. So, what is the rule? Rule is pretty simple supply voltage is balanced better draw that; that is A s B s C s which is balanced I know that is why I could make a equilateral triangle and show it and A s is once again you write with different colour say A s means what? A 1 C 2 A 1 C 2 and B s means what? B s means B 1 A 2and C s means what? C 1 B 2 C 1 B 2 is not same points.

And on the secondaries now you have these voltages available to you, what are the voltages? a 1 a 2 you know a 1 a 2 similarly parallel voltages of equal length a 3 a 4, similarly b 1 b 2 another voltage is available to play with b 3 b 4 and c 1 c 2; so c 1 c 2

and c 3 c 4. Now, I want to make some connection delta and secondary side zig zag. In this case you will find D z 0 degree or D z 60 180 degree is possible or so, how it is possible?

Because with respect to neutral on the primary side, this is the artificial neutral secondary side voltage will be also in phase with this parallel to this, a phase voltage of the secondary side and zig zag connection means star connection. Two coils belonging to two different phases are to be connected in series, one should be taken from group 1 other should be taken from group 2 the same rule.

So, and I would like to have the secondary voltage because no phase displacement, perhaps it will be I will take a 1 a 2 and is this voltage available? Yes a 1 a 2. Then I have to connect a another voltage from other group of this kind which is available in c and I will take it as c 3 c 4, is not? And the b phase voltage will be 120 degree apart and b phase is horizontal actually do not put it like this it is horizontal b 1 b 2 and this is b 3 b 4 these are horizontal why? Because b 1 b 2 is this. So, this voltage is the secondary phase voltage and it will be it can be obtained like this a and b.

So, it can be drawn like that I mean this no. So, here I would like to have b 1. So, I will sketch it b 1 first which will be horizontal here b 1 b 2 and then a like this and what is this voltage a 4 a 3 and finally. So, you can sketch it like this, this is a 1 which is this, this is b 1 and this is some c phase here similarly this can be drawn like this here and you can see this will become b 3 this will be horizontal actually b 3 and.

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b 4 and this point is c 1 c 2 is this ok b 1 b 2 was like this. So, this is fine a 3 b 3 c 3 are to be shorted you short them and then a 2 c 4 you join a 2 c 4 you join and then b 4 c 2 you join; b 4 c 2 you join. And finally, a 2 c 4 I have joined a 4 b 2 you have to join a 4 and this is 2 b a 4 and b 2 you join these two will be output similarly you will be able to calculate this one. Only one thing I will tell in this case suppose I want to this turns are known N 1, N 1, N 1 this is N 2, N 2. Now, same flux is linking this suppose you have applied a line to line voltage VLL here try to understand what I am doing, I know the turns ratio I have applied VLL which is known. I want to know what will be the phase voltage on the secondary side and what will be the line to line voltage in terms of this VLL, how should I proceed?

What is the voltage per turn? VLL by N 1 because it is delta connected line to line voltage comes here by N 1 and what will be the induced voltage? RMS value, VLL, voltage per turn into N 2 and this RMS voltage will be same for all this coils because they are all having same turns. So, I know the length of each phasor here to be VLL by N 1 into N 2 across each secondary coil, is not? That is voltage here VLL by N 1 into N 2, VLL by N 1 into N 2.

So, the lengths of this are known, then what will be the phase voltage? Secondary phase voltage very simple this is 30 degree, this is 30 degree and I know this length. So, each length that is VLL by N 1 into N 2 cos of 30 degree will give you half twice of that, cosine 30 degree into twice of that because projection of this is also same. So, this it will come out to be root 3 VLL N 2 by N 1, root 3 by 2 two cancels out and what will be the line to line voltage available on the secondary side?

Root 3 times this phase voltage that is this one is the phase voltage. So, secondary line to line voltage will be root 3 times this root 3 VLL n 2 by n 1. So, what are the things it comes out to be this? Similarly try your on your own that star star star zig zag connection if the line to line voltage is known, what is going to be the phase voltage and the line to line voltage. So, we will continue our discussion on transformer in next lecture.

Thank you.