Electrical Machines - I
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Lecture - 41
Zig Zag Connection

Welcome, to lecture number 41st lecture.

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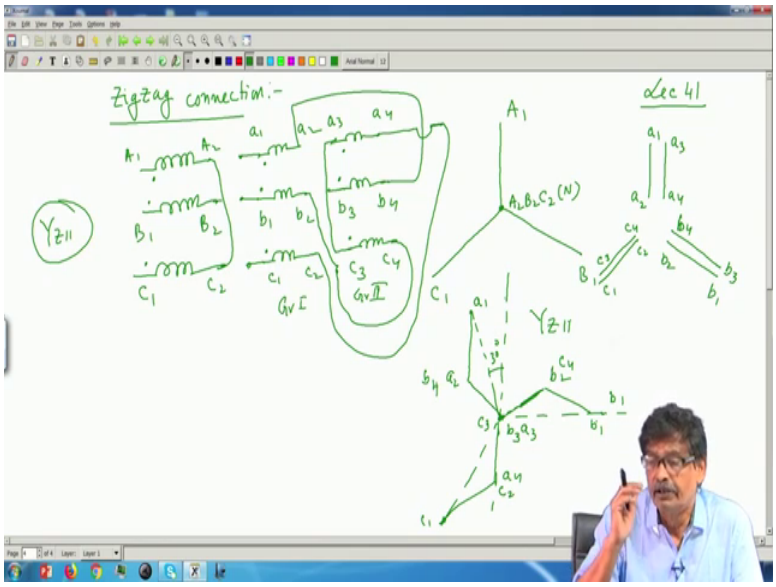

And, we were discussing Zig Zag Connection of three-phase transformers this three-phase transformers could be three individual units. So far as connection is concerned you can implement any connections, but to implement zig zag connection of course, there is a condition that each phase must have two secondary coils A 1, A 2 this is small a 1 a 2 and B 1, B 2 b phase primary it will have two coils a 1, a 2 and a 3, a 4 and then small b 1, b 2 and here it is b 3, b 4 and finally, the C phase and this I have assumed these are dots odd numbers.

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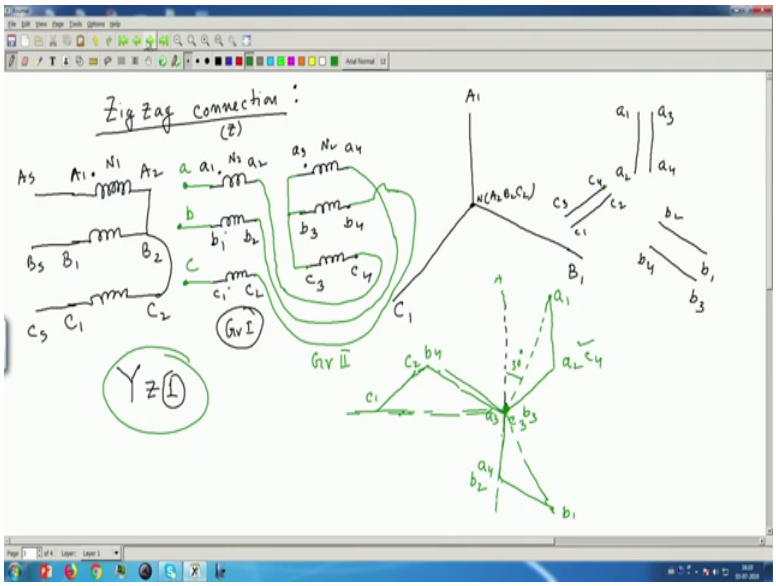

And, last time I told you how to implement Y z 1 connection see Y z 0 is not possible you cannot have a Y z 0 connection you think about that, but Y z 1 is possible. Now, let us try today say Y z 11 so that you can practice it Y z 11 connection whether it is possible or not that will also come out Y z 11. So, in this case primary I will short steps are like this and then primary phases I will draw. It is star connected, it is like this is A 1, this is B 1, this is C 1, this point is A 2, B 2, C 2, this side neutral and, on the secondary the moment you do like this you apply voltage secondary you immediately get two sets of voltage for each phase and these two sets are identical a 3, a 4; a 1, a 2, a 3, a 4.

Similarly, b 1, b 2 and you draw these not b 3, b 4 and then finally, this two parallel to c phase c 1, c 2 small c 1, c 2 and c 3, c 4. Now, in this case this is the primary voltage whether 11 is possible, zig zag connection I know three terminals will be shorted. So, there will be a neutral point available looks like a star connection. Therefore, whatever will be the phase voltage staring from that neutral of the secondary side that a phase voltage must lead this a phase voltage.

Therefore, I draw first this a phase voltage that is at 12 and then I am expecting my thing here at 30 degree you know this is also straight forward; similar to the previous one, I am just doing so that you get used to it. So, this must here from the a phase from the secondary side must come in and I will prefer that it comes out from small a 1, that is what I prefer and naturally and similarly your b phase with respect to waver will become

the neutral that I will see after completing this b phase also should come from b 1 I would prefer and similarly the this is 120 degree apart c phase must come out from this.

Now, as you can easily see this a 1 it can be nicely placed here a 1, a 2; then how to reach from this point to this point by a b-phase voltage; should I use b 1, b 2; no, better use b 3, b 4. You can use b 1, b 2 mind you, but you should be systematic. So, this is group 1, this is group 2. It does not matter whether you either of them you can use, but I will use put this conditions. So, this will be your b 3, b 4; is not?

Similarly, this b 1 phaser is this b 1, b 2 I will quickly draw and this must be come from c 3, c 4 c 3 c 4 and I know b 2 c 4 is to be shorted and this fellow will come from this; that is this is c 1, c 2, c 1 c 2 and then this is only left out thing is a 3, a 4. Therefore, you will be joining this time a 3, b 3, c 3 I will short and then I will take out the secondariess from this, this, this then a 1, a 2 should be joined with b 4, b 3 coils.

So, I will take a piece of wire a 1.

Student: (Refer Time: 06:30).

Ah.

Student: From a 2 from a 2.

Oh sorry, correct not this one a 1, a 2 then a 2 should be joined with b 4. So, a 2 I will take and join with b 4 then b 2 I will join with c 4 that is this one and c 2 c 2 with a 4 c 2 with a 4 and your connection is over and this is Y z 11 ok. Similarly, you can try d z connection. These I leave you as an exercise whether primary delta, secondary zig zag can be connected or not and what are the possibilities.

So, zig zag connection essentially means that it will be two coils in series essentially star connections, but they will belong to two different phases there are some advantages of this connection. Now, after I have given you how to connect logically how to implement logically different connections I give it to you that I will be able to do. Now, I will discuss that after this discussions I am now familiar with the connections the question is when to use what connections.

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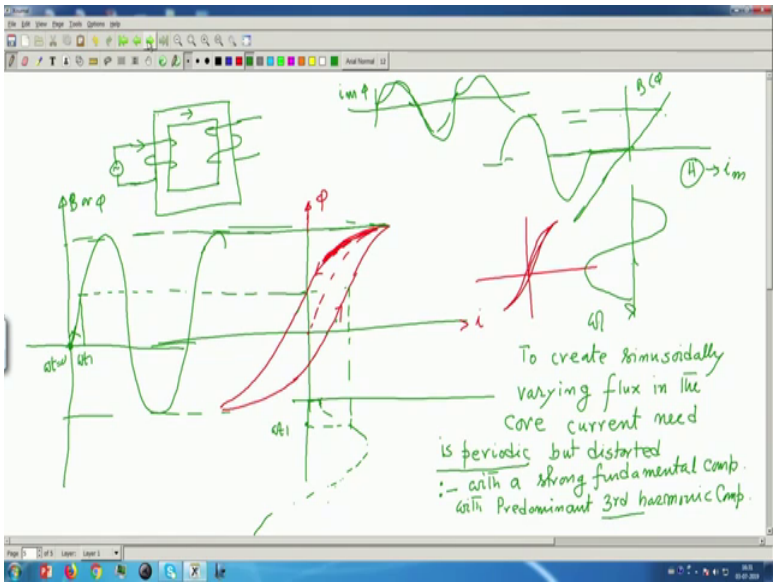

Before I start discussing on that now I will tell you one very important things that happen in particularly three-phase transformers, three-phase practical transformers. You know that if the B-H curve of a cone material is linear. Suppose, the B-H curve is linear of the core material B means this is also phi, B into area.

So, if the core material and H means what? Effectively magnetizing current it means also that you we are now familiar with this. If this informations are important to understand what I will be talking about; what I am telling if I say in the core of a transformer I will go first but it will be a qualitative discussion primarily. Suppose, you have a transformer single phase transformer. What I told you that you apply a sinusoidal voltage, a sinusoidal flux is guaranteed nothing doing because it has to satisfy the KVL equation there and your supply side is a sinusoidal voltage that is fine.

So, I will now examine two things: one thing is, suppose, flux in the core of the transformer is sinusoidal, what will be the nature of the current? Nature of the current if the flux is sinusoidal, suppose flux is varying like this, this is B-H curve. So, go to a particular B and sketch the this side is what should I say is this the thing I mean yeah this is omega t suppose I mean be it different values and here it is omega t.

Then if this is B or should I have being drawn here. So, for sinusoidal flux, the projection if you want to generate this much flux the current value too will be maximum there. It

will be also sinusoidal because projections it is a linear line nothing is everything is fine. Sinusoidal flux you want to create you require sinusoidal current that is the conclusion.

Reverse way, if you pass sinusoidal current you are guaranteed flux will be sinusoidal in the core ok, but we know that B-H curve of the core of a practical transformer is neither linear not a single valued function because of the presence of the hysteresis. See, in our derivation of hysteresis laws I did not discuss that because till this time because I now it is now you will appreciate this point because what happens is this B-H curve is not linear not only linear it is double valued function for a particular H for going up.

So, so it will be B-H curve will be something like this, This is the B-H curve; this is for raising value of current you have to use this for decreasing value of current you have to use this. Of course, we must see that this area is thin. I have drawn it exaggerated it should be like this very thin , but nonetheless there is some hysteresis in order why it should be thin because hysteresis laws you want to minimize. Area of this curve represents the hysteresis laws per unit cycle per unit volume or kg of the iron material that we have discussed.

So, this side is the current and this side is the B or flux I can denote it. Now, I will ask myself that if I say the value of the flux with respect to time changes like this I will better do not put omega t like this suppose this is time axis and I say that B value is changing phi or B value is changing with this. The question is very innocent. Suppose, this is B or phi, suppose I want to create a sinusoidal flux what should be the nature of the current? I now know it cannot be purely sinusoidal because it is not a linear line relationship.

For example, what I am telling when B is 0 at this point and it is increasing where from should I read the value of the current? This is omega t equal to 0 say, B is increasing. So, from this curve so, you drop a for example, take this point at omega t equal to 1 omega t 1 at this time, this is the flux how much current is necessary, go horizontally. Which point should I read; this point or this point; it is a double valued thing, phi is increasing. So, phi is increasing means this one. So, come here and read the value of the current this much current and this where should I plot? I will plot it at omega t equal to 1. This much I will say is the instantaneous value of the current needed.

At omega t equal to 0, phi is 0 but flux is increasing; should I read from this curve or this curve; from increasing flux. So, from this curve only. So, at omega t equal to 0 also it

will have some value here; not 0, phi 0 it is not that exciting current is 0 because of the presence of this one. So, in this way I can map each value of flux and get the current wave form.

Now, this current waveform will be periodic no doubt, but will be distorted not purred suppose it is 50 Hertz phi is changing I want to create a 50 Hertz flux 1 frequency and why I want to create a single frequency flux here because my induced voltage across the secondary which is going to supply a load that will have a single frequency voltage I do not want any other harmonic component of voltage to be induced. Only phi should be there, that is my ideal thing I am desiring here whatever phi is there that must be phi max cosine omega t. But, what I am telling this flux distribution the current distribution here will not be linear it will be distorted but periodic in nature.

I am not sketching in the notes I have drawn nicely. So, the thing is the conclusion is because of the hysteresis loop because B-H curve is of this type to create sinusoidally varying flux in the core current needed is periodic but distorted. What this distorted means? It means that since the current wave form is periodic I can do the Fourier analysis.

Periodic with same frequency omega, I mean time period will be 50 milli what with that supply periodicity this because this flux is moving with some period periodic time. So, with the same periodic time it will be changing, but the question is that can be then Fourier analyzed that is it will be a 50 Hertz only this.

So, current waveform may be it will be like this and repeating, are you getting? This is the magnetizing current but not sinusoidal and it can be broken up into a fundamental 50 Hertz and lot of odd harmonics because it is the negative half is same as the positive half and so on. Therefore, only odd harmonics will be present if you Fourier analyze this x exciting current and you know with higher order harmonics the amplitude of the coefficient of the harmonic terms they get reduced generally and therefore, is periodic, but distorted with a strong fundamental component with predominant third harmonic predominant third harmonic component; got the point?

That is the exciting current, in this coil then I will demand do not pass pure sinusoid current. If your goal is to pass to create a sinusoidal flux in the core and you are planning to get one frequency voltage across the secondary of the coil of fundamental frequency,

then the exciting current pure sinusoid will not do. If you neglect the other higher order harmonics you will demand that there should be a 50 Hertz component current as well as 150 Hertz component of current must be present.

In order that flux in the core can be sinusoidal of 50 Hertz 1 frequency flux 50 Hertz to be created and you require a 50 Hertz component current and 150 Hertz component current other higher order harmonics fifth harmonic 250 Hertz ok, we are neglecting for the time being. So, this is the thing.

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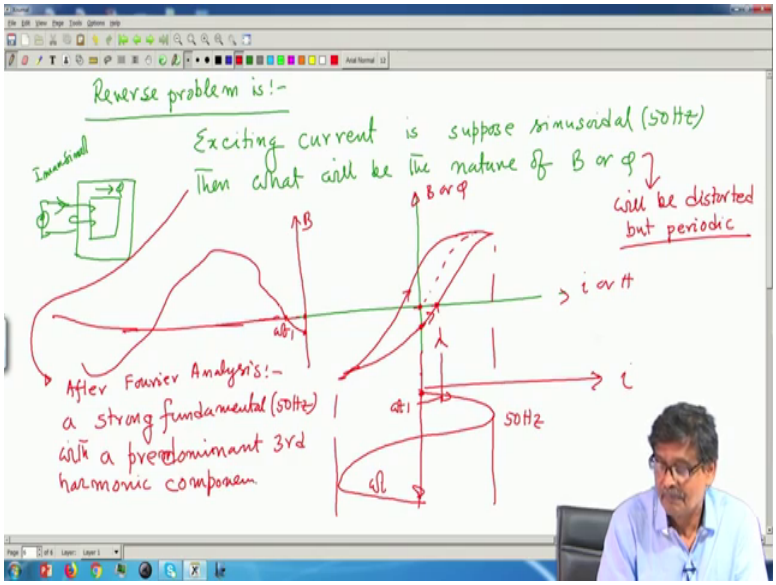

The reverse problem is; the reverse problem reverse problem is that exciting current is suppose sinusoidal is suppose sinusoidal; sinusoidal of 1 frequency say 50 Hertz. Then, how the flux will look like; flux how the flux will look like means what I do not know very good English but anyway it is there. So, the problem is like this same core, but this time you pass sinusoidal current from a current source.

This exciting current I will pass some I max sin omega t, I have forced it current a current source imagine, you need not bother. Suppose, sinusoidal current it is excited I want to know what will be the nature of then what will be the nature of flux waves; then better what will be then what will be the nature of B or phi? That is what. So, same problem; so, draw the B-H curve as I have drawn previously this is the B-H curve.

Now, what I am telling is this is omega t and I am telling now this current waveform mind you, this axis is either current or H this axis is B or phi for a transformer. Now, what I am telling, I will make the current waveforms sinusoidal 50 Hertz, 1 frequency will B the reverse way current is sinusoidal what is the nature of B? In the previous case, what I told, if you want to create the B sinusoidal what is the nature of the current; current is distorted.

In the same way if you want to create pass a 50 Hertz current what is this axis? i then the flux will be produced once again I will sketch it suppose current is 0 and increasing this point. Current is increasing and 0, this is the B produced, not 0; is not? So, B will be some negative value at this time and I can go for each of the point when the current has positive some value that is this value this is corresponding to say omega t 1 at omega t 1 how much is the flux; negative.

Student: (Refer Time: 26:48).

Ah?

Student: 0.

Oh flux is 0, correct omega t 1 flux is. So, it will be some somewhat it will now be distorted are you getting point by point if you go because of this double valued nature of the function of the B-H current. So, the nature of B or phi will be distorted will be distorted, but periodic why not, but periodic. Then this B distribution or phi once again can be Fourier analyzed and you will see that it has got a strong fundamental with lot of odd harmonics because the positive and negative excursion of this B will be same.

Therefore, I will say that what will be the nature of B or phi? The answer is it will be distorted, but periodic after Fourier analysis I am sorry. After Fourier analysis, you will come to the conclusion that a strong fundamental that is 50 Hertz in this case with a predominant third harmonic component.

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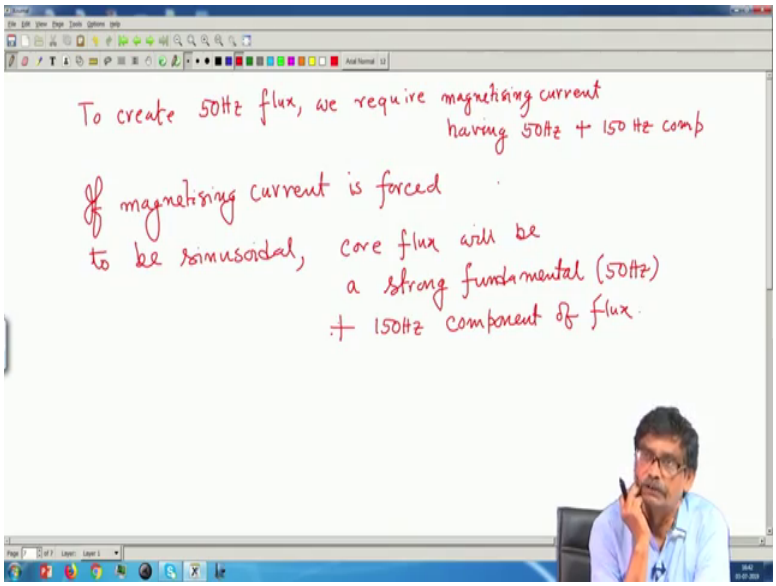

So, in summary I will say that to create flux to create 50 Hertz flux in the core I am not writing this we require we require magnetizing current magnetizing current having 50 Hertz component 50 Hertz fundamental plus 150 Hertz component; amplitude I am not telling a little a thing it will be required for majority will be this.

Similarly, to create similarly I will say if magnetizing current if magnetizing current is forced to be sinusoidal to be sinusoidal core flux will have will have a strong fundamental strong fundamental that is 50 Hertz component sane result opposite way and plus 150 Hertz component of flux. So, this is necessary to know and this is all because the B-H curve is not a straight line ok, it is because of the hysteresis loop.

So, what happens is, if suppose the core flux want to create 50 Hertz 1 frequency that is 50 Hertz only sinusoidally varying, then I am telling exciting current then should have a 50 Hertz component plus a 150 Hertz component. The reverse way if somebody says magnetizing current I will somehow manage it to be 50 Hertz 1 frequency fundamental 50 Hertz component; no distortion. Then what will be the nature of the flux; then also the core flux will be distorted and it will have both 50 Hertz and a 150 Hertz predominant harmonic component.

We will continue with this discussion in the light of transformer connections.

Thank you.