Electrical Machines – I
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Lecture - 42
Effect of 3rd Harmonic Exciting Current and Flux

Welcome, to lecture number 42nd and we were discussing about some 3rd Harmonic Exciting Current and 3rd Harmonic Flux. And, the conclusion drawn from discussions in my last lecture is that if the exciting current or magnetizing current is 50 Hertz sinusoidal only pure sinusoidal 50 Hertz exciting current, then flux created in the core will have a fundamental and a third harmonic component in the reverse way if you want to create sinusoidal flux 50 Hertz pure sinusoidal flux then the exciting current must have along with a 50 Hertz component, a predominant third harmonic component exciting current will be needed.

So, this is because of the fact the Mac B-H curve of the material has a loop double valued function sort of thing that creates the problem although the area of the B-H curve that B-H curve is very thin, but nonetheless that third harmonic thing will be produced. Now, in the light of this knowledge it has nothing to do with I mean as such transformer magnetic material is given whose B-H curve is like a hysteresis loop. Then I can come to these conclusions thinking that somehow I will pass sinusoidal current, what will be the nature of the flux? I ask myself and get the answer.

Similarly, if I want to create sinusoidal flux what should be the nature of the exciting current this is the thing we have discussed, although qualitatively no mathematical analysis, but which was reasonably good it can be appreciated yes, this is going to happen.

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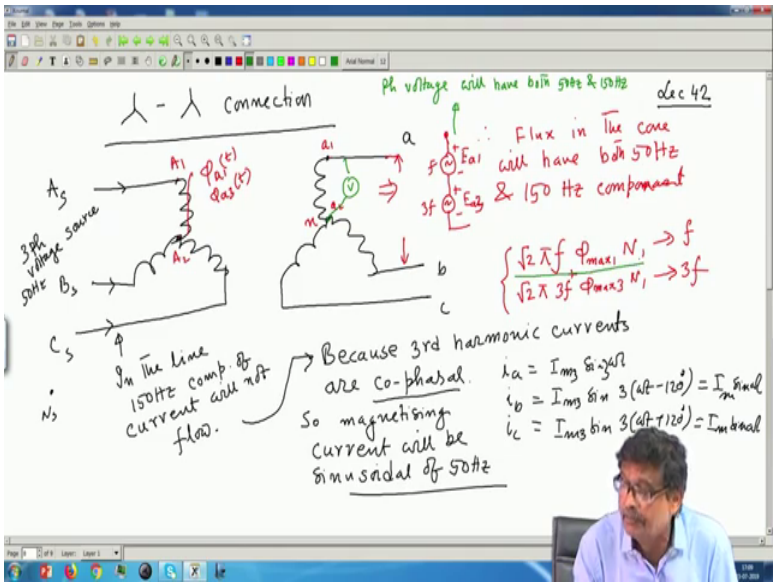

Now, today I will discuss for example, take the star-star connection of a three-phase transformer ok. Now, continuing with that so, consider start star connection of three-phase transformer and this connection can be obtained by using three single phase transformers or a single three-phase unit transformer first let us see that, but the connections are same in both the cases. So, suppose I will simply draw like this now because we will presume that whoever is connecting is connecting correctly.

So, primary is star connected so, draw it star; secondary is also star connected, draw it star this is the thing and what I told you that I will connect it to supply A, B, A s, B s, C s is the supply. Here the output is a, b and c star-star connection. And, the neutral point of neither of them is grounded nothing is done, but what have done is this I have applied a three-phase voltage source here voltage source balanced voltage source, supply may have a neutral, but that has not been connected anywhere only the three lines I have connected.

Now, the with secondary opens suppose nothing I have connected here what in general I was discussing you have applied line to line voltage, you will get root 3 times less this voltage is not b l l by root 3 will come across a phase that into n 2 by n 1 etcetera you will get phase voltage like that we are discussing. Now, first thing I will say in this connection one thing is clear. Now, it will draw some magnetizing current with

secondary open magnetizing current it will draw and in the core of the transformer my attempt will be to make the flux sinusoidal.

Why? Sinusoidal with 50 Hertz component alone because of this fact that I want to get 50 Hertz voltage only to be generated in the secondary coil. I do not know want that third harmonic voltage in any way coming across the secondary and creating problem for the load I want a 50 Hertz supply for the load.

But, if the connection is like this and with our previous knowledge we immediately conclude that this currents whatever current magnetizing current it will draw it cannot have a third harmonic component. To create flux in the core you require a 50 Hertz suppose 50 Hertz source in that term will say and to create 50 Hertz flux in the core of this transformer I require a 50 Hertz plus 150 Hertz component of the exciting current also higher order fifth, seventh, but those I am neglecting predominant thing is third harmonic.

But, what I am telling is in the line; in the line in this type of connection in the line 150 Hertz component of current will not flow will not flow ruled out why because third harmonic which is 50 Hertz third harmonic currents are co-phasal because if you say i a is equal to some I m magnetizing currents sin omega t i b will be very quickly m writing I m sin it will be.

Student: (Refer Time: 08:10).

Sorry, i a sin 3 omega t suppose third harmonic current then i a sin 3 omega t minus 120 which is same as I m sin 3 omega t co-phasal and i c is equal to also I m sin 3 omega t plus 120 degree same as I m sin omega t. Fundamental component, this will be sin omega t, this will be sin omega t minus 120; I m 3, third harmonic magnetizing current it will be like this.

So, they are co-phasal meaning that if third harmonic current flows here at any instant if this current going this way is 5 ampere, this will be also 5, this will be also 5 ampere and they will meet here they will not vanish KCL will be violated which is not the case with fundamental component fundamental component if it is at any time suppose the instant when F s current is maximum positive say 10 ampere then b c will be minis 5 minus 5. So, it will return via this path.

Therefore, in the lines I am here about one thing if no neutral etcetera is connected to the system here about this fact no one can contest. In these lines only 50 Hertz component of current will flow, no third harmonic business. So, exciting magnetizing current will be sinusoidal of 50 Hertz only no question of other it will be [FL]. If that be the case then we have learned you are exciting the coils with 50 Hertz current can be flux in the core be sinusoidal? Certainly not; the flux in the core then will have both 50 Hertz component and 150 Hertz component.

That is the conclusion is therefore, flux in the core will have will have both 50 Hertz and 150 Hertz component of course, the amplitude of the harmonic flux will be much less compared to may be 10 percent of the rated flux fundamental component, that is there. But nonetheless both of them will be present. So, in the core of this transformers there exists now two fluxes of 50 Hertz and another is 150 Hertz.

Therefore, induced voltage in the coils say this is A 1, A 2 this is small a 1, small a 2 and so on b 1, b 2, b 3. So, here these coils will then be linked with phi 1 fundamental say f s 1 t plus phi a 3 t both of them will be linking this. Therefore, both of them will induced voltage induced voltage remind you it is equal to root 2 pi rms value of the induced voltage f phi max fundamental into N 1 due to fundamental component. And, due to third harmonic component the rms voltage will be root 2 pi 3 f mind you this factor will come here; phi max of third harmonic component into N 1 both this voltage will be present this is of frequency 3 f that is what I am telling.

And, this induced voltage will be also here in this secondary because same flux links both primary and secondary. Therefore, across the phases of both primary and secondary as if there will be two sources of m f between a and this n small n, there will be one source E a 1 and another source rms value E a 2 of course, they are of different frequency E a 3 3 f and this is f two sources of emf will be existing between a 1 and a 2 and, similarly for b phase and c phase.

Therefore, across the phases both in primary both in primary and secondary coils, the induced voltage will have a 50 Hertz component as well as 150 Hertz component and that is what I am telling is not desirable. Now, the question is what about line to line voltage? So, the conclusion is here the phase voltage will be corrupted with a 150 Hertz component apart from that 50 Hertz component.

So, so phase voltages will write here phase voltage phase voltage that is this diagram suggest will have both 50 Hertz and 150 Hertz. Now, what I am asking is what will happen to line to line voltages? See once again this is the f s. Let me go to the next page.

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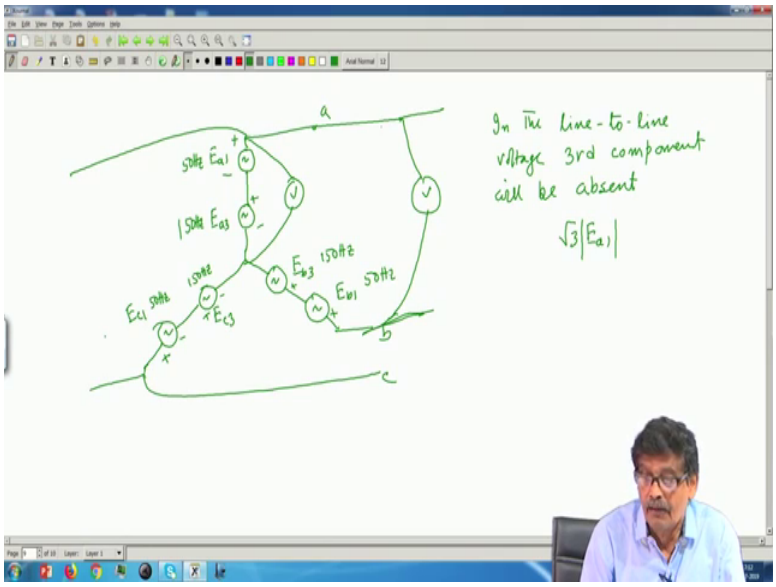

So, I am telling that I am drawing the secondary induced voltages suppose. So, I told this is E a 1 50 Hertz in series with another induced AC another induced voltage E a 3 a phase third harmonic 50 Hertz and then this is your a terminal. Similarly, for b phase E b 3 this is 150 Hertz; E b 3 150 Hertz. Then E b 1 fundamental component 50 Hertz and finally, this c phase E c 3 third harmonic component plus minus AC 150 Hertz and then fundamental component E c 1 50 Hertz is it not? This will be the thing, this is your b terminal going towards load c terminal. Similarly, in the primary coils, do not worry about that.

Now, so, if you take a voltmeter, connect it here across the here suppose I take a voltmeter connect here what it is going to read? It will be reading there are two AC voltages of different frequencies, but this voltmeter reads rms values. So, rms values square plus this rms value square by root 2, is not? Whatever is that formula I can I will be able to calculate that rms value. So, it will not read this fundamental component rms value, that is what I am telling if you connect it here.

The question is what will be the if I connect a voltmeter here between the lines what will be it is reading? See, third harmonic voltages once again are co-phasal. Therefore, if you

traverse this path third harmonic voltage will cancel out therefore, in the in the line to line voltage in the line to line voltage. Third harmonic component will be absent will be absent and here you will get this reading will be root 3 times E a 1 what I am trying to tell because E a 1, E b that is rms value.

Therefore in the line to line voltage only 50 Hertz will be there, but across each phases the third harmonic component will be there, got the point? Therefore, in star-star connection like this with no neutral connected anywhere isolated, the supply neutral I have never connected, but I can tell you one thing about this.

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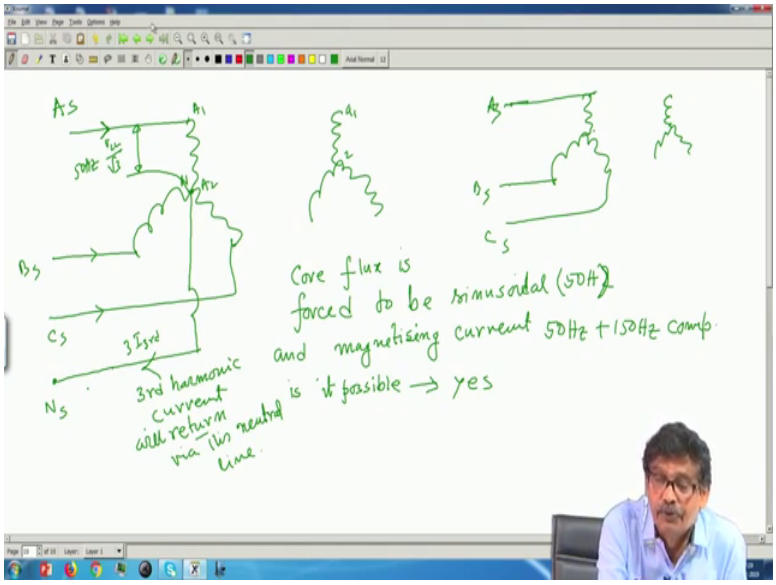

Suppose, I say that this is the primary star this is the secondary and for a change what I will do this is A s I wrote this is B s B s 1 I wrote like that. So, anyway so, this is B s I wrote is not B s and this is C s I have drawn and the supply neutral listen to this point also I have connected to this primary neutral.

Suppose, it is this connection is slightly different from the other balance three-phase voltage to this and also neutral to this; supply voltage is balance three-phase voltage. Therefore, I have applied across A 1 and A 2 a sinusoidal voltage across A 1 it to I have applied a sinusoidal voltage. Earlier how much voltage I have applied here I cannot say the voltage across the terminal of the coil is V a by root 3 where neutral was not connected that is the let me draw on the same page.

What I am telling in this case when neutral was not connected situation was like this A s, B s, C s supply neutral was not connected. I can only claim that between these two lines I have connected a 50 Hertz voltage. But, I am not sure if I did not know anything about third harmonic voltage I would have perhaps concluded that the voltage appearing across these is this by root 3.

But, that notion is to be changed now because of the fact that we know similarly, in the primary side there is a fundamental component voltage there is a third harmonic read this capital A 1, B 1, C 1 also same thing. So, between the lines only fundamental will come it is matching that KVL is not disturbed so far as supply is concerned. Only thing is that V l l by root 3 is phase voltage you will never get because of the fact in the primary coils also the fundamental and third harmonic will appear, got the point?

But, now in this connection when you have forced this supply neutral to be connected with the primary side neutral of the transformer supply is being balanced. So, A s N s connected across these one is a 50 Hertz voltage I am sure about that are you getting here this voltage applied is V l l by root 3 that I nobody can contest 50 Hertz of 50 Hertz only pure 50 Hertz because supply is balanced 50 Hertz. Supply I am considering it has got no harmonics.

So, it will come here, but if this voltage is 50 Hertz then the flux in the core has to be sinusoidal because KVL is to be satisfied here. Then in this connection the core flux will be sinusoidal 50 Hertz, no this way that way. So, so in this case core flux is forced to be sinusoidal 50 Hertz only 50 Hertz nothing. But, we have learned code flux is sinusoidal then exciting current must have a fundamental and third harmonic.

Is there a path for third harmonic current to flow? Yes, there is. This current drawn from the supply third harmonic current can be drawn very easily, because of what? They are co-phasal, but there is a return path for the third harmonic current each this current, this current, this current their instantaneous values are same so far as third harmonic current is concerned. But, they will converge here and through the neutral it will go back to this supply.

Therefore, in this case flux is forced to be sinusoidal with 50 Hertz and magnetizing current, then must have both 50 Hertz plus 150 Hertz component. Is it possible? Answer

is yes because of what? Third harmonic current will find its return path by this third harmonic current will return via this path the neutral line, got the point?

And, if that be the case third harmonic current can flow in this connection flux will be sinusoidal. Therefore, in the secondarys of this transformer small a 1, a 2 etcetera only 50 Hertz voltage you will get both line to line as well as phase because not third harmonic flux exist, very nice, but only objection to this connection is this neutral wire will carry 150 Hertz current and it may disturb other electrical utilities. Earlier we used to say transmission line used to go via the telephone lines also, earlier days telephone lines where there. So, they can interfere with communication lines 150 Hertz slightly higher frequency.

Therefore, that way it is slightly disturbing, but otherwise things will work everything will be fine. So, third harmonic current 3 times the third harmonic current will flow for A phase third harmonic plus B phase third harmonic. So, you understand. So, 3 times I third harmonic current for each phases will flow here, but everything will be fine, got the point? We will discuss with these with other connections, but now looking back to single phase transformer what is going to happen?

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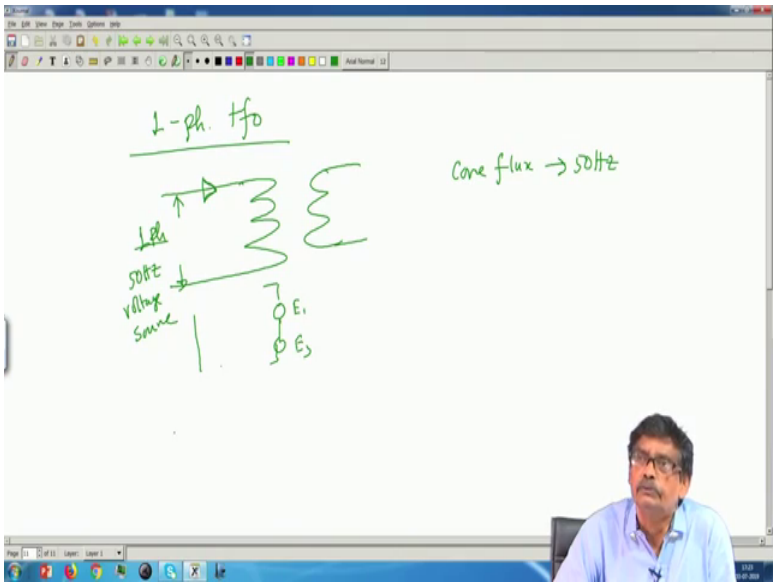

It is qualitative discussion let us do that. So, in single phase transformer what is the implication of this knowledge third harmonic flux, third harmonic excited current etcetera? In single phase transformer you know this is the supply you are connecting;

single phase 50 Hertz voltage source and this is your secondary. And, I have ensured that this voltage applied is 50 Hertz. So, what will be the core flux? If this voltage is 50 Hertz core flux has to be 50 Hertz core flux also we have only one component 50 Hertz.

How? Because you have applied sinusoidal voltage it has to satisfy and secondary voltage you will be also sinusoidal 50 Hertz. But, then we ask what about if the core flux is sinusoidal the magnetizing current must have a third harmonic component. It cannot be 50 Hertz current alone. The question is there a path for third harmonic current? Yes, it can flow like this no problem because no three-phase business is there return path through star nothing like that.

So, third harmonic current can flow here like this. Now, only question is where is the source of this third harmonic voltage? People say that you imagine first that the core flux is suppose the magnetizing current drawn is 50 Hertz only suppose you start arguing like that 50 Hertz current is drawn flux will be distorted fundamental and third harmonic. So, this coil will have a fundamental voltage induced third harmonic voltage induced and this third harmonic voltage itself will circulate that current because it is a closed path it is getting. Therefore, it will self correct itself and the flux will be restored to 50 Hertz component alone.

So, the problem in a single phase transformer so far as third harmonic flux etcetera is concerned is not that very critical, in the sense that if you assume the current drawn is sinusoidal only then you will say then flux must have got disturbed 50 Hertz and 150 Hertz. So, here there are two sources that is the way I drew, fundamental component and third harmonic component. But, this circuit is closed, and third harmonic component can produce its own third harmonic magnetizing current to restore the flux to the sinusoidal value something like that and everything will be fine.

So, further discussion on these I will do in the next class where then will try to understand which connection to use when.

Thank you.