Electrical Machines- II
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Lecture – 15
Flux Density Distribution along the Air Gap (Contd.)

So, we have discussing about the B distribution along the air gap of a rotating machine we considered a single stator coil if you recall.

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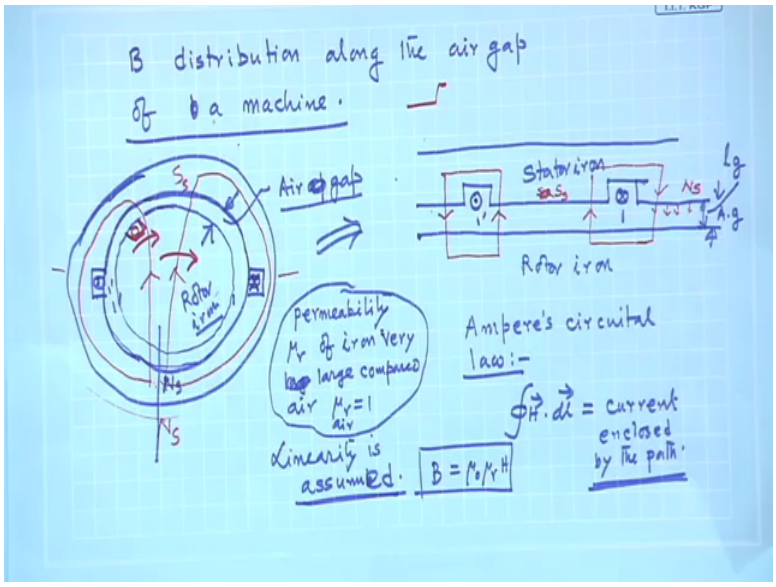

Only a single coil which can have multiple turns and if you pass DC current to draw the MMF we are assuming we are passing DC current. It will not at all be difficult to sketch the waveform if it is a time varying current that I will tell you give you glimpse very simple, but anyway and suppose there is the rotor iron and rotor has not got any coils to begin with that is what I told and if you do this, this fundamental things always you apply to have to convince yourself what is what.

For example, here the lines of forces will be doing like this. So, this stator this surface will become a South Pole and stator this half will become a North Pole and this is the developed diagram that is suppose I have cut it like this spread it around. Then one will appear here, one dashed here, then same currents and this coil this is a coil means at the back they are joined, it could be a multi turn coil and then this is the current.

So, along the flux lines will be if you consider any flux line it will cross the air gap twice and it will also complete it is path by this stator iron and the rotor iron under the assumption that the permeability of iron is infinitely large very large so, that we conclude that no MMF is necessary to send flux lines through the irons. So, all the MMF's will be consumed to establish flux in the air gap of the machine, air gap is that thing stator inner surface and rotor outer surface this separation that is l g.

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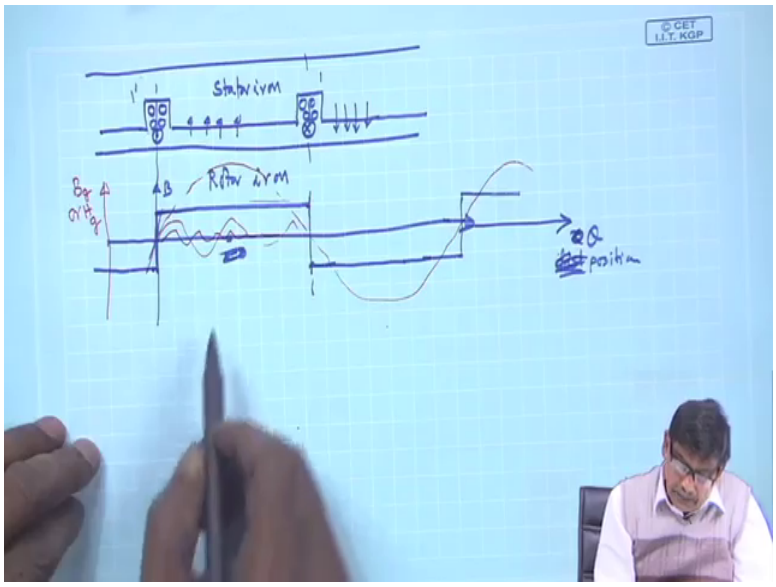

So, doing this we ultimately last time I told you if you have a stator coil like this nothing wrong in repeating that. So, that it is really understood it is the multi turn coil it is also a multi turn coil and this is stator iron and here is air gap and this is the rotor iron below. And then against the distance space if you sketch B, B or H B g H g generally g I will avoid later after you get a custom with it. Then if this conductors are carrying dot currents this conductors are carrying cross current constant magnitude, then what you do at the center of this slots you draw 2 vertical lines.

And between them it will remain constant and it will switch over to negative sign because lines of force here are like this, South poles and here the lines of forces will be like this. So, so it will be like this here till once again you will see this one dashed and this is one symmetric square wave plus 2 minus series you will get. This is B or H and here as I told you it will this jump from here to here by applying ampere circuital law one could do further more detail that is you go by your small distance what is the current

enclosed like that it will go on increasing. Let us assume like this that linear increase or decrease we neglect will just say vertical.

This is how distribution is because after all slot width is very small compared to the pole pitch of the machine, anyway this is the B distribution. Now this B distribution we never know will decide what will be the nature of the generated voltage in a conductor which may be housed on the rotor surface and is rotated. So, same B distribution will be the induced voltage collaborative that is why knowing the B distribution pattern is important this is x distance and where is x is equal to 0 is your or my business you can set x equal to 0 is there. And that is not very I mean one has to of course, fix where is x equal to 0 then he knows everything write this waveform.

Now this is fine, but as I was telling our intension is to get sinusoidal voltage generator. So, to get the sinusoidal voltage generator I would expect that B should be made also sinusoidal, then no one can contest way if distribution is sinusoidal we have induced voltage too will be sinusoidal, but it is not going to be as we are seeing a single coil like this, at best you can say it has got a strong fundamental sinusoid with lot of odd harmonics with reduced amplitude perhaps you can neglect those and only fundamental you can say.

For example if such a square wave voltage is applied to a iron circuit how to analyze that I will say that this I will Fourier analyze get a fundamental, then third harmonic, then fifth harmonic with reduced amplitude and for the fundamental if I pretend that if this amplitude are too small compared to these their effects on current will be less and you satisfy this is a sinusoidal voltage. Of course, in detail it can be analyzed fundamental you find that find out the impedance root over r square cross omega square l square, for third harmonic the impedance will be root over r square plus 3 omega l whole square and so on and for each of them you will get sinusoidal terms and add them up to get the total current.

But target is to get a very strong fundamental sine wave that is to be done now how this can be done. One way of doing this at least trying to get to that sinusoidal thing is to say that instead of single coil why not use several coils, which will be connected in series and that will alter the shape of this B H curve, how this can be done, what I mean to say that in turns of coils let me draw what I want to say that so, long.

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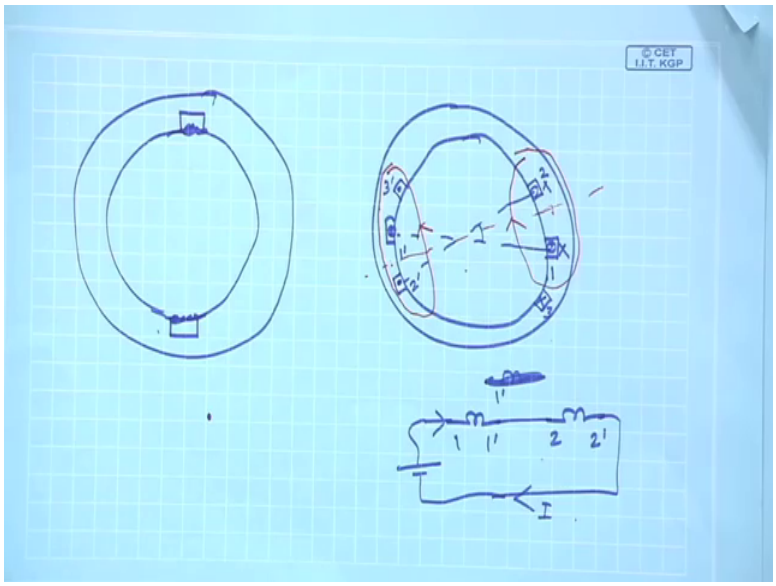

I have taken a I will draw very first let this be very bad drawing, but it must go to your head what am telling that ok. So, long what are done I have taken a single coil and 2 poles I am restricting it.

So, these are the 2 slots oh I drew it other way round. So, let me just put it. So, here I put one coil is not this is 1 dashed multi turn coil am just doing one this is 1. Now what I will do, I will place another coil, 2 dashed and 2 this slots are diametrically opposite and when they will carry current they will produce 2 poles I know that. Now what I will do is, I will have 1 dashed say this is 1 1 dashed electrically what am going to do now, 2 2 dashed this there are 2 coils separated by some angle or space whatever this is 1 1 dashed, 2 2 dashed and then I will connect them such that current enters through 1 and come backs to that that is connected source here.

And then the distribution of the current will be 1 cross, 2 cross and this 2 are dots, is not. Now I last time get you an exercise what happens to this, but if you see this pair of coils carrying currents in this way also produces some poles right because this 2 cross can be grouped together and it will produce lines of force like this and this 2 dot can be grouped together and this will also produce a lines of force like this.

Therefore, any bend of cross current distributed over space and opposite side dot currents which are also equally distributed in effect that is as if a single coil in middle and producing a field. So, each one produces 2 poles 2 poles resultant will be like this. So, in

that case what happens is this half will become South Pole and are you getting and this half will become your North Pole like that you can easily see.

So, instead of using a single coil if I use 2 coils which is named as 1 dashed 1 and 2 dashed 2 and each of them are and they are connected in series. So, that they are carrying same current then what will be the resultant wave form, resultant waveform will be then first I draw the developed diagram of the system.

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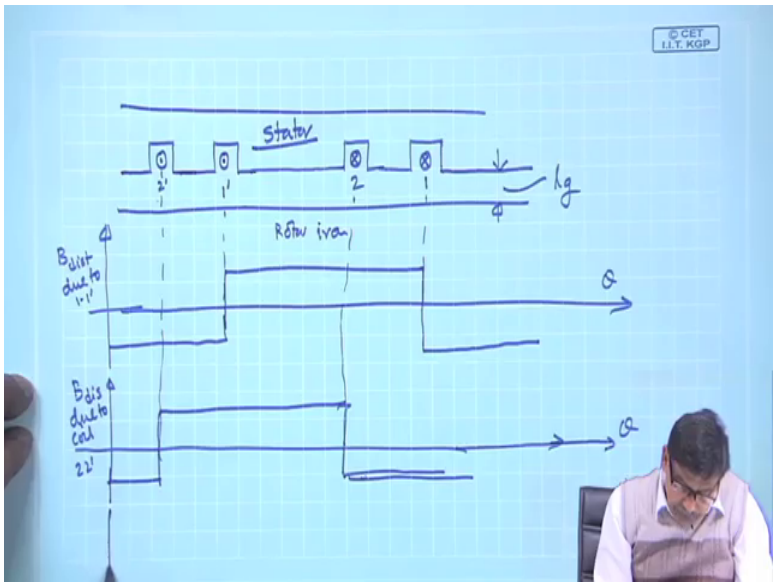

So, this is suppose from this side I am drawing. So, this is suppose 2 dashed here then after a little bit of this you will see this 1 dashed multi turn coil am not drawing here this is 1 dashed, then you will see 2 as you go this way you will got 2 then after 1 2, 1 2 you will get 1. So, pole pitch is this one 1 1 dashed or 2 2 dashed whatever it is.

Now, I have connected the coils as I told you in this fashion. So, I reproduce the current distribution in space by dot and cross marking and I want to examine what will be the resultant field ok. Resultant field will be 1 1 dashed is a coil if I find out it is resultant field, 2 2 dashed will be a single coil find out it is flux density distribution and just add those 2 waveforms to get the resultant that is the whole idea. So, this is stator, and let us see how this B distribution changes this stator iron and this is rotor assume rotor is having no coils, even if it is having coils it is not carrying current.

So, this is rotor iron; iron and this is your air gap which is very small in length l g. Now this distribution here what I will do I will sketch B distribution due to 1 1 dashed and I know for the single coil 1 and 1 dashed B distribution will be like this here is not. What will be the B distribution due to coil 2 2 dashed B distribution due to coil 2 2 dashed is in this graph I am sketching. It will be similarly like that because for a single coil I know how to sketch it. So, it will be like this and these 2 coils are identical same number of turns. So, their amplitudes will be also same and this is the see in rotating machine of course, I was writing last time I also wrote these terms.

This is not really very correct in the sense that the moment you have developed it and it is rotating structure you can show the position by some angle theta, are you getting are you with me, because if this is the thing. So, a particular position in space in a rotating environment is to specify the angle with respect to some reference point where you are. So, instead of distance we can write theta position although we have developed the diagram, but that theta will also get translated here. So, theta position, the B distribution is with respect to position. So, here it is theta mind you I hope you have understood the point. So, this is the thing.

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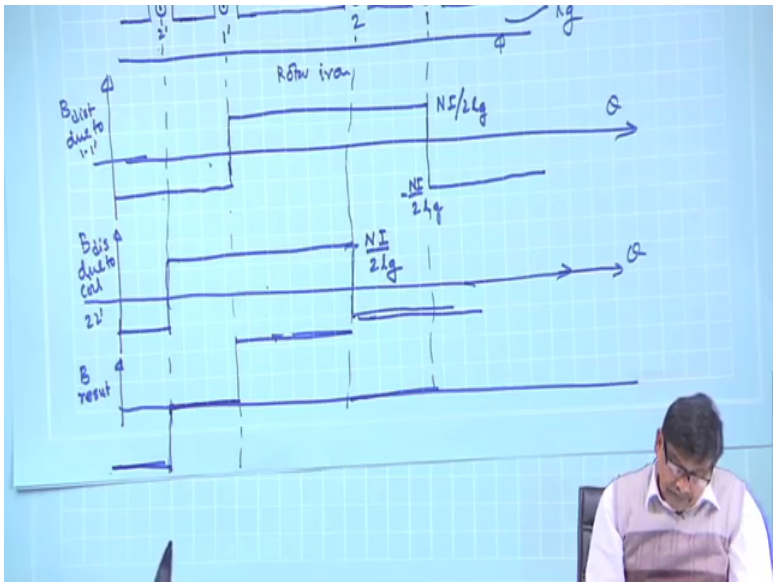

Now, what I will do, I will add this 2 waveforms to get the resultant that is all, B due to both 1 1 dashed 2 2 dashed that is what I am going to do.

So, here in this zone you can see suppose this is how much N I by 2 l g N I by 2 l g minus N I by 2 l g is this level this is also N I by 2 l g because the coils are identical. Therefore, during this zone it will be this plus this so, it will be higher like this during this interval it will be this plus this. So, during this interval what will be the value how much is it correctly drawn now this is fine. So, during this zone it will be 0. So, it will be 0 and during this zone, it will be once again 0 and thereafter in this way I can go on adding this 2 MMF obtain separately for each of the coils and add them up and then here on this side it will be negative here of this amplitude, got the point?

Therefore, you see earlier there was a distribution like this which were sharp pure square wave. Now we will have stepped waveform in fact, the MMF distribution or B distribution can be made like this here.

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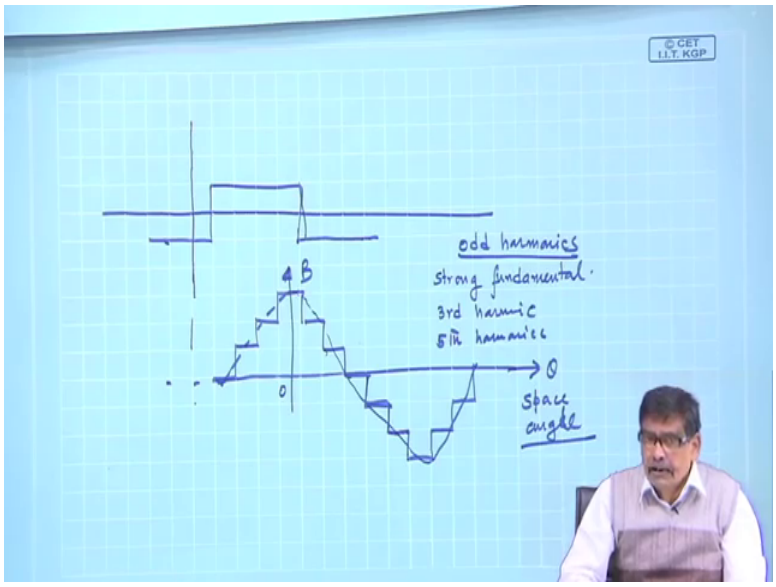

I will give one example with difference slots instead of earlier it was like this something like this , now it will be like this I can make it like this by using more than one coils , are you getting? This is suppose the 0 level. So, there will be some 0, but using 3 coils I can also make it like this. I leave it to visualize this things instead of 2 coils if you use 3 coils separated by same distance 1 1 dashed, 2 2 dashed is another coil, 3 3 dashed and add them up you will get a waveform which may resemble like this. And this one is visually is much closer to sine wave what am trying to tell ultimately.

Therefore, to make the distribution sinusoidal first conclusion is better do not use the single coil you for a 2 pole machine only a single coil produces 2 poles, but have a distributed coil that 1 1 dashed, then 2 2 dashed, then why not 1 1 dashed, 2 2 dashed, why not another coil here and let this be 3 3 dashed dot. Resultant field will be once again 2 poles, but the nature of the waveform will now straight somewhat like this and it is much better if you fully analyze it, you will find the fund once again it is it will have a strong fundamental and third, fifth, seventh all those harmonic B will be there, but their amplitudes will be much smaller compared to the amplitude of this waveform.

This is how you approach a sinusoidal you cannot do anything better than this in a rotating machine. The Fourier analysis of such a waveform as I told you will have a strong fundamental in Fourier analysis you know the next harmonium, in this case it will be all odd harmonics mind it no question of even harmonics. So, strong fundamental then will be third harmonic and the amplitudes you know generally decreases by 1 by N.

So, that way it is amplitude will go on decreasing compared to the fundamental. Then fifth one harmonic, it is amplitude will be further less harmonic therefore, in such a scenario you have to construct a machine to have sinusoidal B distribution why sinusoidal B distribution because you want to generate sinusoidal voltage. Therefore, using a single coil to have a space variation theta variation of B sinusoidal no, that is not possible, that is pure rectangular square like inward or output voltage.

Then the, what is the way out, way out is instead of using a single coil. You use several coils to make a group and pretend that this is a single coil it produces 2 poles and the b distribution here will be more closer to a sin H. Later we will see that by disposing the conductors in a particular fashion that is this angle should be how much and things like that. We will show you that it is possible to nullify the predominant harmonics one predominant harmonics at least can be eliminated by properly choosing the angle by which angle between 2 subsequent conductors of a particular group.

Therefore, this is the thing what is done that is do not use the single coil, use distributed coils and get a stepped B distribution mind you this is B, you can select your origin wherever you like, but that you must fix up then you can only describe this and this is the space angle theta with respect to that it will be like this, then we argue that this waveform is not sinusoidal, but certainly better than the earlier proposition where the single coil

was used because it looks more like a sine wave, which mathematically means that the strong fundamental of this one is really strong and third feet harmonics well any seventh, ninth all this things we will none the less I have reduced and reduced amplitude that can be neglected. But the point I want to make is it, is the question of predominant harmonic, whether predominant harmonic can be done away with by doing something quickly we will show you this can be done.

So, conductors are that I will discuss after few lecture, but the point is better do not if you have to use a single coil, better do not use the single coil distributed coils, how many distributed coils amount of space available this that is there, then you can use the coil span as a very as a variable to see that predominant harmonics a particular predominant harmonic is eliminated. Then we have own many things I mean first thing is you have made it more sinusoidal then you are telling us on this.

So, that third harmonic will not be there, third harmonic is the most predominant harmonic most predominant harmonic will have highest amplitude among the harmonics. So, that if you can neglect then higher order harmonics can be eliminated ok. Therefore, this is how a sinusoidal B distribution will be obtained and if you take a generator mode of action, then roter conductors if it is moved by a prime over it will have a voltage of this form only, but am telling that voltage will be more closer to a sine wave.

And there are methods by selecting span of the coil etcetera you can reduce even a desired harmonic and in our next class what we will do, we will. In fact, start windings now with this preliminary understanding of the things we will show you how to make windings of a induction motor AC windings of an induction motor or that of this stator of a 3 phase screw case induction motors things like that.

So, from our next class we will start windings do not miss that that is very important you must go through that. So, that everything together you must have an understanding of the whole thing that is, it is not that in piece mill, my approach is this that from very fundamental things how real things are approach that is what am trying to tell you.

Thank you.