Electrical Machines- II
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Lecture – 14
Flux Density Distribution Along the Air Gap

Welcome to the 14th lecture.

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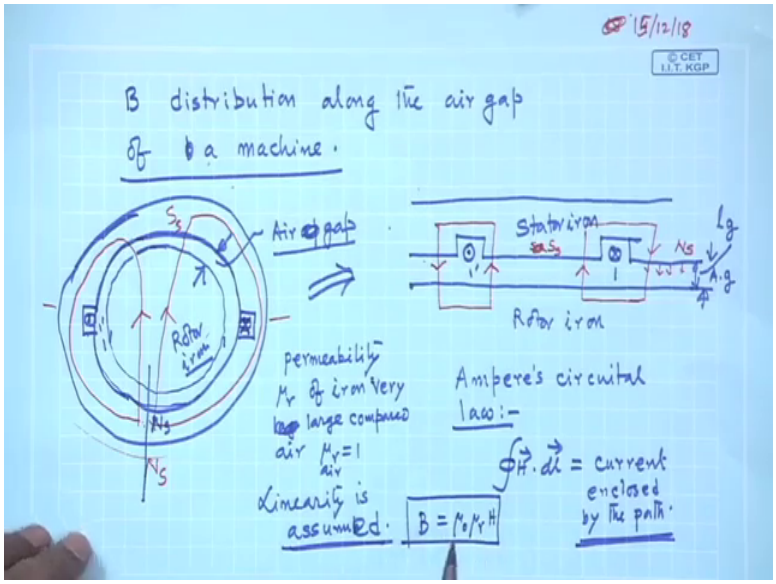

And we were discussing about how to find out B distribution Flux Density Distribution Along the Air Gap of machine. This is our machine, on the stator there is a pair of 2 conductors; that means, a single coil at the back they are connected in series and you are passing current cross dot like this and I know lines of forces will be going like this. Indicating that this surface this to this will become a south pole and this to this will become N S, that is inside this will be N S, inside this S S and if you cut it here and imagine you have separated it out made it flat then this from this you will get this. And all the things here this is 1 dashed so, 1 dashed 1 and this is the air gap A g, suppose the length of the air gap is l g.

Now, to find out the B distribution along the air gap we will make one first one realistic assumption. One is this that the permeability of iron permeability that is mu r of iron part is very large compared to air, for air mu r is 1 air we assume approximately 1. So, mu r

of iron is very high and I will neglect saturation and linearity is assumed, these are the 2 assumptions I make.

Now, to find out the field around a conductor what we apply is known as ampere circuital law, which you know is mathematically written as H dot dl over a closed path is equal to current enclosed by the path. And B and H are related by this, B is equal to mu 0 mu 1 into H this is the thing. You must have undergone courses and know how to analyze a magnetic circuit, I will just in review of this what is the implication of that I will quickly tell then come back to this problem once again.

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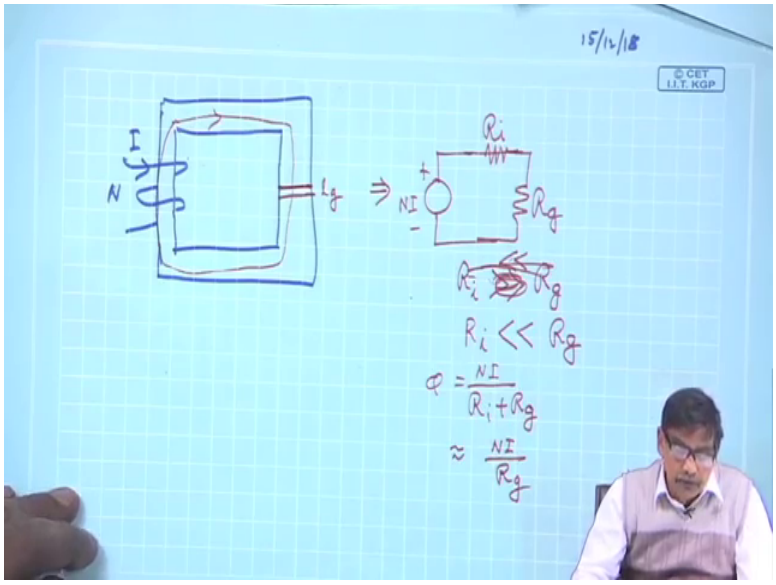

Suppose you have a magnetic circuit like this and here is some number of turns N and this I. And, I want to find out this field here and suppose there is an air gap in this of length l g. Now if at this permeability of iron is very large compared to the air gap permeability which is 1.

And it is a series magnetic circuit mind you so, this circuit can be written as plus minus NI, this also comes from your ampere circuital law application and there are 2 reluctances. One is due to iron, another is due to gap, these 2 are in series because same flux flows through both of them. Now, what I am telling the implication of the term that mu r of iron is very large means reluctance of iron is much much higher than R g gap.

Therefore, all the MMF will be dropped across air gap under such a condition. You can assume that 2 resistances reluctance of iron is very very small thank you, reluctance of iron is very very small than gap. Gap reactance is very high, although gap length is small, but because of the fact that it is permeability value is so small 4.5 into 10 to the power minus 7 and this will be a 10000 your values 5000 of the order of 1000.

So, reluctance of the gap is very high, imagine a circuit having a low resistance and high resistance in series and connected to a source. Since they are connected in series current will be same therefore, what will be the current in the circuit all the voltage will appear across the high resistance. Similarly you can assume that all the MMF will be brought across R g, in such a scenario if R g is many times higher than R i you simply divide this total MMF by R g and you can quickly get what is the flux produced MMF by reluctance.

Strictly speaking this flux will be MMF by reluctance of iron plus reluctance of gap. But reluctance of gap is very high compared to R i. So, whether you add R i or not it is simply like this that is the meaning of that assumption. So, all the MMF's will be dropped across the air gap. Now we will apply ampere circuital law here.

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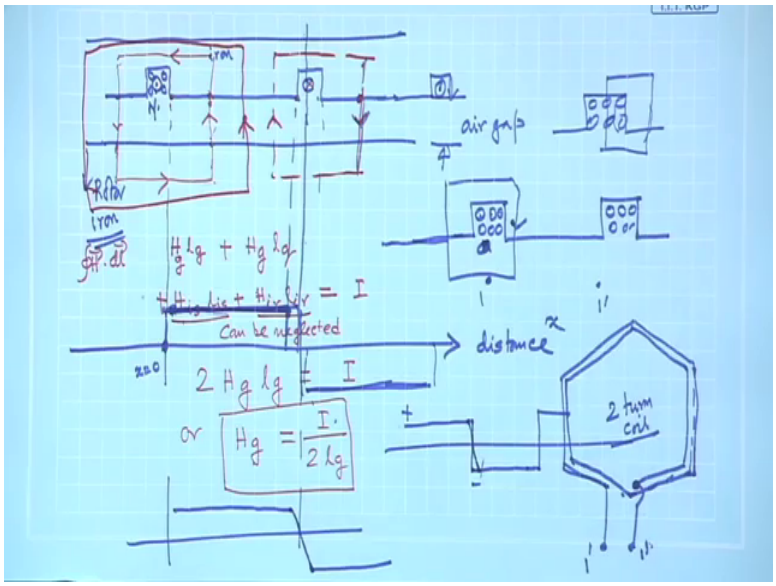

So, once again I draw slightly neatly so, that this is suppose one slot, this is another slot, this is suppose 1 dashed and this is suppose 1. This is the outer stator ring circumference this is our iron and on the rotor I have not assumed any coils there may be coils, but that

is given as just, but I am showing the air gap at a larger scale it is much smaller. So, this is rotor below this is rotor iron the developed diagram view is this and diagram of rotor and stator they are very high compared to I mean mu r of rotor iron stator iron are real when compared to the air gap and this is your air gap. Now suppose I want to find out the and this current deduction is also known to me this is cross this is dot.

Now, suppose I want to find out what is the value of H the plan is like this at this point in space you want to find out the value of H at a given point in space, suppose I want to find out here. Now you see around this point I have a lines of force consider a lines of force here ok. So, H suppose the value of the gap H is H so, H into l g H dot dl have to do. So, H dot dl becomes H into l because along that direction only I am going. So, H g into l g plus H i into this li stator plus H g into another l g plus H iron into l iron up to this, but this 2 drops I only get it that is the meaning of that mu r. So, the integral H dot dl along any closed path that is what I have chosen and I have taken everything H g l g and if you like I will write this H iron stator whatever is this length l iron stator plus H iron rotor l iron rotor that is this length is l iron.

And this must be equal to the current enclosed, what is the current enclosed it is I ok, but I am telling that this 2 terms can be neglected. We will always assume iron is very good type of iron you are using with respect to air gap, it does not require that it physically means that it requires very little MMF to create a flux in the iron most of the MMF's will be dropped in the air gap. So, ultimately what you will get is 2 H g l g is equal to I and I will say H g is equal to I by 2 l g that is the thing.

So, at a given distance from this point say x this is the field, what about at this point, at this point what is the value of H oh you then consider another lines of force here and repeat this calculation H g l g, but once again current enclosed is same therefore, the value of H g at any point from this to this will remain constant. Similarly the value of H g if you calculate for this point that will also remains same is not therefore, this value of H at this point will remain constant.

In other words I will spoil this paper because to be consistent with the directions suppose now I this is the distance wherever you choose your origin you choose suppose you choose your origin here x equal to 0, this is x axis. Then I will say between these and this point the value of H will be like this, after this cross what is there you will because it is a

rotating machine you will eh eventually once again 1 dashed will appear here dot, but the direction of if it is south pole here which I have shown by positive here in this plot, what is this thing this is this H g I by 2 lg, but between this to this it will be negative are you getting from this to this it will be negative. Because sense has changed it has become North Pole so, this is how we can show.

Now the straightly disturbing point is here that what happens in this zone ok, we do not care what people do is this up to this point it is like this when at the center of this slot and it is done there. In fact, at this point I would like to tell in this way that this is a coil I told you one listen carefully this is a single coil, how many turns this coil is having? Only one turn, I can make a coil having multiple turns single coil I will make, suppose these are the 2 slots you take a single piece of wire long piece of wire you start winding like this you go this way at the back you come back draw that wire. So, that by doing this we will get say 1 dashed to one sort of thing, but here you do not stop once again take that wire push it once again through this slot at the back.

So, another bring it down, another bring it down and ultimately of course, you will get 2 terms 2 terminals available to you 1 1 dashed, have you is the picture clear you take a long piece of wire one wire only you push it in at the back you go then draw to this designated return slot of that coil and then repeat this once again do not stop here once again push it in at the back come. So, it looks like this go there come out through this slot once again come here, bring it back I mean draw fine line how does it matter come out here and suppose I stop here. So, this will be my one 1 dashed 1 dashed 1. So, it will be a coil of 2 turn coil. In fact, in machines multi turn coils are used because b lb is the voltage and when these things move in b all these conductors have Blb Blb and they will be a added up.

So, what voltage we will get therefore, it is multi turn coil therefore, in a situation where there is multi turn coil each slot suppose is having N turns like this. Therefore, the as this point I was telling that discontinuity point, what is happening is this between that there is no problem in estimating correctly if these are all cross current or dot current. This is the lines of force that is fine H dot dl equal to current enclosed. Now, if you choose a suppose it is a multi turn coil like this and if you choose a lines of force like this then H dot dl will be the current enclosed here not all this things it will be slightly lesser.

So, what happens correct sketching perhaps will be like this, it is constant, constant here, then it decreases here and then this one that is taking in to account each current crossed and deleting those currents. So instead of that what people do that, discontinuity you forget at the center of the slot make the change that is how you show the H distribution it is after all from positive value going to negative value along the distance.

So, this one whether it is doing slightly like this because this slot width is much smaller compared to the pole pitch of the machine therefore, the H distribution of a multi turned coil like this if I finally, sketch it.

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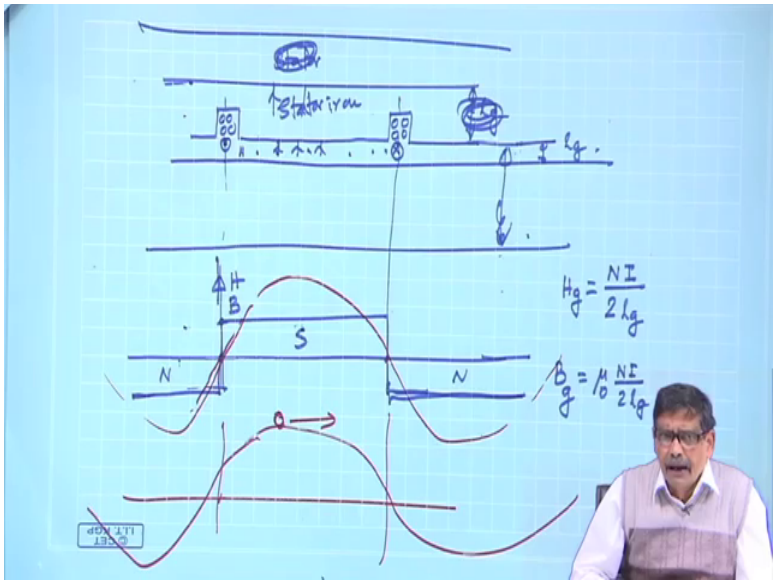

Let us repeat that it is nice, this is this, this is this, this is stator iron here a number of turns are there all are connected in series and all the conductors in a particular slot will either carry dot or cross current. So, suppose this is dot all the conductors were carrying cross current, then the H distribution here, this is l g, here gap length iron length it does not matter stator iron sorry stator iron this is the outer thing not this is stator iron. And, this is air gap I have showing in a larger scale it is must smaller like this or let us show this is the rotor iron this is the air gap understood.

Then what I am telling the MMF distribution draw line at the center the slot and it will be like this rectangular shaped and it repeats this is the H distribution in the air gap, how much is the value of H at this point, at this point, at this point and if you know H, what is the value of d, just multiply that H with B. So, H g will be equal to N I by twice l g there

are 2 air gaps in series and then I say B g will be equal to only mu 0, in the air gap I want to find out the flux density. So, this will be N I by 2 l g. So, this is the shape of H multiply it with mu 0 in some other scale this curve is also B say this will be the air gap distribution of the flux density with constant over one pole pitch constant value of the b sum of wavelength per meter square.

And if you say that this is lines of force entering this south pole if you assign this to be North Pole then this must be South and so, on reverse. So, this is south pole it will be cross lines of force will be entering like this so, south, north, south, north. So, this is how a single coil you must understand what is happening in a single coil, first in a single conductor then each time will not go to a single conductor, single coil, single coil will be the elemental think in any rotating electrical machines there will be several coil. So, we will see in a few lectures from now, but remember each of these coils suppose belonging to stator structure will be identical. Similarly each turn each coil on the rotor body will be also identical what is the difference, difference is one coil is displaced in space by some angle that is all.

Therefore in course of time whatever is happening to one coil same thing is going to happen to other coils. Therefore, it is essential if you know, what is happening to a single coil. So, a single coil has produced a flux distribution like this now at this stage let me tell you suppose this is the stator of this one and it produces field like this. Now I want to create I want to generate ac voltage. So, what I will do, I will on the rotor surface I will put suppose one conductor that is here, suppose you put a conductor a slot is there you put a one coil and write this conductor open circuit rotor is open circuit therefore, it is not it same as the thing which started with that is there are South north pole patterns like this and a conductor is moving.

And if this conductor moves there will be voltage across the 2 ends of the conductor and what will be the pattern of this voltage, same as this south north pattern, whatever is the pattern of B that will be the voltage pattern as well, only thing this space will be replaced by some vt velocity into time there by time will come. So, with respect to time you will get a square of voltage for such a machine which is having on the stator a multi turn coil having some current, this field distribution will be rectangular. And, you have a single conductor placed on the rotor surface and suppose by some external agency the it is moved in this direction, then this thing is this thing.

And the value of the voltage individual is Blb lb constant therefore, whatever is the nature of the that will be trust by the induced voltage pattern, but the irony of all this things is this because we know by this time all of us know that our voltage whatever is available in your top and here in their plug, that is AC voltage only it is AC voltage no doubt, but it is not a sinusoid voltage sinusoidal AC voltage you know 220 volt 50 hertz supply. It means that it is a sinusoidal time varying voltage with peak value 220 into root 2. But here if you have a generator like this you can only say it is AC voltage, but it is the square wave voltage. It is some plus fixed value negative fixed value in the one half cycle and in the next half cycle, but you would like to generate AC then the question is how that AC voltage is generated sinusoidal voltage.

So, the answer to this question I can give, you also can give, you will say that to generate AC voltage in this conductor your B distribution must be sinusoidal. Then only Blb lb constant if B is sinusoidal distributed then you will be ensured about sinusoidal induced voltage. Otherwise in general whatever is the nature of B under which relative to that B distribution if a conductor is moving you will get a voltage induced which will vary with time the shape of that voltage waveform against time is the same as distribution of the along the distance.

For example, the this waveform for example, you know Fourier series, I can Fourier analyze this and get a fundamental sinusoidal with lot of harmonics one good thing is higher order harmonics they will have reduced amplitude. So, you can say that it is a square wave, but it has got a strong fundamental sine wave lot of odd harmonics. And the idea is whether this B cannot be made a very nice sine waves smooth like this, what can be done is that an approximation to this sine wave we will try to get and that I will discuss in the next class.

Thank you.