Electrical Machines - I
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Lecture - 72
Field Flux Density, Armature Flux Density and Resultant Field Distribution

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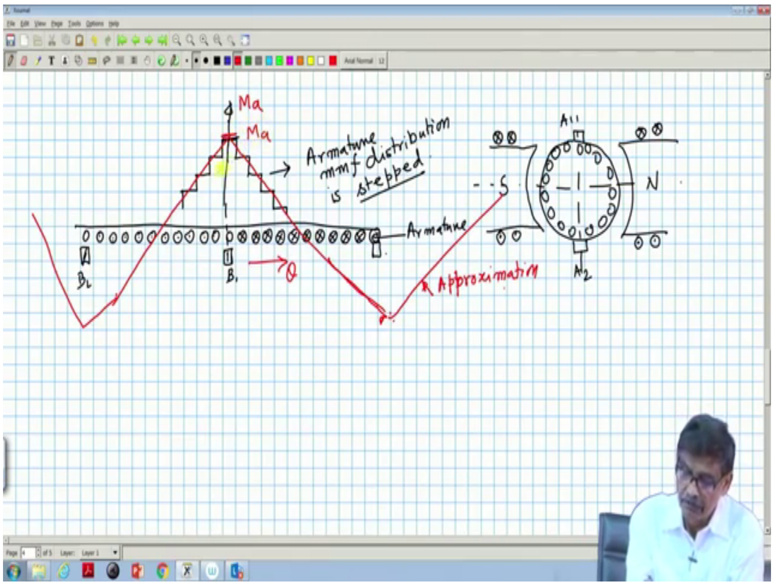

Welcome to the next class. We are discussing about armature reaction. And in our last class I told you that, the how to find out the armature mmf distribution along the air gap between the brushes currents polarities are same dot and the sides suppose to cross. These are armature conductors; they will carry current. And, then I know for a single coil how to sketch the mmf distribution which will be rectangular plus minus.

And we found out for individual currents. And, if you sum them up you will get an mmf distribution, which will be strictly speaking stepped. If large number of turns conductors are used this can be approximated to a triangular waveform like this thick value of the armature mmf will be occurring at the brush positions here.

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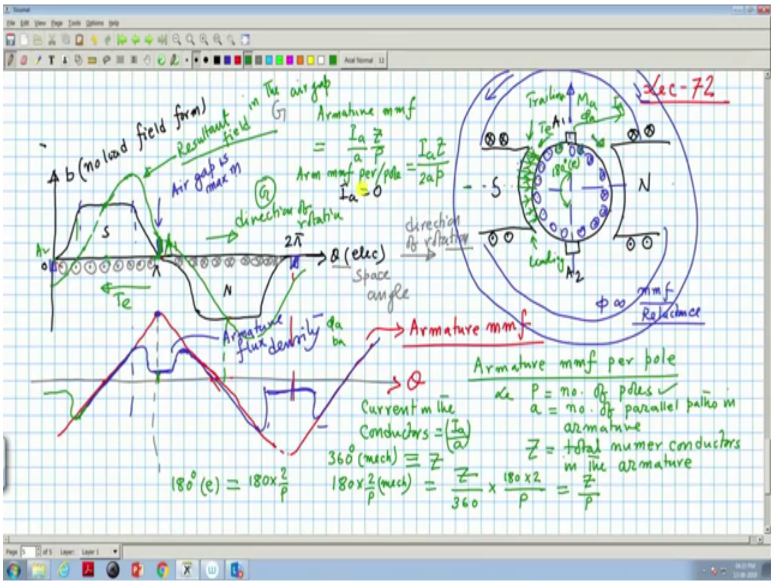

So, then we come to this one this is the no load field form mind you. So, this is the no load field form b; no load field form. This is produced by whom? This field coils, where is d axis? It is here at the middle where is q axis? It is here, from this to this it is 90 degree electrical. So, this is the peak value I mean central value from that to 90 degree. So, this distance is 90 degree ok.

And then where are the brushes? Then brushes are here. This is the position of the brushes this is one brush, there will be brush here, there will be brush here is it not? This is the armature terminals. Now where are the armature conductors? I will show beneath the field distribution, that is a armature conductors will be here. Let us consider generator, now listen carefully.

It is otherwise very simple that is why ultimate thing is very simple this is generator mode. And these are armature conductors, it will move with respect to this field. This conductor after some time will come here. If you assume the direction of rotation of the armature conductor is this direction of rotation. It will be like this armature conductors are moving brushes are fixed.

So, this same thing it is now translated here. Now, if this is the direction of rotation we know the conductors under south pole that is this conductors will carry dot dot so these are dots. See I am now translating one to one correspondence with this figure with this. So, this is all dots. I will go slowly do not worry and these are all cross under south and this dot cross and not only the direction of the induced voltage, but also the direction of the current in case of generator mode.

So, this will be like this ok. And, if generated e m f will be always present current may or may not be present depending upon whether you are connected load across the generator or not. Now, let us assume that if armature current is 0; that is I a is 0, then this will be the only field distribution this space angle mind you this is space angle this will be this. Then what will be the moment armature carries current?

There will be armature will produce its own mmf and how it will look like? It will be like this right middle point you identify this is this one brush. This is the say approximately this is the 1, 2, 3, 4, 5; 1, 2 I mean somewhere where the middle point. And it will be then like this. It will be a at least crossing this one middle. And it will actually this diagram this and these are not equal they should be that is why that thing is coming.

But you understand what I mean once again this peak will here at the brush and it will continue like this. This is the red one is the armature mmf and this is same theta. Here once again not pole that is why it will go up. So, this is the peak value of armature mmf is along the brushes consistent with this current distribution cross, cross, cross, cross, cross, cross, cross this is one armature terminal. So, armature mmf will be here that is also depicted here peak value ok.

So, this is, but this is, but this is mmf not be flux density. The moment you know the value of h at a given point the flux density can be easily calculated by. It will be proportional to this mmf divided by reluctance of the path. Flux, flux is proportional to mmf by reluctance of the path. Therefore, I have to divide by the reluctance for example, at this point I know the mmf how much is dropped here?

There are two air gaps and these two air gaps the drop will be same that is why that n i by 2 i did whatever is the mmf. That divided by the reluctance assuming the iron permeability is very high compare to the air. I can assume all the mmf will be dropped across the air gap. Therefore, this divided by this reluctance you do you get the flux here. But in case of DC machine one interesting thing happens.

The air gap is more or less constant between this to this zone. But after that the air gap will be very large; because this is the yolk portion, where the air gap is very large. Similarly are you getting although armature mmf is acting this is the yolk of the machine. Flux will continue its path like this comeback this way we discussed earlier. Therefore, air gap is not constant.

So, armature flux or b distribution will be proportional to mmf in this fashion. So, between this zone and say this zone it will be in some other scale this will be same as a b; this blue curve I am drawing is the b distribution it will be like this. And then the flux will decrease and it will have a minimum value here because air gap is maximum along this line air gap is maximum.

During this zone air gap is minimum and uniform almost. Then it will be like this then once again it will be something like this here getting the ideas and it will be somewhat like this got the thing. So, this blue curve is the armature flux density armature flux density this is the thing. So, I am repeating what I have done?

This was the no load field form when I a is 0 that will be always be there individually. But when armature current is not present; this is the only field which will be present b distribution flux density at a different space positions in the air gap. Then when armature is loaded armature will carry current. In the same direction as that of the induced e m f so, this I have shown.

Then I got this red curve which gives you the armature mmf drop across the air gaps in the two air gaps. And this red one is the armature mmf. So, what will be the flux density? It will be proportional to armature mmf divided by the reluctance of the path etcetera. But only thing is the air gap is not constant in the DC machine. Over this zone air gap is constant here it is maximum.

Similarly here it is uniform here it is maximum. So, in some other scale the blue curve is drawn it will be proportional to armature mmf during this zone, where the air gap is fairly constant. Then it will decrease drastically I mean smoothly some curves it will follow like this it has to it has come down how it has come down? We do not bother about equations, but it will have some minimum flux.

And then it will continue like this similarly in the other half it will do like this. So, drawing of red curves is very simple. I know the armature current there are so many conductors which are almost uniformly distributed. So, the peak value where it will occur here why I have put plus? Because for south pole I have put plus. So, this lines of force is also along this line cross and dot will give this line.

So, positive you draw it and get this that is the whole thing. Therefore, what will be the resultant field? Resultant field will be the sum of this plus this blue curve here got the idea? This b because of field coil and this blue curve because of the armature conductor mmf, these are the flux density present in the air gap. So, resultant field will be this blue black curve and this blue curve if you add point by point.

Now if you add at point by point I will sketch it I will make it clumsy it does not matter. But you get the idea very clearly what I am doing. What I it looks like that the resultant field I will use say green curve. And at this point middle point it will be 0; not 0 at the middle point it has to be this much this plus 0 like that I am doing.

At this point this plus this much blue curve this ordinate plus this ordinate, I will go on adding. Therefore, flux density will become more and more. So, it will become something like this if you go on adding like this is not? Then after sometime you go up to this point then after sometime this plus this plus this you do. And here it is 0; but here it is some finite value.

So, this armature mmf resultant field will be somewhat like this got the point. There will it will not cross 0; here it will have some positive value. On this side, similarly it will be less this b minus this like that. And once again it will be like this therefore, there will be some field here existing in this. So, this will be a this one is the resultant flux distribution resultant field.

That is this trapezoidal field plus this blue curves not the triangle that is the mmf mmf by reluctance gives you that filed. So, these two together will be this thing. I have assumed generator mode and generator is moving in this direction. So, in this case see this one is your A 1; this one as I told you make one to one correspondence here A 1 this is A 2. And you can easily see the this part is the trailing pole tip where is this portion this portion is the trailing pole tip trailing half of the pole.

Because conductors are moving this one this is the leading pole tip this is the trailing pole tip. So, half of this one is the leading I mean trailing pole half. And here you see bs are high lines of force will be concentrated. And here lines of force will be b value is less means lines of force will be radified, but the same area lines of force present will be less and here it will be more. Similarly, for this half one can continue it will come here once again it will cross line. I mean it will be distorted and it will be something like this I will be able to add these two points are along the same particular lines.

So, the resultant field distribution will be like this, resultant field in the air gap. Therefore, compared to a unloaded d c machine there was no flux along this line q line, that is along A 1 this is A 1.Now, I find there is a flux density present which kind of flux density present same south pole. If the main pole is so, here exist some south pole here is that point clear.

So, this must be understood very clearly. This is the detailed flux density distribution waveform, when the machine is loaded when armature current is carrying which is otherwise simple. Because it tells me many things flux density direction of rotation is this. Generator mode flux density will be concentrated on the trailing pole tip.

This is the trailing pole tip trailing and this is the leading pole tip with respect to whom? This we have defined you are sitting on the armature you will first see here as you are moving. Then you are living this pole tip that is why it is called trailing. So, in this case it is moving like this. So, this is the leading pole tip and this is the trailing pole tip.

And in the trailing pole tip normally when I a is 0 it is very nice no flux. But here when armature carries current. Here it is also consistent with this fact line of force will be concentrated here in this half and it will be radified there. So, that electromagnetic torque is in the opposite direction. So, T e will be acting here like this. So, everything has a one to one correspondence between this diagram and that diagram.

Now, in my last class I told you that and that is what I am telling this increase in flux in one half. May not see there is a loss of flux, here it is increased in this half flux per pole. And, here it is decreased because resultant flux per pole will decide what will be the induced voltage that is p z by a phi into n that phi is the resultant flux.

Now, the moment armature carries current resultant flux is to be considered to calculate the induced voltage. But what I am telling, if there is no saturation taking place for some low value of armature current. May be increase in flux in one half will be equal to the reduced in flux in the other half that is this area and this area are same.

So, that flux per pole will remain same. And we can neglect armature after all carrying current has no effect. But that is not to be because of saturation present. Because the mmf more mmf here may cause this flux increase in one half less than the decrease in the other half. That is why there is a net there may be a net reduction in flux per pole.

And therefore, there will maybe a voltage loss induced voltage loss that is phi no load and phi loaded condition flux per pole will be slightly lesser. It can be taken into account by some factor may be five percent flux loss takes place for large value of armature current. And as I told you with brushes in this position, this is the direction of armature mmf that is the peak value armature mmf is along this line. And the flux density waveform will be only distorted.

There is no direct component of this armature mmf or armature phi this blue colour is phi a or b a whatever you call it this blue curve. So, that will be like this. And and it will be here this height is same as this armature flux along the quadrature axis. So, it is only distortion that is the main issue here. There is no direct component of armature mmf which really negates in direct opposition to the existing stator field that is the whole idea. In my last lecture, I told you in my qualitative part of discussion that when a conductor is this side that is dot and it will cross this brush the quadrature axis. It will come over here but the moment it goes there it has to carry cross current is not?

And if it has to carry cross current then that will be prevented that legacy of this dot current in a scenario. When armature carries current still continues when the conductor reaches here. Because it is still south pole the polarity of the induced voltages current. So, will be this dot, but the moment it crosses it has to carry cross that is the destiny.

You cannot for these conductors the way the bindings are done. Therefore, the commutation will be delayed. So, one way of saying this is that you try to put the brushes in positions where the flux will be 0 where the flux will be 0. But before that let us calculate this armature mmf per pole how do I am calculating? Please listen carefully.

Armature mmf per pole let us first calculate that. Calculations are pretty simple at least for this. So, this is the two pole representation of a let p is equal to number of poles total number of poles of the machines is P. a is the number of parallel paths between the armature number of parallel paths where in a armature. And let z is equal to total number of conductors in the armature.

What is this angle? This angle is 180 degree electrical is not? Multiple and machine I have represented it as a two pole machine. So, the thing is what is the current flowing through each conductor I know current, external current in the armature is I a. But in the conductors how much current current in the conductors is equal to I know I a by a parallel paths will be there so, I a by a.

Then, I have to calculate what is the number of turns here? Now, you see these calculation are. So, simple algebraic calculations but follow me carefully over 360 degree mechanical. There are how I am writing is this there are z number of conductors present over 360 degree mechanical. If it is a p polar machine 360 degree mechanical what is the total number of and that is the uniformly distribute at whatever it is.

Now, I want to find out what will be how many conductors are present over 180 degree electrical. So, 180 degree electrical is equivalent to 180 into 2 by p mechanical angle is what?

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I am just putting. So, 360 degree mechanical there is z conductors. Therefore, under 180 degree electrical; that means, 180 into 2 by p mechanical degree, how many conductors will be present? It will be z by 360, 360 into 180 into 2 by p that is equal to z by P. Therefore armature mmf will be I am writing here. Armature mmf will be equal to current flowing through the conductor, I a by a into z by P.

This will be the armature mmf that is along this line, what will be the armature mmf. All this turns I have taken. And this is this is caused by two poles in this electrical representation. Therefore, armature mmf per pole let it be clumsy.

But let everything be on this paper armature mmf per pole should be I a z by 2 a p is not? I found out the total number of conductors this calculation is z by p? Therefore, I a z by 2 a p armature mmf per pole mpa turns ok.

We will continue with this in the next class.