Electrical Machines - I
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Lecture – 71
Armature Reaction Continued

Welcome to next lecture on Electrical Machines I and we were discussing about Armature Reaction.

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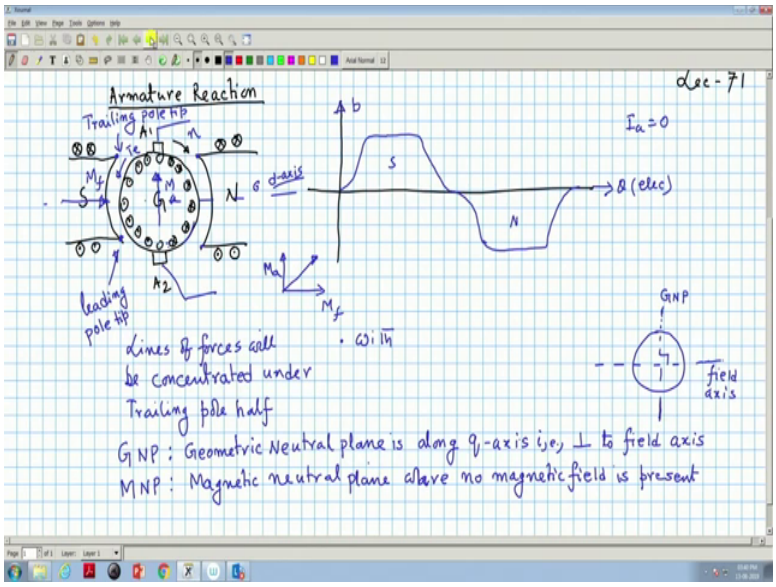

And in our last lectures we qualitatively discussed what the is the armature reaction and then water its bad effects and also we discussed about how to get rid of this ill-effects of armature reaction by using compensating winding and also along with interpol winding, and as I told you this discussion was on qualitative basis very simple to explain.

Today we will try to draw the field pattern in the air gap of the machine because of the stator field which are projected poles and the nature of the field is trapezoidal and then, we shall try also to draw the mmf distribution of the armature currents along the air gap of the machine.

And this mmf we will cause armature air gap, in the air gap also this amateur mmf will produce some armature flux therefore, resultant flux will be the sum of these two. And from that also whatever we got in our earlier qualitative discussion, we shall try to

conclude those things once again, but this time really drawing the net air gap field in the machine.

Now, before that you recall that this was my armature I just want to point out one thing and these are my projected poles field windings I will symbolically I will show by one turn that is this is suppose South Pole and this is suppose North Pole and lines of force will go there. So, this is symbolic representation of field coils sectional view, and here also these are the field coils. They will carry direct current called field current and this will be also cross and dot they are connected in series, so and this is this thing.

Now a I told you that a DC machine like a its AC counterparts may be a multipolar machine that is number of poles may be greater than 2. In this representation mind you that if I know what is happening under a pair of poles, the remaining things will be repeating for the other pair of poles same things will be repeated. These I told you on many occasions during AC machines as well as during where DC machines also.

Therefore, if we concentrate our attention what is happening under a pair of pole, then that will be a good thing to study and then I can say same thing is happening in the other pair of poles as well. So, in this simplified diagram no matter whether it is a multipolar machine or not only two poles are shown and all angles here are in electrical degree ok, that is how it will be carried out and this is your armature reaction armature terminal sorry, I will just copy this down because many times I have to sketch this.

So, this is the thing and then there are armature conductors. So, this is under a pair of pole, all angles are here in electrical degrees and this is direct axis along this line and this is the quadrature axis, ok. Now, suppose it is operating as a generator that is what I told you then and the direction of rotation of the armature with the help of a prime mover is supposed clockwise then this dots will be the direction of the EMF as well as current, this you must understand when the armature will be loaded. So, this side under North Pole, this will be all cross and this side under South Pole this will be dot.

Now in this one when there is no armature current that is the machine is not loaded then of course, the field will be same as this field; field produced by the stator. And we know that this field will look like this one along the air gap of the machine, this field as I told you it will be trapezoidal in nature like this and it continues. So, this is the South Pole and this is the North Pole that is it is and this is the b flux density distribution along the

air gap of the machine and mind you this angle is in electrical degree; electrical degree, ok. So, this will be the b distribution when there is no armature current that is I a equal to 0.

Now the moment, this armature is allowed to carry some current to deliver power to a load, then the direction of the currents in case of generator mode will be same as the direction of the induced EMF. Therefore, these dots once again we will represent the direction of the current and cross will represent the direction of the current in the under the two poles as shown.

Now, in our qualitative discussion we told you that the direction of this armature field will be vertical like this because this is cross this is dot; so, current direction will be up. So, this is the armature mmf, it will act along in a line along the axis perpendicular to the direct axis that is called quadrature axis. And this armature mmf there will be no component which will demagnetize, this poles had there been a component in opposition to the original field; original field was like this that is say let us call it a M f and let us call it M a, M a I have written already.

You can easily see this MM there is no component of MM M a armature mmf which opposes this directly, but only thing it will distort this field such that the lines of force will be concentrated in this side and it will be ratified this side that is what I discussed I am not repeating that. Therefore, lines of force will be concentrated on this side another thing is this is the direction of rotation, another term people use often so far as the direction of rotation is concerned every pole can be thought of; there are two pole tips this is one pole tips this is another pole tips.

Suppose you are sitting in on the armature and moving like this, you will first see these poles and after some time you will see this pole. So, that is why these poles are named as this pole is named as pole tip leading pole tip; leading pole tip and this pole tip is called trailing pole tip trailing. So, armature is moving this way similarly this one will be leading pole tip and this one will be trailing pole tip because the moment you first see this not pole you see this pole tip and then this one. So, like that.

So, in case of generator mode of operation, the flux will be concentrated more towards the trailing half of the pole because lines of force will be concentrated here and it will be ratified here such that the electromagnetic torque will be in the opposite direction.

Therefore, in case of generator mode; remember, lines of force lines of forces will be concentrated in the trailing pole half, this is this half can be called trailing pole half, this is leading pole half concentrated under trailing pole half and it will be ratified under leading pole half we know that.

And electromagnetic torque will be always experienced from the denser concentration of lines of force towards the ratified portion of the lines of forces therefore, electromagnetic torque will be in the opposite direction, these things we discussed. Therefore, it looks like the flux per pole will remain same as I told you because increase in one half will be perhaps compensated by the decrease in the other half and so on, flux per pole remains same and whatever formula we derived for the induced voltage really remains intact. But because of saturation the increase in one half may not be will be slightly lesser than the decrease in the other half therefore, flux per pole decreases slightly.

But nonetheless there is no reduction in the lines of in the value of flux per pole because of demagnetization component, everything is concentrated this is an a M f and this is M a therefore, M r will be somewhere here. So, lines of force will be concentrated this side that is the whole idea. Anyway this was the scenario, now today we will go a step forward we will try to investigate really we are how this armature mmf will look like when it carries current. So, with brush position in the this point is what mentioning with and another thing you just note down this axis the field axis it is this one, ok.

Then there are two terms used, one is called GNP is a Geometric Neutral Plane; Geo Metric Neutral Plane. So, this is GNP; no, this is not GNP, Geometric Neutral Plane will be at this is d-axis with I a is equal to 0 is along q-axis. Geometric neutral plane is along q-axis that is perpendicular to field axis by field axis I mean stator field axis.

So, so geometric neutral plane will be this is the armature, this is your field axis, geometric neutral plane is called this one GNP, clear this is the field axis. So, GNP is a line perpendicular to this GNP and there is another term called MNP which is called Magnetic Neutral Plane; magnetic neutral plane sorry. Magnetic neutral plane is the plane where b will be 0, where no magnetic field exists that is called magnetic neutral field.

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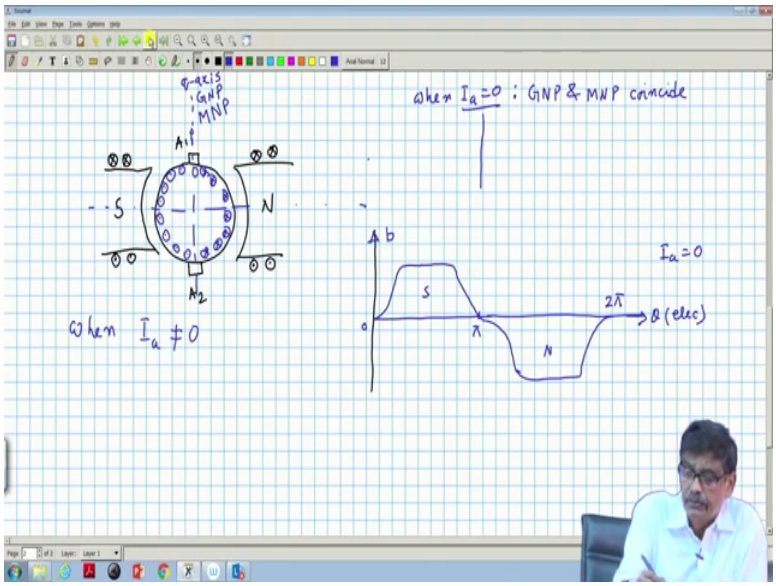

Now, let us consider a this same machine, this same machine let us consider here. In this machine therefore, what is the geometric neutral plane? Geometric neutral plane is defined this is your field axis perpendicular to that is the q-axis is your geometric neutral plane, q-axis which coincides with geometric neutral plane. When I a is equal to 0; when I a that is the machine is under no load condition which one will be, where in which points here the field will be 0 along this line only because b distribution is like this, can I go and copy this, yeah. So, this is you are; this is the b distribution.

So, in this case this is the line and on which theta is measured and what is d-axis? d d-axis is middle of this 0, pi, 2 pi or 360 degree electrical. So, magnetic neutral axis with no armature current, if there is no armature current no armature field therefore, where will be the flux 0, here only at pi that is q-axis. So, this happens to be it will coincide with GNP. So, when I a is equal to 0, conclusion is GNP and MNP coincide with I a equal to 0 mind you, that is fine.

Now, there are conductors as I drew earlier and once again let me keep a copy of this, it will be otherwise I have to draw often [FL]. Now, here that is fine, GNP and MNP coincides when I a is equal to 0, but the point is the moment the armature will carry current such that these are dots these are dots and this side are cross. I can easily see there will be now a field here because of armature field, if I applied right hand rule there will be some magnetic field here.

The contribution of the main field will be 0, no doubt here, but because of armature current when I a is not equal to 0 there will be some field existing along the q-axis or q-axis is nothing, but geometric neutral plane along that line there will exists some flux. And we want to find out where will be MNP that is what I am telling. So, your resultant field is like this armature field, cross field then we will find out where that armature field is there.

Now, so, GNP and MNP you just keep in mind we will be using that concept therefore, without any load on the armature this is the field form along the air gap of the machine and this is also the resultant field form. But when I a is not equal to 0 I a; when I a that is the armature current is not equal to 0 that is we are passing currents then this field will be there as well as field due to this current distribution will be there.

Now, the question is what will be how to sketch these field due to this current distribution? We have discussed it in case of electrical machine too, but I will quickly tell you how to find that out, it is like this.

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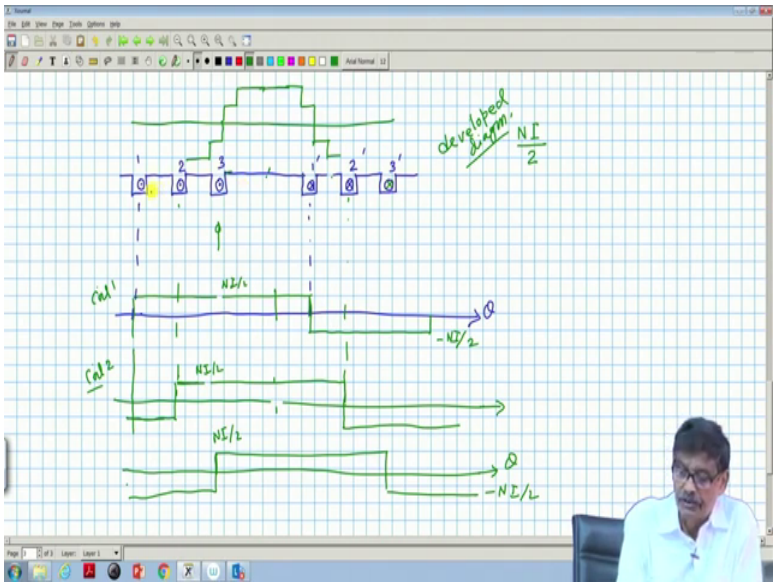

Suppose you have got say three conductors three coils say, it was on these slots of the machine I have used the developed diagram suppose this is coil 1 and its return is here 1 dashed and it is carrying a cross dot current, got the point. This is coiled 2 its return is here 2-2 dashed and these angles are pi, mind you full pitch coil this is pi electrical or

180 degree electrical so, 2-2 dashed, in our case they will carry same current similarly 3-3 dashed. This is the armature slots got the point.

Suppose only for three, suppose the armature is having only three coils like this; if it is like this then after this much a length, here once again 1 2 3 you will see because you have developed diagram the machine. Now, the question is what will be the mmf distribution? Consider one coil at a time for example, 1 and 1 dashed it will be like this, suppose I will sketch it here and against the space angle electrical this, during this to this 1 1 dashed, it will be let me use a different colour so that.

So, this will be the mmf distribution due to coil 1, why I am telling like that forget about 2 3 and 2 dash 3 it is from your memory, only 1 and 1 dashed is existing. If you consider at any point a flux path which will cross the air gap above it there are North Pole, South Pole etcetera this is the thing. So, how much is the mmf include; a mmf includes by this path if it is a multi-term coil, NI is the total mmf acting in the circuit apply that circuital law of magnetism, this mmf will be dropped in the two air gaps and NI by 2 will be the mmf in each path.

And this will forget about 2 and 3 number of coils they are suppose not there. So, it will be NI by 2 and why I have a sign positive sign because this is cross this is dot lines of force will be in the vertical direction a sign positive sign. So, it will be NI by 2 and then in this half what it will happen, minus NI by 2 is not; because 1 is here once again dot so, it will be directed downwards. So, for one coil I know therefore, I will do the same thing for the second coil and third coil so, this is for coil 1, then for coil 2 it will be like this identical coils.

Only thing is it will now exist between these two points this and 2 dashed it is there so, it will be like this and so on, this is the develop diagram mind you of the circular thing developed diagram. And similarly for the third coil it will be like this which will be here third coil starts here crossing same cross dot continues up to this point here, this is also NI by 2, this is also NI by 2 and minus NI by 2 and so on.

Therefore, the resultant air gap; so, for individual coils I have found out separately. So, resultant field because of this sort of current distribution will be sum of these three waveforms. In this zone here, in the middle you see in this space all are additive, it will be 3 NI by 2 in this zone I did not intend to make a line like this.

So, it will be like that, then between this space 2 and 3, 1 NI by 2 another positive, another negative. So, it will be minus NI by 2 resultant plus NI by 2 plus NI by 2, NI and then minus NI by 2 so, NI by 2 plus. So, in this way it will be therefore, it looks like if I draw it with a red curve because space is not here anywhere I can draw it here forget about this. So, resultant field form with a red line if I sketch, it will be suppose you also remove this here this dotted line, so it will be someone this is the axis.

So, in this zone it will be 3 NI by 2 so, mmf distribution will be somewhat like this, it will come in the middle. So, it will continue the maximum value up to this point and so, on and this side also it will be like this, it will be stepped wave form we know that got the point. Therefore, the resultant field waveform will be stepped and peak will occur here at the middle point of 3 and 1 dashed.

Now, in case of DC machines of course, they there are coils all along it is uniformly distributed almost, it is also uniformly distributed not 3 coils only, we considered 1 2 3 and 1 dashed 2 dashed 3 dashed for drawing that one middle-middle, but there exists other coil also and same thing can be done.

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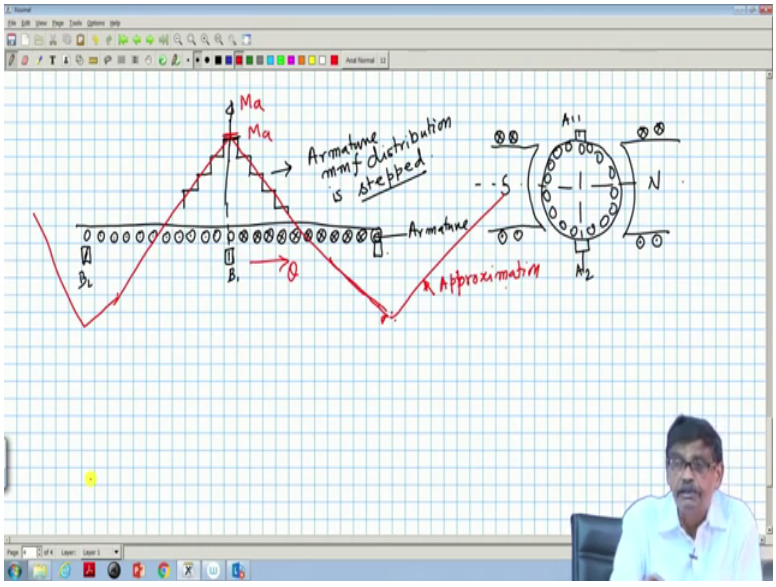

Therefore, the for a DC machine since the b distribution, the current distributions are like this dot like that these are all under South Pole as we have drawn earlier and then there will be a perhaps a neutral coil, and then as many as 1 2 3 4 5 6 7 8 9 10; 1 2 3 4 5 6 7 8

9 10 it would be like this. These are the current, this and this one coil, this and the second of this is another coil like that.

Therefore the peak value whatever will be it will be here at the middle depending upon number of turns and magnitude of the current, I can earlier it was 2 NI by 2 or 3 NI by 2 something like that. So, it will be a waveform distribution of this fall which you can work out, understood this is the whole idea. Mind you these, here the brush axises are there in the this is the armature coil armature, this is the brush positions which are 180 degree apart brush B 1, B 2.

Similarly here there will be one brush in the DC machine, it is consistent because the mmf resultant mmf will be along this line how do I get it this side cross this side dot; so, right hand rule thumb will indicate that direction. So, peak will lie here and it will be a step to a form. So, armature mmf distribution armature mmf distribution is stepped.

And if there are number of coils so, that the distance between the two consecutive slots are very less that is uniformly distributed coil this can be broken up, this can be approximated as straight lines, why not; armature mmf I can write like this this is an approximation.

So, in a DC machine we say that with large number of conductors you forget about this small variation and assume it to be triangular in nature this is the peak value of the armature mmf M a. So, M a distribution along the air gap of the machine will be can be approximated to a triangular sort of waves function.

We will continue with that and mind you this is your space angle theta therefore, I now have stator field as well as armature mmf mind you, this is not flux armature flux. And we will discuss in the next class how to superimpose the, how to get the armature flux and then superimpose it with the main field flux to get the resultant field wave form.

Thank you.