Electrical Machines – I
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Lecture - 60
Armature Winding of D.C Machines – II

Welcome to 60th lecture and we have been discussing the most interesting part of DC Machine that is the Armature Winding. It is slightly difficult, but at the same time, so interesting that is the point I want to make.

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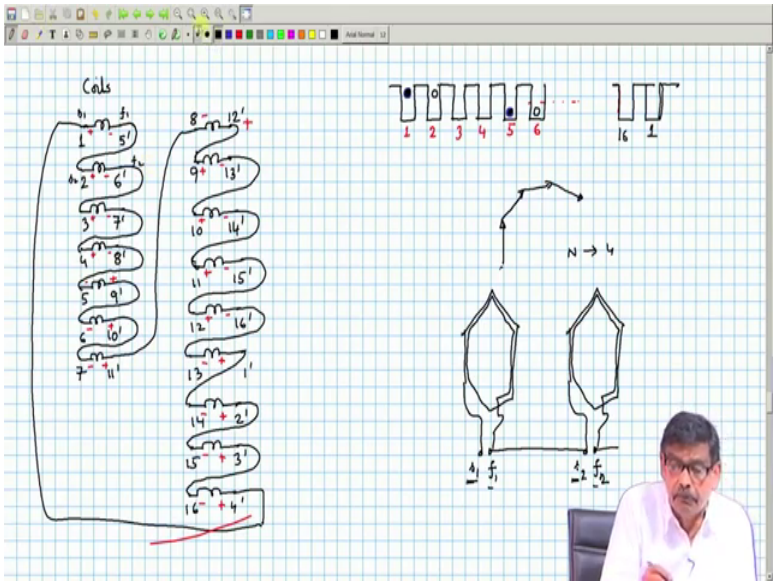

And you recall that, in my last class I told there will be slots, let us assume the number of slots 16, each slot will house two coil size belonging two-two different coils. All coils are identical and the coil span is this one ok. It is a multi turned coil I have drawn, these are the two terminals distinct terminals, this coil has got its own identity, ok. This coil I was marking it has got a starting; start and finish terminals. This start terminal this coil sides, if you start with slot number 1, that coil you calls coil 1, it will be designated at start 1 finish 1. There will be a second coil, which is identical, ok, this is the coil, this is identical.

This coil is identical; only thing is its number is to be changed like this. This is second coil start from slot number 2, I am showing it because it is displaced. It will be marked as that is what I am telling you, s 2 and f 2 start finish. And this is in slot number 1, this is

in slot number 2. Of course, slot number 1 and slot number 2 will be close by, it is like this it will come here. But for clarity I am showing you, then what I am doing I am connecting all of them in series. In the machine actually I am doing like this; similarly s 3, f 3. Where in this simplified diagram it can be shown like this, ok. This is actually start of coil 1 and finish of coil 1; finish of coil 1 is in slot number 5 dashed, this is start of coil 2, finish of coil 2 and so on. Then you get this, but this type of winding is called lap winding, ok.

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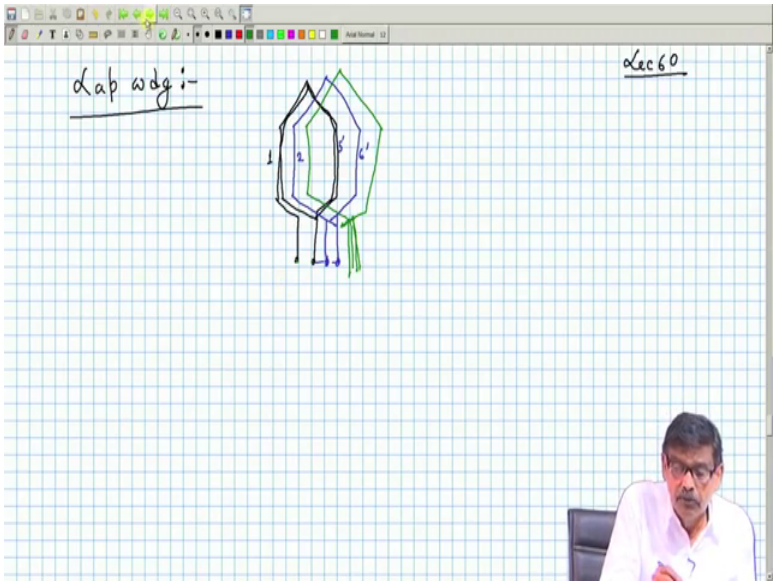

The reason is clear because of the fact, the first coil which was here I will just draw the by this simplified diagram. This is the first coil, it is in slot number 1, second coil which I will draw with a diagram like this will go like this, is not? And these are the 2 terminals of the second coil. So, this is in slot number 1, this is in slot number 2. Where this fellow is there for this problem we have considered, this is slot number 5, 5 dashed because it is in the lower deck, this is 6 dashed. So, you see and these coils I am connecting in them in series.

Second coil is on the lap of the first coil, similarly third coil will be here in slot number 3, I think you have got the idea. Is not? Start finish of the third coil that will be on the lap of the second coil, that is why it is called a lap winding, ok; in this way I have proceeded to complete the winding of the coils, ok. If that be the case that is fine as I told you, but we know that if a coil is moving this stator field is stationary, nobody is rotating because

DC current you are passing to the coils and stator poles have become magnetized alternatively as north-south, north-south like that. And their magnitude is same and they are stationary in space, unlike say induction motor, it produces a rotating magnetic field.

Therefore, to induced voltage in the rotor coils to make it run as a generator I must use a prime mover to run the generator. Coils will move and I know that there will be AC voltage induced across the terminals of each coil, depending upon its position in space relative to that field the polarity of the induced voltage will be decided, that we have discussed. Now, the question is I want to make a decision latter, that is this voltages which have alternating in nature with time the polarity of this voltage across start and finish of a coil will change reverse its polarity AC voltage you will get. So, how to do it, let us see that.

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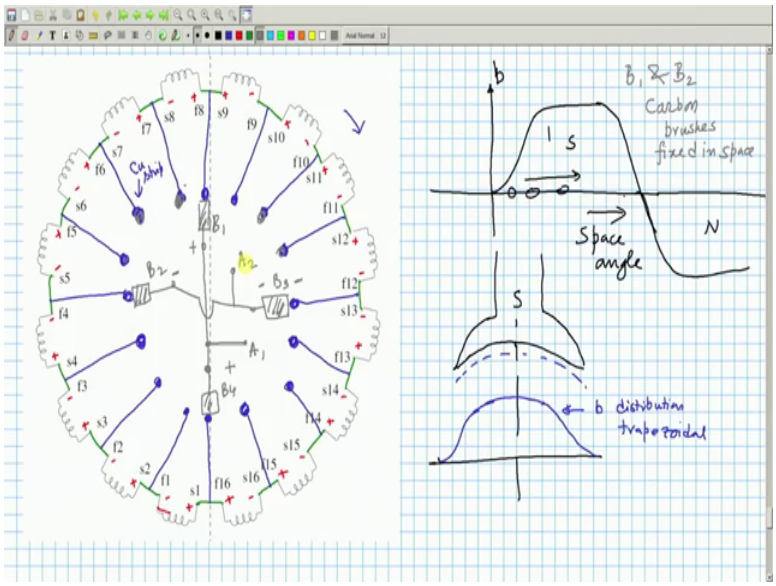

Now, I will draw another diagram like this. Look at this diagram. Here I have shown it the coils I have represented it is abstract; abstract in the sense I know how the coils are disposed in these slots specially. Suppose for example, s 1, f 1 this is the coil number 1. I know it starts in slot number 1, returns from its finish some slot number. I am sure about one thing, if this s 1 fellow this coil side of this coil 1 is under North Pole, the other its return will be under South Pole, is not, that is what I know. Therefore, these all these 16 coils, I have shown like this. They are displaced from each other by that angle 360 by 16, I make some 22.5 degree and so on.

And what I have done. I have connected all the coils in series ok. So, I have done it like this, finish of the; follow me very carefully, this I have shorted because all coils have been connected in series; these what I have done. All the 16 coils have been connected and the circuit is closed; is not, this is what I have done. Now in the previous diagram, I drew it much more simpler way, but this is a somewhat better representation to my mind. Now what I will do is this, remember this conductor will be moving in a particular direction and I have taken a snapshots at a certain time frozen everything. Then I would expect, the four coil sides, the four slots will be under the influence of the North Pole, next four slots will be under the influence of South Pole and so on.

Let us assume that 1, 2 these are slots number also. 1, 2, 3, 4 these slots are such that the induced voltage polarity are positive. And obviously, they are returned they are under South Pole that is this side, coil sides, this must be minus, this is how? Then the next four coil sizes, that is s 5, s 6, s 7, s 8 direction of prodigious same but they will be suppose under South Pole has to be if it is under North Pole s 5, s 6, s 7, s 8 must be under South Pole and the polarity of the voltage will reverse. So, it will be minus plus, minus plus, minus plus and minus plus. And similarly, then 9, 10, 11, 12 will be once again under North Pole 9, 10, other will be negative 9, 10, 11 and 12.

And this will be then once again opposite, minus plus, minus plus, minus plus and minus plus. So, I have taken a snapshot and I know this will be the induced voltage ok. But where is DC about it? Mind you the magnitude of the voltage instantaneous values polarities are like this may not be same with this one. Each one of them, because the value of b might change, under the North Pole no doubt, but the value of b may change, is not? In fact, b distribution let me tell, in case of DC machine it will be like this. Somewhat trapezoidal if (Refer Time: 12:10)this is the thing; this is the b distribution, ok. So, this will be the trapezoidal b distribution, flux density distribution, vlv. Here the conductors are moving.

So, the value of b here, suppose this is under South Pole, this is North Pole ok. Conductors are moving here, relative to this field. Those who are having under South Pole, they will have some polarity plus minus etcetera, but each one of them will have same polarity because, they are under one pole. But the magnitude of the voltage of this coil will be different from this, no doubt that is this polarity of the induced voltage, although it will be plus minus, plus minus for this four coil sides, but their magnitudes

may differ, depends upon that position of the conductor and the relative value of the b there ok. b distribution, what is this axis? Space angle. There is no compulsion that b should be sinusoidal. In case of AC machines we insist that b distribution let it be sinusoidal.

But, here my goal is to get DC, why? I unnecessarily insist upon that fact make b distributions sinusoidal. It will be made DC in a very nice way. In fact, b distribution has to be like this because the pole, if you draw one pole, stator pole under this if you suppose this is South Pole, this is the center ok. Air gap air it will be minimum here it will the influence of the previous North Pole has ended so, your b distribution will be somewhat like this then flattened, ok.

Rotor structure is like this. So, here air gap is more uniform it will be flattened and it will once again come to. So, trapezoidal; b distribution trapezoidal, but in a single coil it goes on the south, north what will be the induced voltage, if you see in the oscilloscope. That will be also trapezoidal. Whatever is the nature of b distribution that will be the induced voltage pattern, what else, is not. So, alternating voltage will be induced, that will be trapezoidal in nature.

Now this is the crucial part now. I want to get DC voltage out of this picture I mean what should I do and this mind you it is rotating, time elapses. Once again another it is; right now it is 1, 2, 3, 4, 5, 6, 7, 8 will be there after some time the 16 coil will come this side and coil 8 will go to that side, are you getting this is rotating nah, I have taken a snapshot.

But at any given time this name is now not important. What I am telling, I would expect there will be 8 coils on this side and 8 coils on that side. Because this fellow is rotating ok, this coil goes to that side, but it will be filled up by this coil coming to this side; are you getting the point, this is most crucial. That is at a given time, this numbering I have done fine to understand what is happening, but after some time 8 will come to this side, 7 will occupy the position of coil 8 here, 6 will advance here, if it is rotating in this way and so on, got the point?

Therefore, it looks like that in this space, these are position of this space. Suppose I say that I will from the junctions here, I will bring out some wires; are you getting. From all the junctions I will bring out some wire and this is conducting wire, this is suppose some

copper strip thick copper strip, like that. This is the most nicest part of this whole thing, whoever first imagined this way it can be done excellent, I mean ideas.

So, you think in this way; that ok, from the junctions what I will do? I will drop down some wires here and terminate it on thick copper strips each one; are you getting? So, it will be brought on to same distance, I mean you understand like this. So, these are junctions of this series connected coils, you have brought.

And then if I say that look what you do, you take a carbon brush and therefore, what will happen? If this fellow rotates this junctions will also rotate in space is not? If this coil is rotating this can be also numbered, this fellow will also rotate it will come after sometime here, if the direction of rotation this way. This fellow will come here like that. But, I am certain about one thing, what is that thing? That you see this junction that is this point in space, whoever; whichever coil comes, it will have a plus here.

Similarly, so what I will do is this, I will connect a carbon brush here, brush 1. And I will connect a carbon brush there, in space B 2. And they will be nicely placed and they are fixed B 1, B 2 are not rotating; B 1 and B 2 carbon brushes, fixed in space, not moving. But, what it will do is this, whenever any coil side come in this position, it will touch that coil end plus and no matter whether it is 5, 6, 7, 8 or 1, 2, 3, 4 has come this side, this polarity of this voltage will always be plus minus, no alterations, ok, newer and newer coils will come this coil will go behind the same, it will go to that side. But this will be occupied by this coil.

The interesting point is whoever comes in this position it cannot escaped. This destiny of polarity of the voltage plus minus, it has to be this side plus this side minus no matter whether coil 8 has right now here or coil 6 is there or coil 14 has come here; whoever comes he will be treated in the same way, because VLV decides the polarity a magnitude of the voltage and polarity by right end. Therefore, I will fish out from this series connected voltage I will identify where is plus minus in space and in the proper space, I will connect the brushes. After some time this copper strip will come in contact, mind you this because of my inability to it is in the same position, when this coil come, it will come in touch with B1; this junctions are moving, this brushes carbon brushes are fixed in position.

And I am we can conclude that no matter let the armature rotate at high speed or whatever it is, across B1, B2 you will always get DC voltage, no AC voltage. That is we are from the space distribution of the polarity of the EMF's we are ascertaining, we are satisfying with arguments that whoever, whichever junction comes here it will have plus. This one plus, oh I am so sorry I would connect it here this you please forgive me, this one this brush B 1 we I will connect it here. That will be the most optimum sequel, wherever plus joined you connect it here. This should be the position of B 1, B 2 is ok, minus minus is not. Always you will get across B 1, B 2 DC and these fellows are moving after some time this junction will touch, after some time this junction will come but, whenever it comes it will a plus plus here.

So, from the junctions you have to drop out some wires terminated some copper strips and placed your fixed brushes in appropriate positions and so on, is not. Then it looks like that wherever plus minus, plus minus, plus minus. This is here also I could place a brush very nice, fixed brush say B 3, because minus minus as joined. So, this is the negative brush, this will be the positive brush. Similarly this one will be B 3 is there a negative brush; B 3 negative it will give and where plus plus has; I will connect another brush here B 4. I can tap the voltage from these positions and then what I will do is this, this is also plus.

So, have you got the idea? This is the essence of the thing. You have AC voltage fundamentally induced in each coil, no doubt and it will be alternating in nature because b distribution is alternating although not sinusoidally, it does not matter. It is trapezoidaly it is varying. Therefore, I will get AC voltage induced across each coil, here if you see the voltage waveform between these two terminals, that will be AC in the oscilloscope and that will be trapezoidal alternating.

See the voltage between these two points, it will be AC. Only thing this voltage and this voltage will have a phase displacement, because they are not put they will not be in phase, their positions are different in space. But the interesting point is, I want to get a DC voltage out of this AC voltage environment. Then it is done like this, argument is imagine that any it is rotating at high velocity like that fine there are suppose 16 coils.

So, at a given time I will expect four starting coil sides will be under North Pole say 1, 2, 3, 4; s1, s2 s3, s4 under the influence of North Pole. And its return coil side must be that

is f1, f2, f3, f4 finished coil sides will be under the influence of this South Pole. And suppose direction of rotation is such, then by applying right hand rule I come across this polarity plus minus, plus minus, plus minus for this 4 coils. If s1, s2, s3, s4 under the influence of the North Pole, I take a snapshot at that time. Then s5, s6, s7, s8 should be under the influence of South Pole and they are returned or finished coil sides f5, f6, f7, f8 should be under the influence of North Pole. And that way I decide the instantaneous polarity of the induced voltage, how in space it is distributed, because each coil has got two terminals.

Then I argue that let the rotor rotate, but at a given time it is expected not that 1, 2, 3, 4; s1, s2, s3, s4 will remain always under North Pole. It is moving s1, s2, s3, s4 suppose it is moving in the clockwise direction, it will move this way, but next s terminals will come another four. And their distribution of polarity will be exactly same, when they occupied the positions of s1, s2, s3 and s4 which was occupied earlier a bit earlier by those 4 coil size. Therefore, in space the polarities of the voltages it remains same. Therefore, we now know what to do to tap a DC voltage out of this AC distribution of induced EMF is that, that where ever plus plus joins drop a; from all the junctions you drop conductors and terminated thick copper strips, ok.

Then place some carbon brush, in space which will not move mind you these junctions will move because they are at these junctions this fellow is moving. But this brush I will not allow to move with some spring this type of arrangement stator structure I will hold it in this position always similarly, B 2 negative-negative, B 3 negative-negative and B 4 positive-positive. Then I will say that across B 1, B 2 you get a DC voltage.

And I will go further, I will join this positive-positive by an external wire, these are all stationary. And I will join this negative-negative together and this I will say ultimately as my armature terminal A 1 and this negative-negative I will say as I may get terminal A 2, ok. We will continue with this in this next time very interesting, I mean how really from AC voltage you get this DC voltage.

Thank you.