Electrical Machines -I
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Lecture – 57
Homopolar D.C Motor

Welcome to lecture number 57 and we were actually discussing some elementary DC machines in the last couple of lectures.

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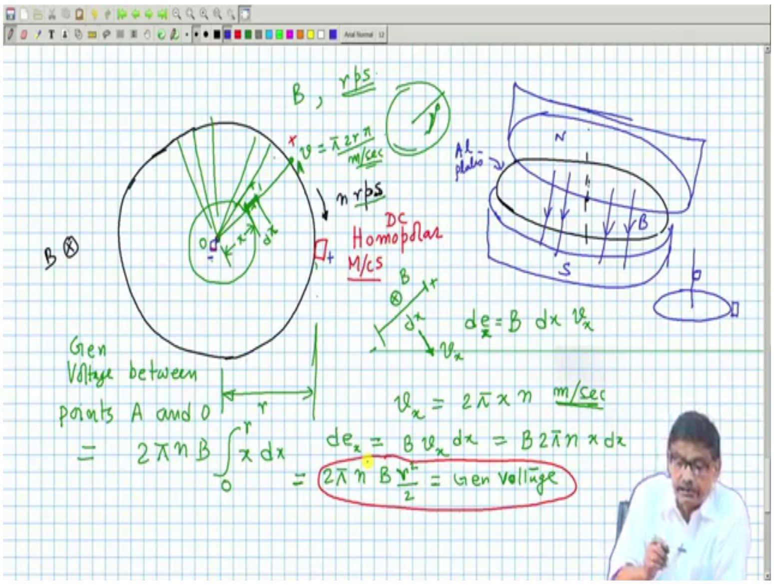

And, recall that in my last lecture I told you about a simple type of DC generator, where an aluminum disk is rotated at some given rps of certain radius r. And, there will be magnetic field from top to bottom penetrating the disk, all over the surface of the disk. Then, what happens is if you consider a radial line, there will be induced voltage between the center and the perimeter of this disk. And, the value of that voltage is given by this expression ok, this expression.

This we got last time. So, it is directly proportional to B and radius square and rps of the machine rotation per second. Now, and also the polarity of the voltage will be this side plus this side minus. And mind you that this induced voltage, that is along the radial lines the voltage exist, but along the direction of the theta along the direction of the r at any radius, there is no voltage difference between this point and this point that does not exist. Because, there will be at equipotential points if you draw a circle that circle will become equipotential. Of course, the value of the potential increases a few a as you travel from center towards the perimeter of the disk.

So, this type of generator of course, it is feasible, unlike your single conductor infinite length DC machine this machine can be easily constructed. And, this type of machine is given a name called Homopolar machine, homopolar machine, DC homopolar machines. Now, how to collect this voltage? What you have to do is this you have to take two brushes, fixed brushes, 1 is here. And another at the center somehow on the spindle suppose you connect the brush ok, this is the disk you recall this is the disk, this is the spindle.

So, you connect I just to give you idea this is 1 brush, this is another brush. These two brushes are fixed and the disk will rotate therefore, it will always touch the perimeter the brush fixed brush. So, 1 brush is here, another brush is there. These will be the negative brush, this will be the positive brush and through this fixed brushes it will supply the load.

Therefore and the magnitude of the emf generated is given by this. So, this is how you can generate DC voltage. In fact, this type of configurations or this type of DC generators are used, when the magnetic field can be made very large as in a superconducting coil will create this magnets whose strength will be very large ok. But, anyway this is for instruction, but for very large power at room temperature this machine is not of mechanically very strong and things like that. Nonetheless this also gives us some idea that, how easily DC voltage can be generated? And, we should not forget also that this type of machines can also be operated as a motor.

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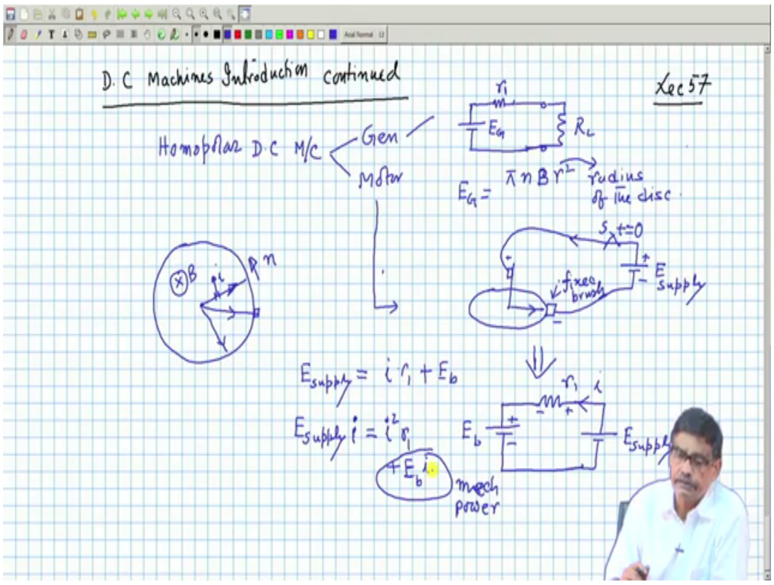

So, as a generator that homopolar machine, homopolar DC machine. It can be also operated both as generator and also as motor, when it is operated as generator, we have seen it can be modeled as the generated voltage between the brushes. And, maybe it is some resistance effective resistance internal and then your load resistance, this is the internal resistance and this is the generated voltage. And, generated voltage we have seen it is proportional to this thing that is pi n B r square this two cancels. So, pi n B r square. So, this is equal to pi n B r square. Let us use different notation here this is r 1; this r is the radius of the disk.

And, this r 1 is the internal resistance of the source pi n B r square, by something was there no pi n B r square 2 2 cancels. So, pi n B r square these will be the expression of the generated voltage ok. If, you want to operate the same machine has a motor, then what you should do as this is generator operation, for motoring operation, what you should do is this. This is disk, these are the 2 brushes ok; one is connected to the spindle these are the 2 brushes. Here you connect a external supply, supply is supplied voltage. If you connect a supply voltage like this with this polarity that current will flow like this, it will come here at the center it is connected to the disk current will all flow radially.

That is if you look at the disk during a motor operation, it will be the way I have drawn, it will be this and this, currents will all flow radially. It will come here then come here; many parallel paths are there for current to flow high. So, polarity of the applied voltage is such it comes suppose it was stationary initially. And, let us assume that B is in this direction into the paper, then you can apply the left hand rule B i l and this machine will start running in the anti clockwise direction left hand rule you have to apply.

And, it will in the anti clockwise direction it will start running. And, once again it will finally, reach a steady speed, when the applied torque that is the electromagnetic torque developed is balanced by the opposite or present on the system. That is friction whatever it is, but nonetheless in this case the moment it starts rotating we must not forget, each this radial lines become source of emf, of this magnitude pi n B r square. At t equal to 0, when it was beginning to start you have switched on the supply with a switch at t equal to 0, before that it was stationery, you have closed the switch at t equal to 0, it was stationery now it will start accelerating electromagnetic torque will be produced. And if it can overcome the frictional torque present on the shaft it will start moving.

And finally, it will attain a certain speed when the opposing torque and the electromagnetic torque will be equal ok. Now, what is the direction of this force, if you calculate it? It is we have seen B i l. Now, this segment what will be the polarity of the voltage. In this case polarity of the voltage will be if you take an element here, it is moving with this v and this is B.

So, B and v this will be the polarity, that is the tip of this finger is towards the centre and that will become plus. So, the polarity of the induced voltage will make this is plus this is minus, it is correct this is back emf. So, it will try to oppose the inflow of current into the motor. The model, in this case will be there will be an back emf with this polarity E b. And, this resistance r 1 in any case present and then you have your E supply like this, E supply and this is the current and polarity of the voltage once again like linear motors.

So, it will try to oppose the supply voltage. And, when these things are running steadily, I can easily say that steadily drawing some current from the supply, I will say it is operating as a motor and they and delivering some mechanical power. How much is the mechanical power 2 ways it can be calculated. You calculate force then multiply with velocity whatever it is integrate or simply it will be the mechanical power will be v into i that will be also.

Power supplied here is E supply into i, a power certain power will be lost here, remaining power will be this one. So, you can then easily write that E supply will be equal to i into r 1 plus E b ok. Multiply with i both sides so, you will get E supply into i E supply into i, will be equal to i square into r 1 plus E B into i, this will be the thing. So, this is power drawn from the supply a portion is lost as copper loss in r 1 and remaining power must be the mechanical power, mechanical power. Anyway, so, it can operate both as a motor and generator mode like, our single conductor linear version of DC machine ok.

So, after this idea of DC machines and here are no complications, only you require two fixed brushes ok. To be touched one at the perimeter fixed brush mind it, they are not moving, [FL] fixed brush. So, this is the power balance equation of this simple DC motor, which has no complications what isoever. So, for it is construction is concerned.

Now, we will discuss about a formal large power DC machines ok. And, that is a DC machine with which will have a rotor, it will have a stator and then it will be having a shaft and it will run in a magnetic field. And, there will be two terminals available to supply the rotor coils, there will be two terminals available to these stator coils and if rotor carries, current rotor coils and stator coils both carry current, then they can produce some force and you get sustained rotation, when the electromagnetic torque developed by the motor and the opposing torque present on the shaft of the machine becomes equal.

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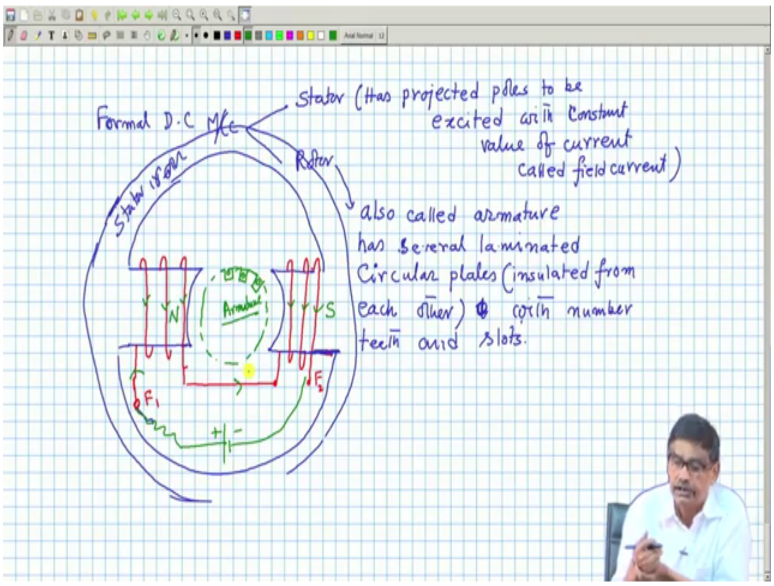

So, before that you it will look like that the DC machine has got I have formal DC machines, DC machine will have a stator and a rotor ok. The rotor will be laminated iron circular plates with slots cut in it and I will that is what I want to tell that the.

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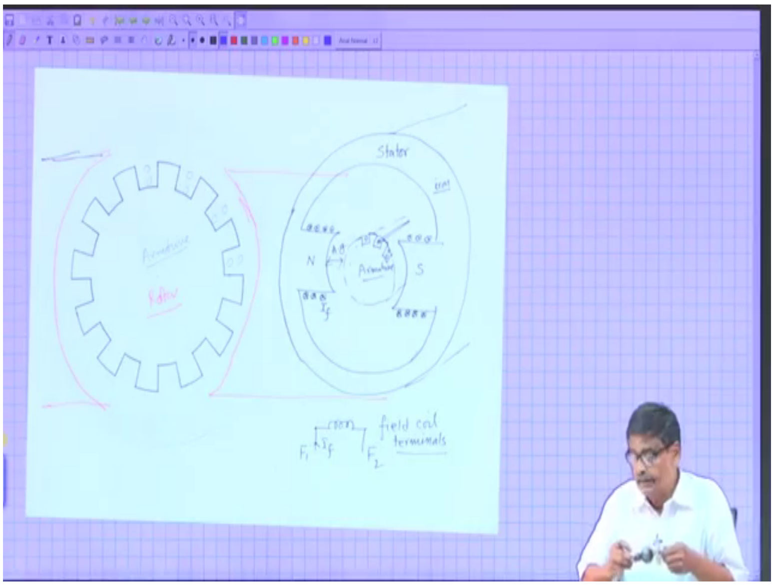

For example, this is the laminated plates of the coil where this is the armature winding of the machines, this is called the armature. So, there will be several such circular laminated plates, they will put one above the other and that will give you the length of the machine. And, these are slot and teeth as usual and there will be conductors placed on the slots in a following a particular logic there they will be placed and they will be connected ok.

And, the field structure of this machine will be this is the rotor of the DC machine rotor, where this is called armature. And, it has got slots and teeth and in which there will be copper conductors of coil will be placed. The stator part of the machine will look like this one to projected poles, one on this side and the other on this side ok. And, there will be on the stator.

So, if I draw it in this in a small version, it will look like this you have two projected poles on the stator; two projected poles on the stators. And, there is this rotor business which has got slot and teeth all along as I have shown here and these will carry conductors. On the stator this is the stator iron and there will be coils here, which is simple coil stator coil is very simple it will be like this. And, if you pass some current through these coils cross and dot like this and these two coils are connected in say series, these two parts of the coils may be connected in series, and you connect it to a DC supply. So, that current flows in the stator coils. And, then this will become a north pole this will become a south pole produced by stator structure.

So, I f is the field current. So, what I am telling these two coils connected in series, will ultimately give you two terminals available to you from the stator and they can be marked as F 1 and F 2 called the field coil terminals; field coil terminals, got the point. And armature is slightly involved that we will see, but the stator structure is made of iron and preferably solid iron, unlike induction machine stator, which must be also laminated.

It is suppose a solid piece of iron and it has got a length mind you. Similarly, the rotor will have a length like that ok. This conductor will run all along this all the conductors in these slots. So, this is the stator structure and stator is therefore, can be represented by a simple coil. And I will connect pass some DC current I f like this. And, these two coils are connected in series F 1 F 2 is the ultimately two terminals coming out and this is armature ok.

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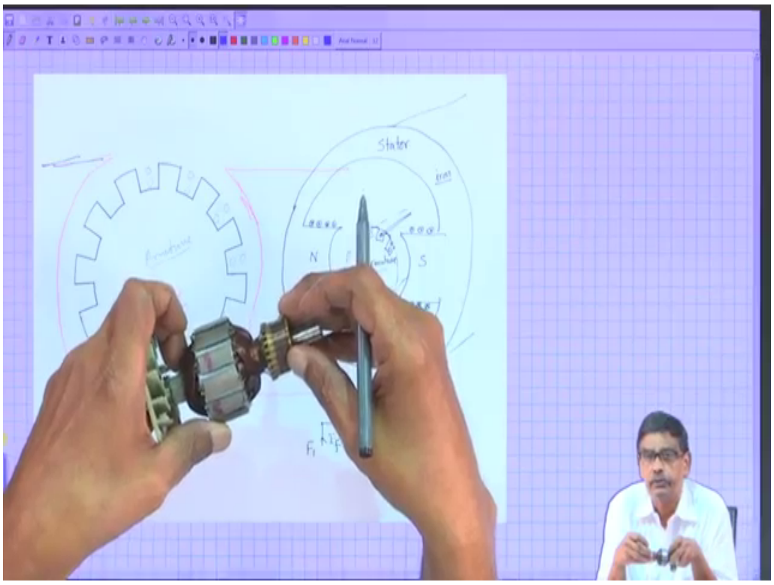

But, armature will be a bit complicated we will come to that and before that I will show you a an actual DC machine armature a small DC machine armature.

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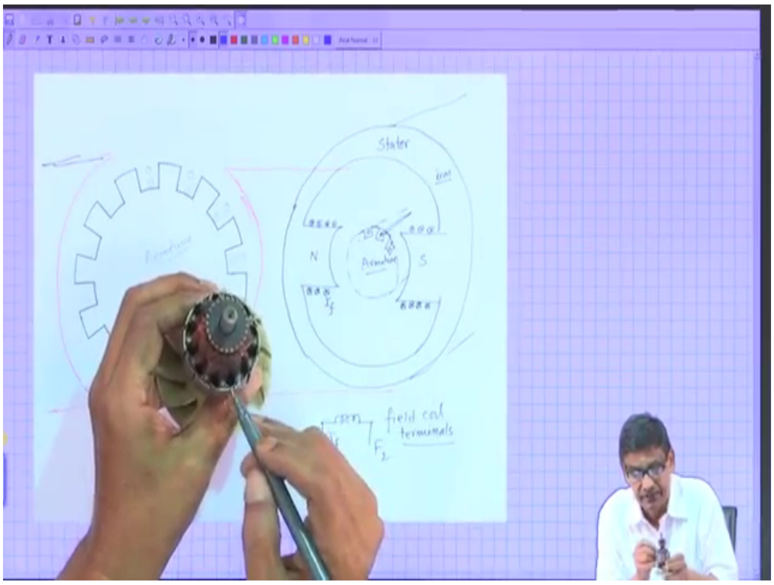

This is what these slots and teeth are slots and teeth, then there are several plates stacked together to give you the length of the machine. And, in these slots you can see multi turn coils passing. And, they will be connected in a particular fashion. And, this part which I will discuss extensively, why this is necessary this is called the commutator segments ok. And, it is this part which will help us to change it the AC voltage generated in the coil to convert it to DC voltage that will take up later, but the idea is clear.

So, this is rotor which will rotate on this shaft like this and it will rotate in two stator magnetic field, one on this side north, another on this side south like this and it will have a stator. So, stator part I have not brought. And, there will be an air gap between these this is the idea I mean you should have a physical idea how the machine looks like, that is fine. Now, before we start this DC machine. So, stator is will give you projected poles like this, stator is has projected poles has projected poles. And, to be excited with DC current with constant value of current value of current called field current ok.

Rotor will have rotor is also called armature also called armature for a DC machine, armature has several laminated, circular plates, circular plates, insulated from each other; insulated from each other. Like transformer from each other, by a varnish coating or whatever it is has several laminated circular plates insulated from each other, to with number of teeth and slot and slots ok.

Now, before so, field winding field coils, they are very simple, you simply have projected poles around it you just suppose this is a projected pole like this. And, you make the coil like that and there is another pole suppose here. And, you have coils like this, here also and this is the structure of the stator poles I have shown their joint like this and it will be a circular thing. So, it comes like this red one are the coils and this is the thickness outer thickness of the iron of the stator, it will be like this joint, this is the stator, stator iron, which is not laminated the reason we will see.

And these two coils what you will do is this these two coils you will connect in series as I was telling. And you connect some and these two terminals may be marked as F 1 and F 2 and your stator coils are ready. Now to this stator coils, if you pass some connect some resistance in say series, you connect some in other I show connect some resistance and connect a DC source, it will send current like this and the direction of the current will be like that.

So, that this will become a North Pole, this will be coming South Pole, this is how stator poles will be created and this is d. So, these two coils will be connected in general series to create a two pole structure like that. And then in the armature, armature part is more crucial, the armature will be here like this with slot and teeth, this is armature. And, here there will be coils placed in the slots following a certain grammar, certain logic. So, that you can ultimately get DC voltage in it so, we will continue with that. So, constructional features we are discussing of formal DC machines.

Thank you.