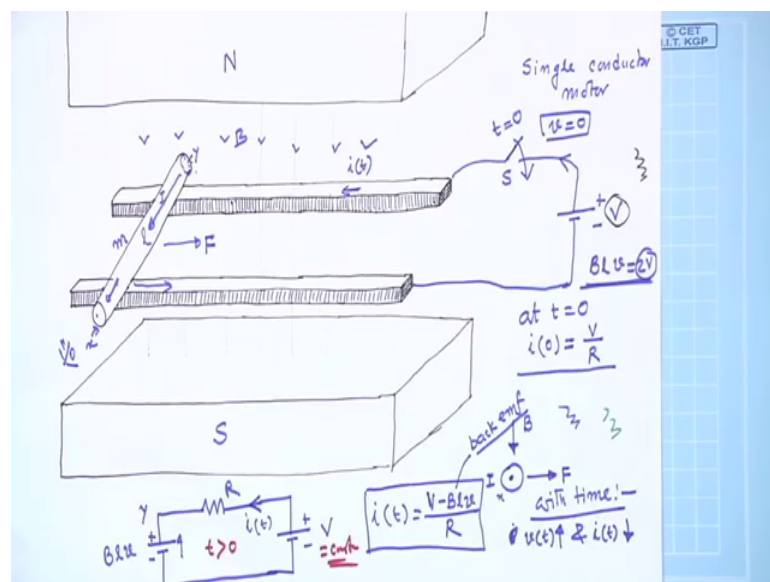


Electrical Machines - II
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Lecture – 10
From Linear to Rotating Machine

Ok welcome this 10th lecture on Electrical Machines II. So, we have started by considering a single conductor motor and generator and recall in our last class this was the situation.

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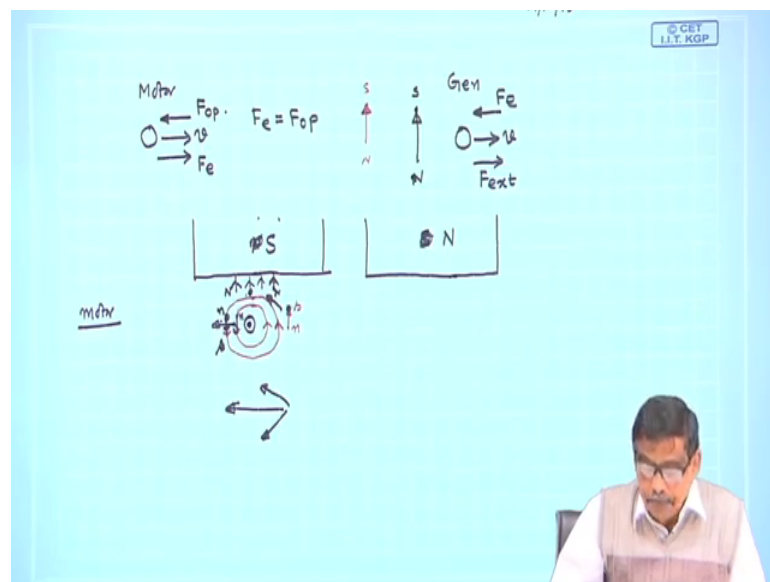
I mean the arrangement was this there was the single conductor of finite length and if it is a motor mode you must connect a supply and if you this is your source voltage, if you close the switch it will start moving by applying left hand rule you can find out and from the word go; that means, when initially switch was opened it was stationary. So, it will gradually pick up speed because of the electromagnetic force produced BIL that is i , that is b and direction is obtained by applying left hand rule and it will start picking up speed.

And if you assume that everything is frictionless here, then final speed will be attained whose value will be such that BLV is equal to your V and then it will settle down. Of course, when it settles down at that steady states speed current will be 0 and everything is satisfied, no power mechanical power output because mechanical power output means force into velocity, no force is acting at that time output mechanical power is 0, input

power is also 0 from the supplier; of course, your battery supplied some energy to the system, which will be ultimately stored as the kinetic energy in this conducting length.

We did this things and we will found out how this current and velocity varies with time and finally, attains a steady state value; of course, just for fun one one is not suppose to produce a motor which will be doing no mechanical work. So, mechanical work means there will be some opposing force and I concluded last time; this is the thing you should remember that if it is motor, if it is motor operation then the conductor if it is if it moves in this direction with a velocity V , then the electromagnetic force will be also acting in this direction.

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And if it is having a constant velocity and if there is some opposing force present, this is opposing force F_e must be equal to $F_{opposing}$ for motor mode of operation. So, electromagnetic force and opposing force they will be acting in opposite direction. Direction of motion is decided by F_e , F_e decides what is V . For generator mode, it will be like this the direction in which it will move is decided by the external force I have applied and electromagnetic force will be in the opposite direction. And when this 2 are equal, it will run at a constant velocity V . Just one point I would like to tell because the next course of action in understanding rotating machine will be to go from linear to rotational thing before that I would also like to think in this way. For example, you have

a field pattern field north here, say north here and then there is south gear these things we were discussing. So, this is south and a conductor is moving in this direction.

Suppose and suppose let me call it south to be consistent with our earlier diagrams, so lines of forces will be like this here you know south of force. And suppose let us consider motor mode, if it is motor mode; that means, I am injecting some current into the conductor and let the direction of the current be dot. If it is dot and if it is south, so conductor will start moving this is b, this is i, left hand rule you have to assume and conductor will start moving in this direction if it is motor mode.

Therefore, now I would this direction is achieved by applying left hand rule no doubt, but you can do another thing; that is, when this conductor moves and this conductor carries current it will produce lines of forces which will be like this here is not, several lines of forces. This, the field around the conductor will be like this. Now I also told you that if I show draw a single line instead of drawing so many flux lines, representative way of showing the field lines is in this way. What the arrow is you will expect this side is south and the other side is must be some north from which you can always imagine like that.

Now, so this is the thing, now if you look at this arrow here this flux lines, you notice that this I will think that here is a small s and here is a small n, this lines of force is there it is heading towards south like this and this is north. Similarly if you look at the lines of force of this stationary magnets, it is like this. So, I will always think that there is a north pole here and south pole is here fine.

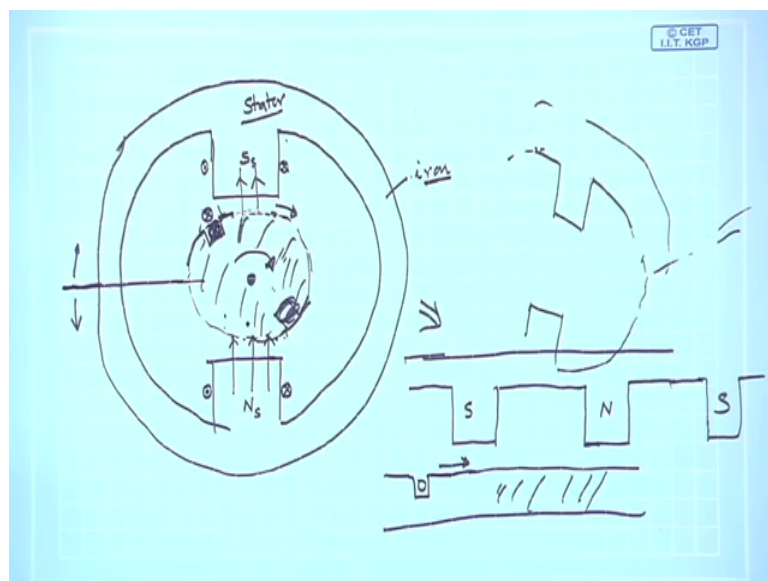
Therefore, this south and north will be attracted. Similarly on this side, this is the south pole, so this is north here and the any of the lines of force you take there this is heading for a south and this is small s and this is small n. Therefore, what we notice is that, the this current and magnetic field they interact and give you torque or force that is fine, but another way of looking at the thing is the argument is like this on the stationary structure you have got some south north poles and the and the conductors which will be moving eventually and if it is carrying some current, it also produces some north south pattern. And it is the interaction of this pole patterns that will give you motion. For example, I will say this south and here is a north of the capital N is by this once, this will have a attractive force here.

Similarly, if you consider this side of this 1, this is north and this is also north small n and this lines of force north they will repel. So, you will get a force like this and eventually it will move in this direction vertical components cancel this time that way also you can think. In other words, what I am trying to tell to know the direction in which the conductors will move one can imagine ultimately it can be traced down to this particular fact that 2 sets of magnets are interacting with each other, one set is produced by this structure which is not moving south north whatever it is.

And the other fellow is the conductor which is suppose to move be it motor or generator, but it will carry some current at a given instant of time and depending upon the direction of the current, I can draw the flux lines it creates and recalling this fact any flux lines, you draw like this means this steep is heading towards a south pole and this side is a north pole. With this simple argument you can easily see indeed the conductor we will try to move from right to left in this particular case ok.

In my last class I also told you that this type of single conductor generator is not very practical, you get very little voltage, perhaps you can connect another coil connect them appropriately in series, get twice the voltage all this things I have done, but constructionally it is not a good practice to have mechanical power from electricity for motor operation. So, the nearest thing that I can have is I will first draw then I will show nice diagram.

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That is I will make an arrangement in this fashion, suppose here is a north pole and here is a south pole and I will make it circular like this, these are iron soft iron I can do like this and by passing some current here. And suppose around this projected pole, so this is circular, this is iron. If you pass some current here, you can make it like this suppose the current direction, this is a coil wrapped around this projected pole, suppose this is cross dot, so lines of forces will be like this. Therefore, this will behave like a south pole because flux lines are entering. Similarly here on the opposite side, you in this projected pole you make a coil wrap a coil around this projected pole and you pass a current like this, cross dot. Then the lines of force which will emanate from this will be like this. So, this will behave like a north pole.

So, in a sense what I am trying to tell, this magnets could be permanent, but as well as it could be electromagnets by having coils wrapped around the projected poles and you pass some DC current, here the advantage is you can change the strength of this field by varying this magnitude of the current wrapped around it. So, this is the scenario I make. Then what I do is this, I take another iron piece which is circular in nature. And there and this as these are all cylindrical you know perpendicular to the plane of the paper the same it is the sectional view of a 3 dimensional thing which is perpendicular to this that is this one is length ah in essence if I very badly I mean draw, but quickly it is like this here circular. Are you getting? I mean 3 dimensional.

So, length is perpendicular to the paper. Now what I will be doing is I will the this is a solid suppose iron cylinder, where I will cut a what is called a slot like this, a groove like your gear thing that is this way I will cut. So, these are all iron these are all iron, but here it is air you have cut it.

Now, here you can place a conductor forget about this slot single conductor, I can place a conductor like this and this will resemble our single conductor generator here in which way in a very limited space everything is quiz now. Suppose this is moving in this direction, you are turning this, this is suppose to move and it is called rotor it has got a shaft suppose by hand I am moving it. Then is not it is same as a suppose you imagine that. So, what will happen? This conductor will move it will come under south pole, remain there for certain time then it will further move, then it will enter under north pole and once again it will come to south pole.

Is it not same as a equivalent machine like this, south north and here is also iron and here is a slot single, slot it is also iron. So, what I am essentially doing is I am cutting this you imagine you have cut this with a something you have cut it and wrapped out wrapped it out like this and you will get this that is you cut it and unfold it.

So, this rotational circulate things will now appear to be linear and this will be your this iron is this iron and this iron is your stationary part iron which is not moving and this conductor is here. So, it is moving, but here it will be moving like this. And after it crosses south pole then north pole, then once again in this one circular diagram it will face south pole once again and once again it will face north pole.

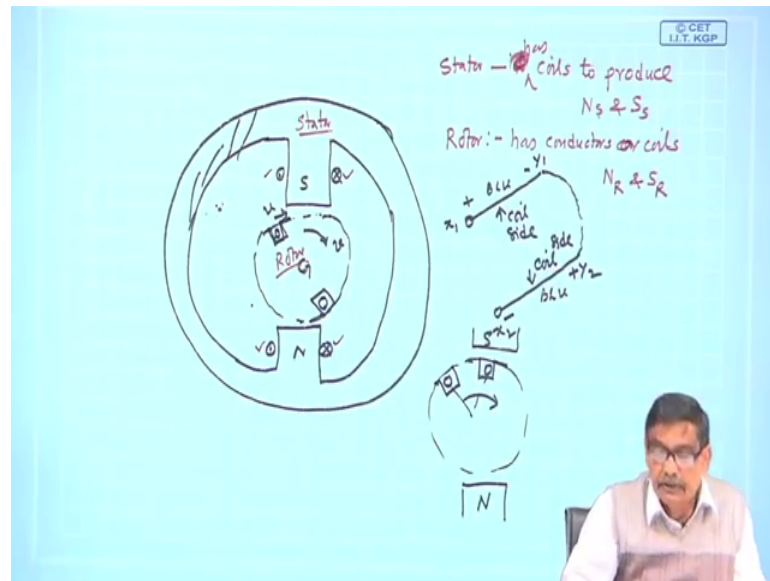
So, these arrangement is equivalent to an infinite south north poles present and this fellow is moving. Is not this just similar to this one? Anyway so ahs so this is how I can make a single conductor generator and if you turn it on it will always induce voltage here across it, across the conductors.

And if it is b generator or motor mode this fellow will also carry current, this conductor and this conductor will also produce a magnetic field and this magnetic field was produced by what is called the stator coils carrying current stator coil they will carry current and this two fields will be produced, let us call it S s and N s, this s stands for stator, the part therefore, every rotating machine will have 2 parts, one is a part which will never move fixed and another cylindrical part, where there will be slots, where there will be conductors and this is free to rotate in any direction this way that way.

Therefore I would expect for example, if I pass some current in this direction a say cross current I am press passing through this I am so bad, so the this is cross current suppose this conductor, then this is the current and the field this is still south pole here lines of force will go, so it will try to move like this.

So, you will get motoring action and for this you do not require infinite space and things like that everything is circular and the conductor will go on seeing various poles. To make this matter I mean what I want to say is before coming to that let us see this. So, now I will use 2 conductors in this structure. So, suppose I will and we will come to this over and over again do not worry about.

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So, suppose this is north pole and this is south pole let me draw quickly and this is the iron these are all iron and it might have some coils to create your north and south pole this becomes south pole this becomes north pole we have seen.

Now, what I can do is this, I will and this is the rotor and here instead of a single slot, I will connect 2 slots in diametric opposite positions and here I will connect one conductor here and another conductor there this conductor at the back end, I will join them that is this conductor runs learns like this, this conductor learns like this and I will join them in the backward direction. It was like I was telling that this is x 1 y 1 and this is x 2 y 2.

And then this 2 conductors if you join at the back in this fashion, then I can call this to be a coil and by placing this 2 coil, 2 2 conductors in this positions, I have ensured one thing what I have ensured? Is that, when x 1 y 1 will be under the centre of the south pole, I am sure x 2, y 2 will be under the centre of the north pole and this two e m f's if it is plus minus here this will be minus plus there and then the voltage across x 1 x 2 will be twice of this 2 voltage, this is BLV, this is BLV, but the polarities are such that this 2 e m f's get added up and you get sum of these 2 voltages appearing across x 1 x 2, if it is operating in generating mode, suppose in generating mode a what are the things we have to give create the field BLV, B I have created, L length of the conductors that is there and this velocity I must provide by some external agent say turbine or by some diesel engine whatever it is, this is this will be provided by tangential velocity is V you give rotation.

So, you will replicate the situation here and this 2 are connected in series by a flexible wire at the backend of this one and so you will get twice the voltage.

If somebody says as suppose I mean you can always think various way suppose you put a slot here and you put another slot there and this 2 you add in series. Ok this will also work it will also give you voltage between x_1 and x_2 , but not the maximum voltage because of the fact if this is say south pole and this is north pole, then the voltage pattern of this coil will be the b pattern existing here that we have explained last time and identical voltage will be created in the second conductor if the direction of rotation is like this, but only after this much angle.

And the difference of this 2 wave forms will give you the resultant voltage and if you arbitrarily place the second conductor it will never ensure maximum voltage you will be getting across the combination of this two conductors. Therefore, it is always when you so new term use this a coil, a coil will have 2 conductors or more correctly told 2 coil sides these are called coil sides, coil side, this is also called coil side.

So, 2 coil sides connected in series is called a coil with 2 free terminals x_1 x_2 available to us, for passing current or collecting voltage from those 2 terminals depending upon whether it is operating as a motor or as a generator. More to this we will come before that therefore, at this stage I will not do any mathematics, but what I will try to tell you try to imagine in this way that every rotating machine has got 2 parts, 1 part which is made of iron soft iron pieces which will never move fixed, grounded to the ground with nut bolts. So, it is not allowed to move.

Another cylindrical thing which will have a shaft, it is free to rotate. Ok then I say that this stator body this is the stator and this is the rotor which is free to rotate, this stator body will have some windings. For example, this coils carrying current, so stator one part and it has coils to produce field to produce N_s and S_s , what is this says? North pole and south pole produced by stator. Rotor 2 similarly has coil stator, stator has coils sorry has coils. Similarly rotor has conductors or coil conductors or coils to produce its own a N_r and S_r and it is this 2 sets of magnets which will interact to produce electromagnetic torque. Anyway I stop here ;then in the next class I will continue with this.

Thank you.