Electrical Machines - II
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Lecture – 11
From Linear To Rotating Machine (Contd.)

Welcome to this lecture. We were discussing about started just discussing about Rotating Machines. How the concept of rotating machines can be built up mentally ok, this is the thing in linear thing therefore, in a confined place if I want to repeat that thing, so a rotational machine is necessary. And I was drawing let me draw several times it does not matter.

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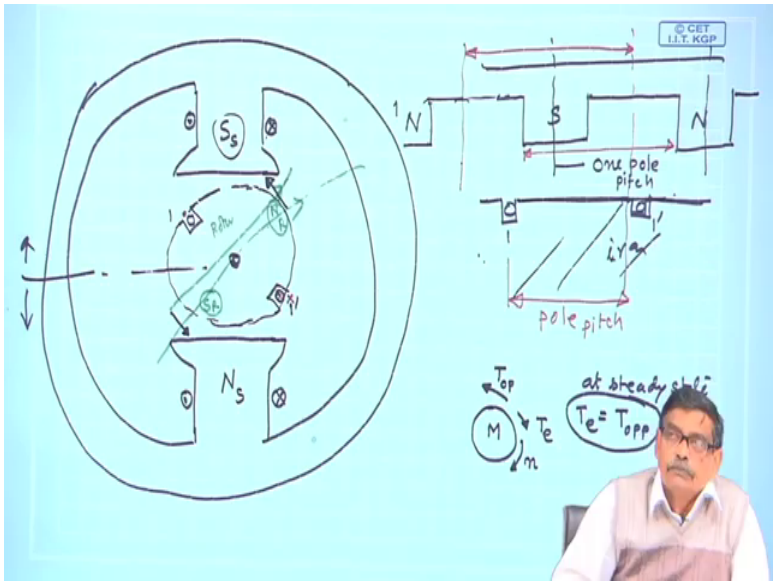

I will draw it somewhat slightly in nicer way; suppose this is the every rotating machine is having some stator and rotor. And this is the stator iron with this cylindrical and there may be coils wrapped around the poles and later we will see there are several other possibilities. But, just and if you pass this current like this, this becomes a north pole of the stator because lines of force will come out and this will become south pole of the stator.

The part which moves is also cylindrical with common center with this stator and the rotor of things, center is common like this and it has got a shaft. And there you can make some slots; a pair of slots at the time which are diametrically opposite which will ensure

if at any time one slot is under center of the stator pole other slot will be under the center of the north pole. That is the this slots are separated by a slot pitch, the term slot pitch I have never used till now, but it is very simple to say.

If you see the develop diagram of the machine that is think you have cut it and like this and unfolded it in both the sides, it will simply look like this. And suppose this is south pole this is north pole stator iron this part is this part and in the rotor there is a single slot and since the rotor can moves this is all iron, you cut it scissor will not be able to cut an iron. But, what I am telling think it is we have cut it and unfolded it, it will be like this and there is another slot here you will see slot say 1 slot 1 dash, if you call it 1 1 dash, these two conductors are there and this fellow is allowed to move, this fellow is allowed to move. .

Now, the difference between this center of the south pole or center of the north pole is called 1 pole pitch. 1 pitch could be; obviously, this distance is also a pole pitch, this to this same thing pole pitch or center of this and center because it is circular, so once again you will see north here.

So, center of this and center of this is also 1 pole pitch; that is from this to this if you go you have finished south pole from this to this, so pole pitch is this. Therefore, to maximize the induced voltage, it is always better to pick one coil side or conductor if it is at any time under the center of the circle the other coil side should be under the center of the south pole. This is moving I have shown it in the arbitrary position. So, as it moves you can say this if it is center here, this is also 1 pole pitch ok. The reason for placing the 2 coil sides under the one pole pitch apart I have explained earlier, but this is how I have done that that is why diametrically opposite I have put.

Now, what I am telling that this general when it is operating as a motor or a generator, these open conductors will also carry current, but the rotor conductors 2 will produce field magnetic field. For example, people say that rotor is carrying current in this direction this is cross, this is dot ok. This, this conductor is carrying cross this is dot. How this conductor is carrying current? Because, we have seen if it is motor operation, this you must have been excited by a source of voltage. Suppose at the given distant of time this is carrying current. Therefore, if it carries current it will produce lines of forces

like this. Is it not this is the rule cross this way, so this will produce a field. Will this is produces a field therefore; rotor carrying current ultimately produces the magnetic field.

And if I ask you what is you know where is S R? South pole of the rotor this will be rotor this pole must be here, I must say this is N R N R right because lines of force are emanating from it and south pole will be there. The point I am trying to driving at is to think always in this way that in any rotating machines there will be a stator structure, it will house a windings and those windings will carry current. Therefore, they will produce a field pattern south S s N s etcetera.

Similarly, rotor will have slots and there will be they will be also carrying current. No matter whether it is operating as a motor or as a generator, they will carry current and they too will be producing their own N R and S R. And then I will say that now ultimately you have got a set of pole existing on the stator structure, which does not protect and you have a set of poles on the rotor iron body this is rotor iron, one side it has become north pole and another side it has become south pole and I will simply argue like this ok, these two sets of magnet then will interact and give you force.

For example, in this particular case you can easily see this N R and S s this N R is free to rotate therefore, it will experience a force in this direction. And similarly this S R experiences a force in this direction and therefore, there will be a torque applied to this whole rotor body and rotor will try to spin in the anticlockwise direction in this particular case. Understood this is very, in that way you will look at the things it will produce a field like this.

For example you switch on your ceiling fan in your city in your room you switch on this supply, what you will see? You will see the rotor of that fan motor is accelerating initially and then finally, it is settled to certain speed. How do I explain this phenomena? Without knowing much, knowing this much I will say that motor must be having a stator winding which is carrying some current and it has produced some field N s, S s like that. Rootor must be also having some coils or conductors in it and it is also carrying some current.

And because why they are carrying current because I have switched on the supply because they are supposed to carry current, rotor 2 will carry current, rotor 2 will then produce N R S R and it is ultimately this N R S R reacting with S s and N s has produced some electromagnetic torque and that is why the machine is running. During the transient

process, so when we accelerate, things changes with time velocity will not be constant, but eventually you will observe it is just observation it is running at a constant speed.

And therefore I now know suppose this is 0 rotor of that motor, I do not know in detail what is inside that motor, but with this argument I can say several things; that if N R S R has been produced N s S s has been produced and it is running at a constant speed. And the interaction of this S s N s and N R S R gives you electromagnetic torque and if somebody says it is running at a constant speed, I will demand that on this shaft there is some opposing torque present in the form of friction your blade of the motor has to run against wind. So, that is the opposing force.

These two initially there was imbalance in this two, that is why machine accelerated with some rpm n. And eventually if it is running at a constant speed my conclusion will be electromagnetic torque in this steady state developed by the motor, who creates the interaction of N R S R and N s and S s. What is T opposition? It is existing in the system or maybe you are doing some mechanical work; suppose the motor is running a pump things like that opposing force against which you have to turn the motor.

Direction of rotation is set by T, direction of T will decide in which direction the motor is going to run. And at steady state T e must be equal to T opposition. It may machine will do find out it is own steady state operating point as we have seen in case of a single conductor generator. Therefore, this is the scenario, it happens in every machines. For example, DC machine; 3 phase induction motor, synchronous motor, no matter what is this machine is such a thing is going on happening.

What is such a things; that is there must be a stator body, there must be some stator windings coils, it may not be the stator coils of this kind all the time, we will see various of thems later. But, essentially there will be some coils or windings on this stator, there will be some coils or windings on the rotor and it is sub they are supposed to carry currents. The moment a coil carries current it produces a pair of poles.

If the poles are on the stator, we say N s S s if the pair of poles are on the rotor N R S R who has created this, this currents cross dot and I should be in a position to clearly put the arrows of the lines of force and then it is so simple to understand in which direction rotor experiences torque and it will start moving. Understood this is very important. [FL] Now, I straightly need diagram I will produce.

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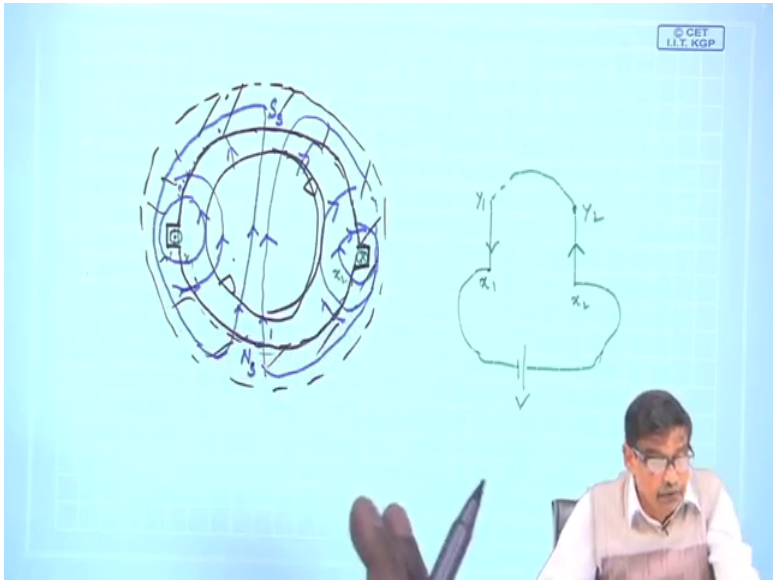

For example you can now think that stator I have till now shown some projected poles, but I can make a stator like this. Totally cylindrical, annular I mean, these are iron and it has got a length perpendicular to the paper and it goes around, so iron made of iron. Now I can, I had instead of projected poles like this, I can touch slots here and here is another slot, so this is the stator. Now only a pair of slots, the there is nothing here, it is open, a groove.

And there I can place a conductor and here also I can place conductor, 2 conductors and at the back I have joined them like this, this is suppose x 1 y 1 this is suppose x 2 y 2 and these 2 are joined. And in front of you 2 terminals are available to you for playing I mean to get voltage or pump current into this coil and so on.

Now, suppose if you excite this coil by a battery, connect a battery across x 1, x 2. Try to understand some voltage, DC suppose that where current will flow like this and if this current flows then in this diagram I must show it in this way cross and dot in this sectional diagram. You must have a clear idea of this thing and this thing. Current is flowing like this, so it will I have not drawn the rotary here, we have to understand or trying to understand all the things goes. Therefore, once it is done stator is carrying a current and it will produce magnetic field as you can see like this here. There are several exercise given in your tutorial 0, please go through that and you will be happy within

that. So, this is the thing this is how you are going (Refer Time: 18:34) see magnetic lines of force will be closing on to themselves.

So, this will be the lines of force it will be created. And there will be several of thems, you must understand that dot here, this is cross current locally if you see it will be like this. There will be here and all the lines of force flows on to themselves. Now, there is a stator here, you have excited this stator coil only and this will be the field pattern, if it is a fixed current this pattern will be remained there and it will be like this.

Now, the question is this stator iron has now become a magnet. Now, where is it is north pole, where is it is south pole? As I told you earlier, lines of force terminating on the iron part is your south pole, so your S s will be here. And this S s exists here also here also, that is half of this stator structure will become south pole. In the same way this inner surface of this stator iron will behave like a north pole because lines of forces are coming out from it N R and lines of forces till this point all are coming out.

So, this will be N R. So, half of this stator body becomes south pole and half of the other half becomes north pole. So, this will be your N s N R N s. This s stands for stator. Therefore, this stator structure need not be like this all the time, but it could be like this also, you can create stator south and north pole. And the question is whether the strength of this south pole here is constant around it or it is varying in nature, those things we will discuss later then produce about that.

But essentially, these are the things I can figure out ok, nothing other than this can happen, that is all. And on the top of it there may be this a rotor coil, rotor 2 will have slots, they can carry current it will create N R S R like this. Similarly, rotor could be also projected poles. You have understood if the point I am trying to driving act and that is the projected poles configurations may be also in the rotor and things like that, we will see now what is that.

So, now what I am going to discuss after having this preliminary ideas of the things which constitute a motor, a stator there will be several slots there will be conductors they will carry current. But eventually the end result is they will create a pair of poles; similarly rotor you will have some iron body on which there will be rotor conductors. They will also carry current they will also produce a pair of poles and this magnetic

poles produced by stator coils and produced by rotor coils they will interact you and give you torque.

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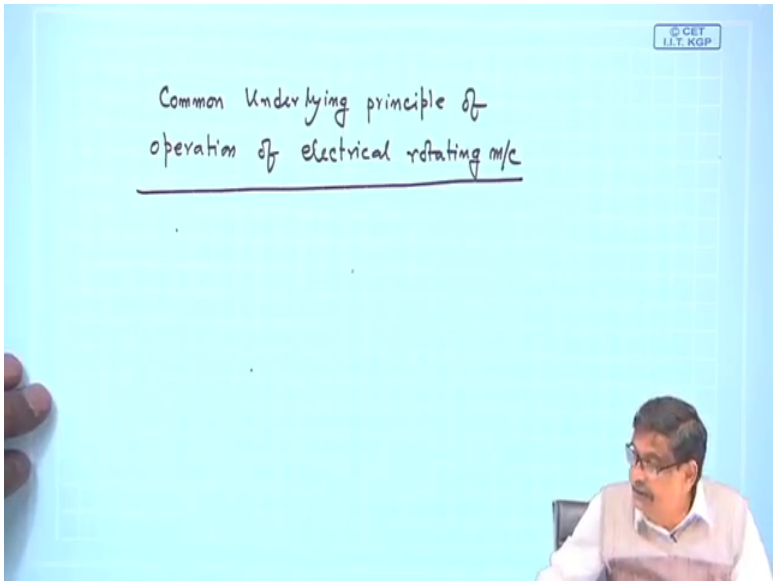

Now, we will discuss for a general the common underlined principles, in this let me write common under lying principle of operation of common underlying principle of operation of electrical machines, electrical rotating machines. At least one condition is very easy to understand.

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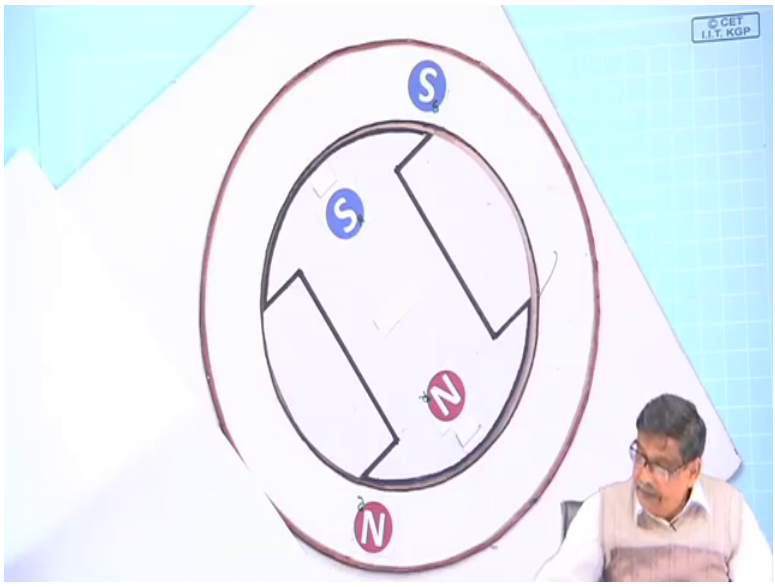

Now, what I am going to show you is this, this diagram you just look at it. It is a stator iron I have for clarity I have not drawn the coils, there will be slots here this side here this side and I will pass some current and half of this will become south pole, half of this north pole that is understood. This is the stator iron, this part portion and this S and N has been created by stator conductors which are not drawn here and it carries current and there will be field here. Now, similarly forget about this projected pole business, I will put it like this, the way I have turned I have done like this stator ok, here is a slot here is a slot I am pushing current this side cross this side dot, so that lines of force will be like this.

Now, suppose you have got rotor body, rotor body will be placed like this here. Forget about this projected poles, imagine this projected it is now no projected poles, projected poles also it is fine it is just like this here and this rotor can rotate ok. So, suppose arbitrary position it is there, you also notice this part can rotate, this part is stator, there must be some air gap in between that is this portion; this portion you mean from air gap will exist in any rotating machine, so that rotor can freely move it should not strike the stator iron parts.

So, for smooth rotation there must be some air gap, you cannot avoid that, so a stator rotor and this one. How this rotor field could be created in this direction? Rotor may be having some conduct coils here, some coils here in this slots. And if you pass cross current here, dot current here, cross current here dot current here, it will create a north pole, north pole is on the outer surface of this stator, south pole is outer these are S R and N R mind here and this is if you allow me, I will write S s N s and this is S R and this is N R understood.

So, this is the thing and this will happen in ultimately whatever complex windings you are using, projected pole are not it does not matter essentially what we are talking about, stator will conductors will carry around rotor conductors will carry current and they will produce a pair of poles like this. And if it is in this position as you can see rotor, suppose I am holding it that by hand this if the pattern of the poles are like this, then this fellow will definitely experience a repelling force here, this fellow also repelling force and it is experienced a torque in this direction it will try to move we will continue this in the next class.