Electrical Machines- II
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Lecture – 13
Basic Underlying Principle of Operation of Rotating Machine (Contd.)

Welcome; we to this 13th lecture on Electrical Machines II.

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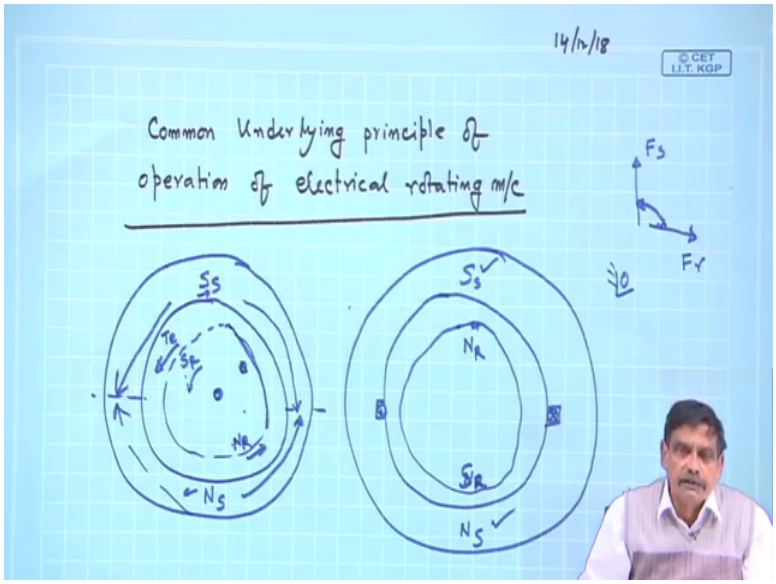

And, the last time we were discussing about common underlying principles of Principle of Operations of Rotating Electrical Machines. And, there I told you that for the production of steady electromagnetic torque; one of the conditions must have must all the machines standard machines must full must satisfy is that the relative speed between the stator field and rotor field that must be time invariant. That is if this stator field is this one and rotor field is this one. I have just drawn with this symbolic line. Then, the relative speed with respect to a stationary observer or for that matter any observer.

You should conclude that at this angle remains same with time. Then only with this machine can produce a steady constant electromagnetic torque, which is required if the motor operates as steady state conditions supplying a constant opposite torque that was the first thing. Second thing is the second condition is the number of poles, I wrote it here.

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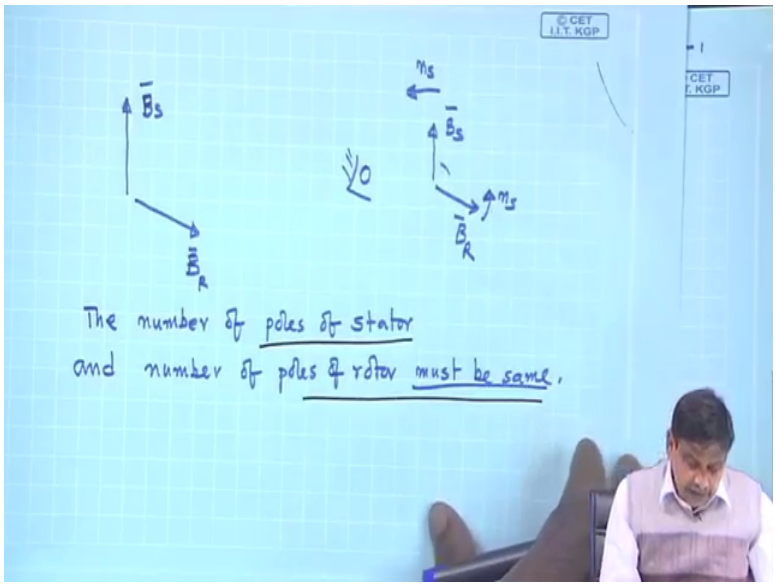

That is the relative speed and the second condition was the number of poles produced by stator coil currents. And, number of poles produced by rotor coil currents. Those numbers must match. The number of poles will be always same and also I showed you last time that 2 poles, you know how to co-produce.

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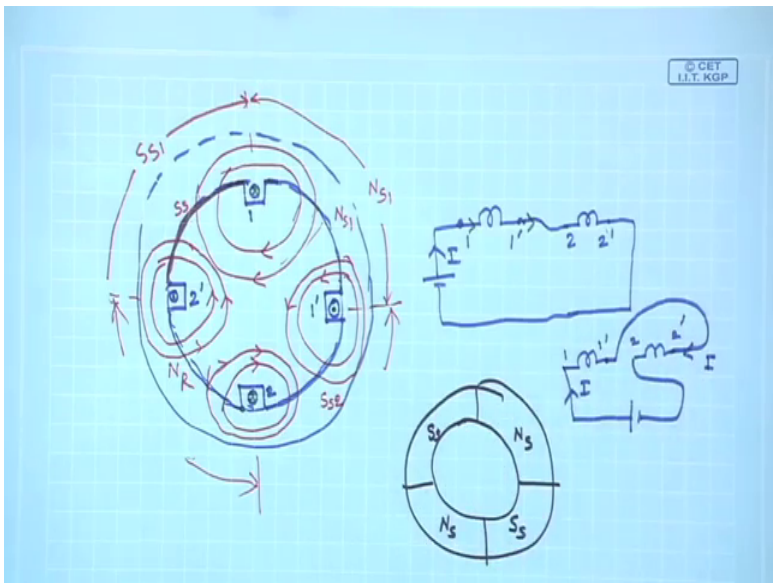

In this diagram, I showed that how can we produce this 4 pole by say by say a rotor here. It is a rotor coil and it produces one quarter of this space is north pole, next quarter is

south pole, another quarter north pole, another quarter south pole , but to produce that you need now 2 coils the coil is 1 1 dashed is a coil another separate coil is 2 2 dashed.

So, the terminals 1 1 dashed is available to me to 2 dashed is available to me and then I will connect them in series like this. And, then if you pass some current to test that how many number of poles that machine is going to produce, you excite those coils by direct current constant current to examine how many poles are produced? Ok. If, it is time varying current same thing at a given point of time it will produce 4 poles ok.

Therefore, you excite it by a constant DC current and it will be producing this one. A just a this I will not do, but I will if you are following me then tell me suppose these are the 2 coils 1 1 dashed, another coil is 2 2 dashed. Remember one is the start 1 dashed is the finish of the first coil, 2 is the start 2 dashed is the finish of the is the second coil. I will ask you to do this exercise that. Suppose this 2 coils are once again connected in series, but this way and excited by a battery.

Then, what we have to do you have to first show the current distribution, special current distribution, and draw the lines of forces. And, and conclude how many poles, this the same 2 coils, but excited in this way that is current now flows like this. Through the one current enters, for the second coil through the 2 dashed current enters and it is like this.

Then, how many poles do you think this machine produce this you please do, then I will be very happy if you can do that you will be following my then currently. So, the, this is the number of poles. Similarly, if you want to create it looks like. Suppose, I want to create 6 pole then each coil produces 2 poles that way if you think it will be 3 coils will be now requiring ok.

And, you can just suggest that 3 coils will be needed. And, show the disposition of the coils separates with terminals of this 3 coils 1 1 dash, 2 2 dash, 3 3 dash and connect them in series and show that it indeed produces 6 poles ok.

So, that you try you do. Now, coming to the next rule that is the next condition is that the number of poles of the stator and number of poles of the rate rotors are same has to be same. In order a steady electromagnetic torque will be produced. Now, how to establish that? We can we are not going to show it mathematically, but intuitively we can easily

understand, that it has to be like that is the number of poles produced by stator a number of poles produced by rotor they must be same.

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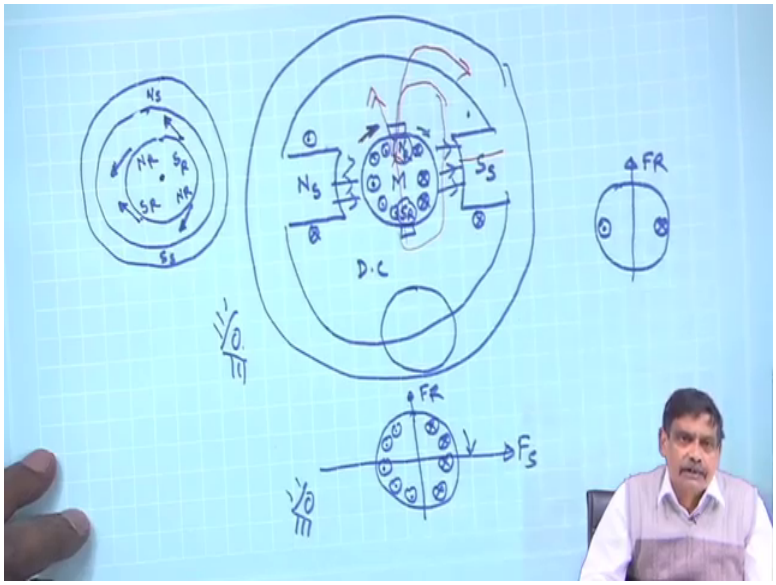

For example, if suppose you have a stator like this which has produced 2 poles NS and SS and for this you need a single coil , but rotor has produced suppose 4 poles. This is the rotor one quarter is suppose SR, then this is also SR, this is also NR, and this is also NR.

Suppose the rotor, because the number of poles how many number of poles will be produced is decided by me. I have made the windings in such a way. I will dictate that terms this windings produces 2 poles, this winding produces 4 poles. So, rotor slots I have placed the windings such that it produce 4 poles. Now, the question is what will be amount of torque produced? Suppose, it is in this position you can easily see rotor is free to rotate. So, NS and SR it will be having an attractive force. So, torque will be in this direction.

But, this SS and this SR will be give you a force like this and this NR and this NS will give you force like that and this NR and this SS will give you force like this. So, eventually the net torque will be 0 is not in this position. So, you can draw in any position you can show the average I mean the rotor will not start accelerating at all, because the force has very cancel each other.

So, net torque will be you require 2 equal forces in opposite directions separated by some distance in order to create a torque. And such a situation is not happening here. Therefore, no torque will be produced. So, it is very easy to establish that number of poles, which will be produced by stator and a number of poles which will be produced by rotor they must be same. And, that number we know must be an even number.

Therefore, these are the 2 basic conditions and this things must be happening in all the motors, but example all though I have I in the syllabus, I have told that dc machines will not be there, because you have studied there.

Let us take the case of dc motor at least you have read it. For example, we draw the DC motor like this. These are the stator poles we draw it like this NS SS. And, which is created by field windings which are wrapped around it. So, lines of forces will come out like this. This way and they will terminate after going through the iron of the rotor. And, DC machine how do I represent there are 2 brasses these are the armature terminals you know.

Now, suppose I want a motor operation, then what I do is, this I pass on current ok. Suppose the current I pass armature current is in this direction cross dot. Now, first thing I will so, so how many poles this armature coil will produce? It will also produce 2 poles cross dot current.

There are several conductors here. All are carrying dot current on the left side of the brass and all are carrying cross current on the right hand side of the brass you know in the DC machines. So, the field will be created also by rotor that is what I was telling. So, rotor will create field what will be the direction of the lines of forces as you can see it will be like this here. (Refer Time: 12:03) There are stator iron like this. So, through that stator iron it will complete it is path. I mean it goes like this; it crosses the air gap, then return this is the direction rate lines of direction of rotor field.

Now, in which direction the machine will rotate it is a motor operation current, I have passed. So, I will apply the left hand rule here it is dot. So, I will place my finger like this. And, stator field is going like this 4 finger this is the current.

So, deduction of rotation will be like this. So, electromagnetic torque in motor mode operation decides the direction of the rotor rotation. Now, this diagram this left hand rule

I have applied and got this result, but I could also do like this. That is you look this is NS this is SS where is NR SR? If, you look at this part of the iron, where from lines of forces coming out must be your NR is not rotor north pole and here it must be your SR stator south pole.

So, you see NS and NR, NR will be repelled and rotor will be start rotating. So, left hand rule application of Flemings is same as now you had extended the idea, in terms of magnetic forces 2 sets of magnets either repelling or attracting produced by stator and rotor.

So, you can see I get the same result correct of course; rotor will start rotating. As, the rotor rotates you there is another interesting thing. So, if I draw the rotor separately this side am just drawing a single conductor. All conductors on this side are carrying dot current. And, all conductors on this side carrying cross current. In general you see if you have a not a DC machine just have 2 conductors on the rotor cross dot, just 2 terminals are available you pass a current it will produce a field like this rotor field fine.

Now, if the rotor rotates then FR 2 will rotate is not, but that is not to be in DC machines. In DC machine the design is such that with the help of commutate segment and basses conductors on the left of this pair of brasses will be always carrying current in the particular direction always. As time passes the left hand side will be filled by newer conductors.

So, which are crossing of a this conductor after some time will come here, but no matter when it comes here it has to carry that constant magnitude dot current. Similarly, any conductor here switching over to this side as the rotor rotates will be always carrying cross current. Therefore, you see rotor rotates, but the field created by it remains stationary, no it is fixed. Therefore, a stationary observer in a DC machine am trying to check, whether those conditions are satisfied. Of course, number of poles have same that, I have seen and with respect to it what is the field of this stator; stator field is stationary. And, also so, stator field is like this he will observe that stator field is stationary.

So, also he will observe that the rotor field is at right angles and it remains stationary no matter at what speed the machine is running. So, the most interesting thing is a this type of thinking is the most fundamental. A single coil without any commutative segment was

you excite it with current, means space of field will be created, and this field will remain stationary. So, along this structure is stationary.

Now, suppose I give a push to it this fellow starts rotating this way then your F of 2 will go on rotating. So, that is why we have suggested that this way of constructing a machine like a DC machine it is a normal, that commutative segment and brass always make sure, that the currents on one side is always cross and current on other side is always dot. And therefore, the field produced by rotor although rotor is rotating is fixed in space it never goes this way that way as it will do like this. So, that thing is taken care on commutative segment on brasses.

So, here we see that conductors are rotating, but field is stationary. And, it must be stationary, because DC motor we know it produces a steady electromagnetic torque. What about the other thing is possible, where this coil will remain stationary, but the field created by the coil currents will appear to move yes that is also possible. That is what an Nicolastus suggested for that of course, you require not a DC supply some AC supply distribute that coils this things will come.

But, the important point is when I say the field is rotating. And, you should not be bothered about the fact, whether this is a stator, whether that rotor is stationary or not anyway either we can do, rotor may remain stationary rotor it carries 3 phase balanced current it is observe that it produces a rotating field.

Anyways, that is the thing, but here you have 2 things I told. One is that instead of applying left hand rule, you know the direction of rotor currents DC machine like this, you can figure out where is NR SR, and where is NS SS, and based on this of the side in which direction it will start moving that is why I am telling. It is at the, that is how we will always think that 2 sets of magnets are interacting and giving a torque ok. [FL] Some diagrams has been made so, that I will try to use that all though as I was drawing roughly in diagram.

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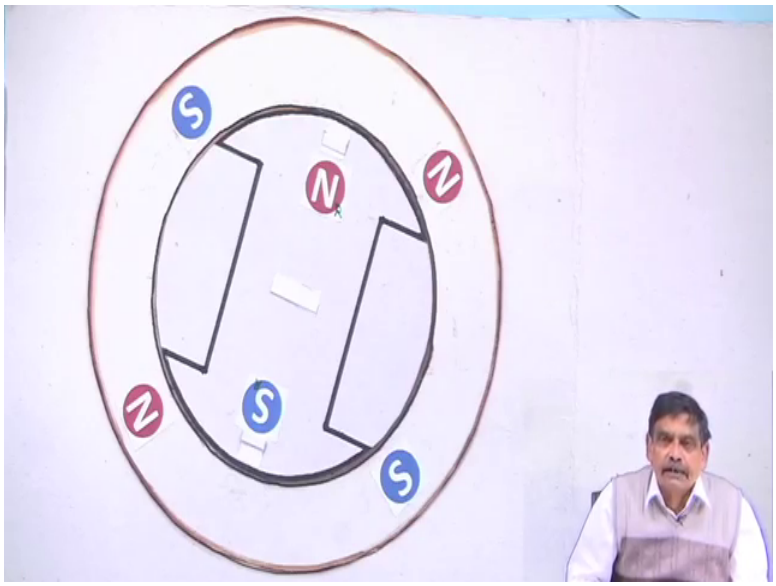

For example, you see it is a 4 pole here I have not shown the windings stator windings. Now, we are matured enough to understand what I mean by this NS SS NS SS ok.

And, suppose a rotor produces 2 poles N and S with rotor windings that also I have not shown. Suppose, it is in this position now, rotor is in this position will rotor experiences a torque or not. See this N and this stator N, it will be repelled in this direction and it will be attracted by here. So, in this direction only you get a force on this side and here this S will be repelled by this and attracted by this S.

So, it will be like this. So, you have 2 forces; one is this way another is also this way. Can this 2 produce a torque no you require this force and this force this side should be opposite, then only 2 parallel forces separated by distance can cause a couple or torque to exist.

Therefore, while then it is not experiencing a torque it is because of this fact someone has thought that, any number of poles that produced on stator any number of poles I produced by the rotor they will interrupt and give any torque, but that is not true. The number of poles produced by stator have produced by the rotor they must be saying very while, for example this case as I was drawing here.

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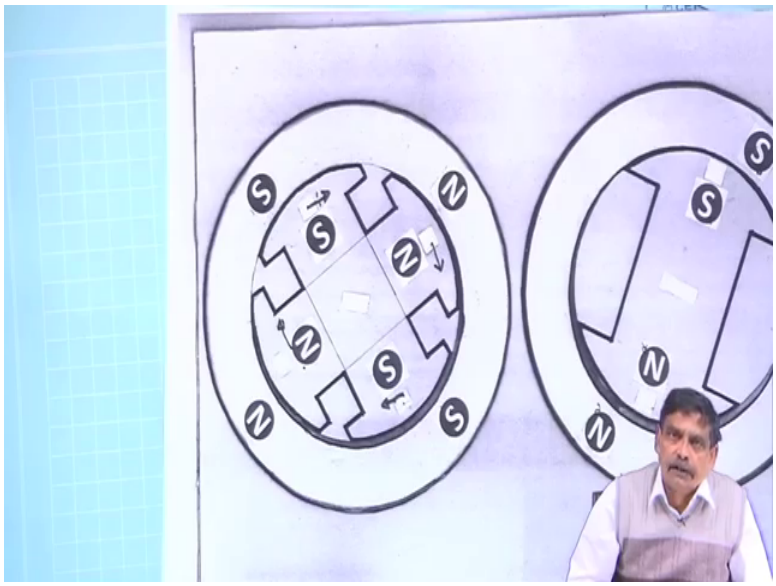

Suppose 4 poles have been produced by stator coils and 4 poles has been produced by rotor coils. Of course, eh it is a small angle exists. So, this North Pole will experience a force in this direction like this repel. And, this South Pole will also repel it will experience a force in this direction. This North Pole as you can see will be repelled like this and this South Pole will be also repelled by this.

So, this rotor will have torque because of this 2 forces and this 2 forces and it will start moving in this direction. So, in any position you place them we will find net torque exists. So, we now know the basic principle of operation or underlying principle of operation is that number of poles produced by stator and rotor as we said. And, for steady production on torque the angle between them must be same the other point that is angle between them is same, I discussed that in my last lecture.

So, that is the after we have understood this I will now talk about the key terms that I will be using the, because we have not done any mathematics or rather any relative mathematics and intuitively we try to understand.

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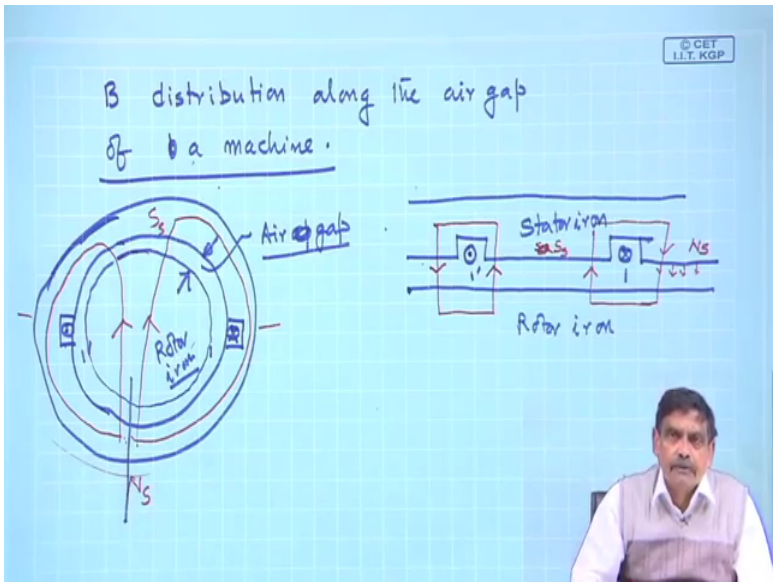

What must be going on in any rotating machine ok? Now, what I will do I will try to get the B distribution along the air gap of a machine of a rotating machine of course, of a machine how to get it? The problem is like this that is suppose this is your stator. And, here is a coil in this pair of slots 2 pole configuration you can immediately understand, whether I have drawn for 2 poles or for single pole. This is cross current this is dot current I am passing this is a 1, this is a 1 dashed and the lines of forces rotor, I have not drawing it is there rotor iron through which the slots path will be completed and it will be like this.

And, there are several others not a very good diagram, but it gives you the idea what I mean to say. So, what will happen this top will become south pole this half of the iron will become a south pole. And, this half will become a north pole NS and SS stator. Now, the question is I want to now estimate that what will be the strength of that field and what will be the nature of that field I want to do it?.

So, for that and mind you that is a rotor iron here. And, rotor coils I am not drawing now I want to show rotor iron. I want to find out the field distribution and this is the air gap. So, what I will do first I will draw the develop diagram of this.

So, I will cut it like this and spread it out in this fashion. So, that you will get a picture like this, this 2 slots, and this outer thing is air and here is air gap and this is rotor iron, this is rotor iron. I think you have got the idea and here is 1 dashed and here is 1 is not it

this is stator iron. And, I have assumed the current as cross and this is dot and just first I will draw the lines of forces it will be somewhat like this cross current, and I will draw the lines of force this it will be like this. Symbolic one I have drawn there are several.

So, this space will become stator South Pole from this to this and this space from which lines of force come out of this iron is your N N SS and NS ok. Now, I want to understand what may be this strength of this B and how it will look like will it is value be like same will it be sinusoidal such things I will now discuss now. So.

Thank you and try to understand this disposition of the coil ok.