Electrical Machines - II
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Lecture – 12
Basic Underlying Principle of Operation of Rotating Machine

Welcome, to the next lecture. And, you recall that in my last lecture I told you very important things that in any Rotating Machines; linear motions to construct such a machine is difficult you must have a compact motor. So, the consequence of that is you can have cylindrical type motors and it will have 2 parts; one is called stator, another is called rotor.

Rotor is allowed to move and both this stator and rotor irons will carry some windings. And, they are supposed to carry some currents, because windings are there and they will produce their own magnetic field and that can be designated as south poles of stator, north pole of stator SS NS.

Similarly, rotor south pole SR and rotor north pole NR. And, it is eventually these 2 sets of magnet they will interact. And, give you the torque to understand what is happening inside a machine.

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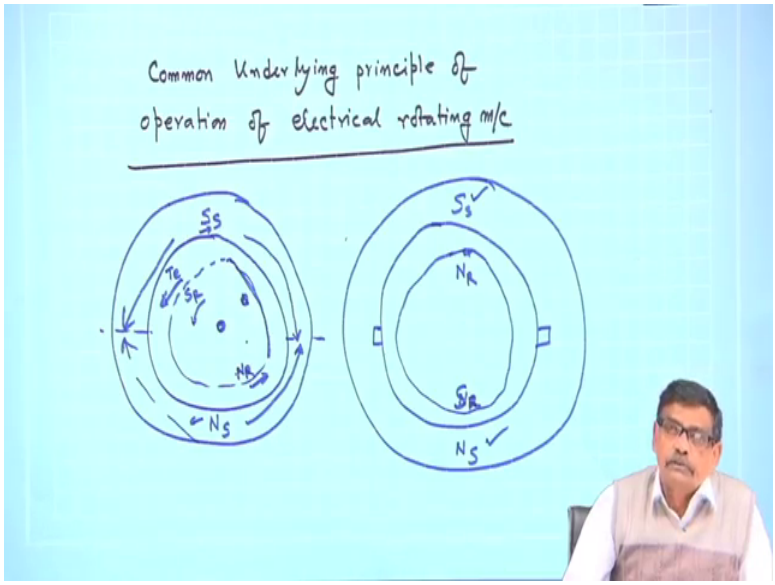

So, I will now today discuss one important thing that is common underlying principle of operation of electrical rotating machines. For example, first I draw very rough sketch so, that you can understand. Suppose, here is your stator and suppose this up is under South Pole from this to this, I will draw very sketchy diagram and this is suppose NS SS like this. So, this is this pole. And, suppose the rotor is also having pole suppose this is say NR and this is say SR. Windings I am avoiding I know how to create such poles.

Now, suppose it is in this position and there is a shaft here. And, I am here if I hold it by hand. The torque experienced by the rotor will be like this here and it will have a tendency to move in the anti-clock wise direction, because as SR will be repelled by SS and so on. One of course, one must not forget that the same torque is experienced by this stator, because SS experiences a force in this direction, and NS also repelling force in this direction. But, rotor cannot move I have put that boundary condition. So, so torque same torque will be experienced by stator poles as well as a rotor poles, but stator cannot move and rotor it is rotor which will try to move.

Now, the question is suppose in this position I and I am for the time being am just holding the rotor, am not also allowing the rotor to move. But, I am sure at this point there is an electromagnetic torque in this anti clockwise direction. Now, what I do I release my hand and rotor is now allowed to move, what will happen? Rotor will start moving in this direction it will go like this, but eventually what will happen is this? This is SS, this is NS a rotor will come in this position NR I am sorry SR will come here and NR will go there.

And, when they will be aligned as it is moving SR is coming under NS. So, like this it has come here. And, it is at this point you can easily see only the stator and rotor fields are aligned along the same lines no torque, nothing like tangential force it will be experiencing.

So, we first note that the for this torque and what will happen the game will be over soon, it will just move, it will come in this position, in spite of the fact there is stator field, there is rotor fields, both of the windings are carrying current, but no torque can exist no, torque means no tangential force exist now. Therefore, one condition is this stator and rotor poles can if they are aligned along this same line no toque will be produced electromagnetic torque. Why it is necessary to produce electromagnetic torque,

because if it is a motor you have to do some work. So, there will be opposing force. And, that much opposing force must be created to have sustained rotation.

Therefore, this is the situation. Now, the question is then what I will demand from this set of poles of the stator and rotor. So, that rotor will be all rotating and a sustained torque or constant magnitude will be produced. So, sustained torque of constant magnitude is to be produced, then what condition should I impose on a stator poles and rotor poles. Let us examinate it is very simple, but interesting at the same time.

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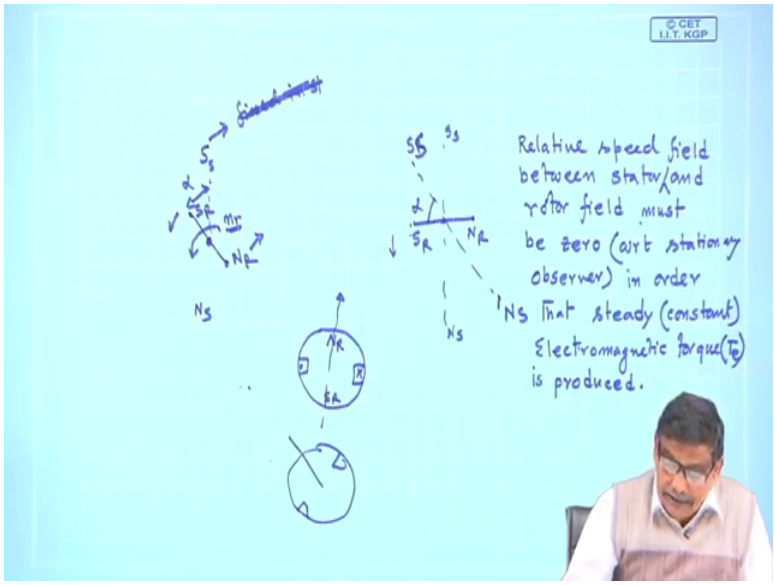

I will just simply now draw SS and NS here ok. And, suppose the rotor poles I draw like this just by a line NR and SR and it can move like this. So; obviously, at this position it will produce a torque.

And, it is needless to say that the magnitude of the torque depend upon this angle how far it is, but none the less certain angle exist between this 2 and SS NS are fixed in space forget about this at this position SS NS SR NR rotor experiences a torque.

Now, certain amount of torque is produced, but the question is suppose rotor will move rotor velocity is NR rotor will move. And, if I say, that I want 2 the same magnitude of torque when it was in this position. Now, rotor will advance here, SR NR will come here, suppose rotor poles come there. And, stator poles it was earlier here SS NS and if I

demand whatever torque it was producing at this instant of time, some time elapses, rotor poles comes here SR NR.

Then; obviously, once again same torque exists here, but the magnitude of the torque depends upon how far this SR is from SS? That separation has increased I do not know. So, the magnitude of the torque in this position is different from magnitude of the torque in this position.

Now, if I say that same torque is to be produced whatever was here same torque has to be produced here. Then, I will say, but that is possible only and if only SS and NS has SS sorry and NS has also moved by that time such that the angle between them. If it is alpha I call this remains alpha am repeating. So, SR NR was there initially SS NS in this position. And, if I hold it experiences a torque in the anti-clockwise direction. Now, some time elapses SR NR because it was experiencing a torque it will come suppose in the horizontal position like this. And, if you say SS NS was where it was earlier like this if it is there ok.

Still toque is produced, but the magnitude of the torque between this SS and SR and this SS and SR will be different. Because, the angle between them is no longer is alpha. So, if somebody says no same constant torque is to be produced, when it was producing here whatever torque. Then, the answer to that question should be then you not only allow SR NR to occupy new position like this. Also advance SS NS by such an amount such that the angle between this 2 fields alpha remains same.

So, rotor will be rotating, but you must make sure that the relative speed between the stator field and rotor field must be 0. At this point one important thing should be understood which we are often forgetting.

For example, the suppose you have a rotor coils cross dot current and this will become NR and SR this is the field. Now, as you rotate the rotor coils this field will also rotate in this position it will come. So, it looks like the direction of the current in the, if the rotor is itself is moving the field along with it will also move.

For example, stator poles examine that SS NS. And, I told you this SS and NS can be created by 2 slots carrying current SS NS concentrate on this. I am now telling on one

end that SS and SS 2 should be moved by the same amount, and am telling stator is not allowed to move stator conductor are all stationary.

Therefore, how this can happen, has NR SR moves, how SS NS will move? This one interesting and important questions to be answered to be understood rather, the idea is we will see after few lectures that your coils may be stationary and it carries current. So, it looks like it will produce a stationary magnetic field, but it is possible a stationary coils carrying currents will produce a rotating magnetic field. That is what the principle of induction motor is. Therefore, whether a coil is stationary, whether SS NS can be also made to move will be clearer.

But, at this stage what am simply telling is to produce sustained electromagnetic torque you must see the stator field and rotor field are moving at same speed with respect to a stationary observer. Such that the relative speed between them is 0 no matter in which position rotor is the angle between this stator and rotor field that must remain constant. Then only sustained electromagnetic torque produced I really at this stage do not know how to achieve this. That is there how to achieve is a big question no doubt, but what am telling from physical consideration that in any machines be it DC machine, synchronous machine, induction machines, this thing must be happening. How it is happening we will see after few lectures or so.

Therefore, the first condition is the relative speed relative you write down relative speed between stator and rotor field, between stator field let me write like this stator field and rotor field rotor field must be 0, must be 0 with respect to some observer, with respect to say stationary observer.

It could be any observer respect to a stationary observer. In order that steady means constant, electromagnetic torque, which I am denoting by Te, is produced. In order that steady electromagnetic torque Te is produced. And, why you want to produce a constant electromagnetic torque, because the measuring in this steady state has to run at constant speed, and there will be machine will be loaded. So, there will be opposing torque. So, Te must balance TL the opposing torque T opposing.

And, so, without doing much these are the expectations out of a rotating machines, unless it cannot do this it cannot produce steady electromagnetic torque, which is very much needed understood. And, one should understand that SS NS should be advanced.

And, if you have a situation like this situation like this and you are passing a DC current SS NS has produced and NR SR is also produce some DC current. Therefore, the this one SR NR SS NS are produced by DC current, then here the field SS NS cannot be moved and that is why it met with this fact that is ok.

After, some time things goes sustained electromagnetic torque is never produced here, but the important point is we will see later that even stationary coils; coils of stationary they will carry some current. And, still it can produce poles which will be found rotating that is a great achievement and it was first pronounced by Nicholas Teslar. That is even a stationary coil can produce a rotating magnetic thing. So, rotor let rotor move, that rotating stator field will also move such that the angle between this 2 will perhaps remain constant and give you sustained torque.

So, one condition so, common underlying principle under this heading; one condition is relativesspeed between this stator and rotor must be 0 all the time. During transient condition it may change either it will accelerate or decelerate, that is steady state condition I must demand steady electromagnetic torque is produced out of any motor.

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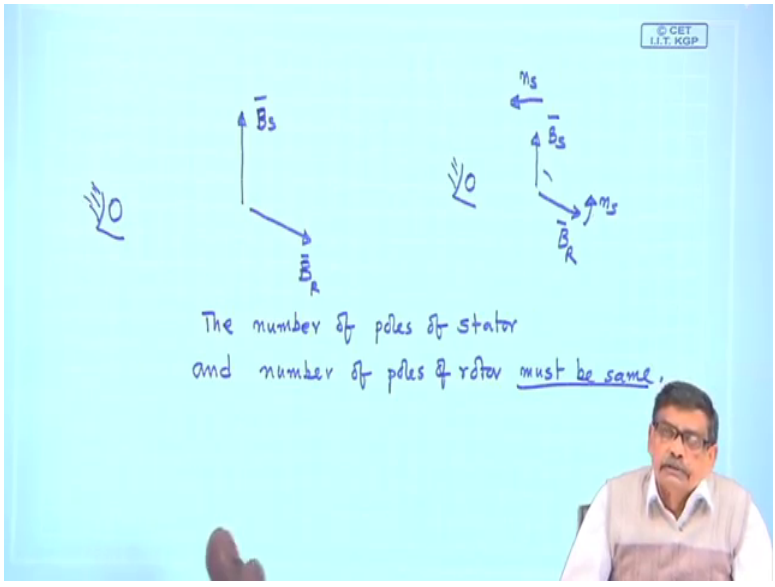

Another important thing is that is pictorially I will say if there is a stationary observer. He is not bothered it is your problem make your windings in such a way, if this is your I will now write a much simpler diagram, if this is your stator field just by your single line and, if this is your rotor field or write B S write B R, stationary observer and if both of

them are stationary observer will be happy ok. This machine can produce a steady electromagnetic torque.

If, you find stationary observer is concluding that with respective him B S is moving with some speed NS or B S. He will say that B R is also moving with the same speed with respect to him, whatever speed he sees B S, same speed he must see for B R such that the angle between them is constant and it will had a rotating magnetic field. I hope you have got the point [FL]. Another important point is there that is the first I write that then try to explain.

This second important point is the number of poles of stator and number of poles created by rotor when it carries current number of poles of rotor must be same, these are must number of stator poles. For example, in this example we have we have a machine where 2 poles are there SS NS for the stator and also 2 poles are there rotor NR SR.

Now, here is a new situation. Now, therefore, it looks like, that we know how to create a 2 pole pattern as I told you for the stator you have 2 coils cross current cross dot and SS NS will be created. Similarly, for rotor you have 2 coils or some DC current those 2 poles will be created. But, how to create more number of poles for stator and rotor that is the question. Because, it looks like number of poles should be same. And, at this stage I must tell you there are machines which we often call it is a 2 pole machine, it is a 4 pole machine, it is a 6 pole machine, or 8 pole machine, mind you now the number of poles must be even.

There cannot be situation where 5 poles are created by a stator, because of the fact the lines of force you must give a sink for a north pole lines of force to terminate on, on a south not terminate it must close this path by a south pole, lines of force coming it must enter a south pole. So, number of poles cannot be odd always even. Now, let us try to see how to create say 4 number of poles very interesting.

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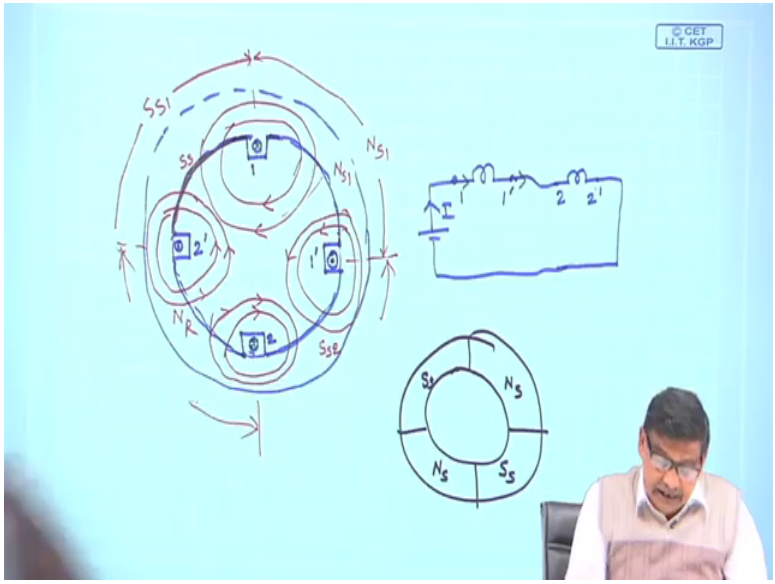

For example, you have a stator structure; stator iron is there. Now, what you do is that you suppose have got a slot here at 90 degree, another slot very interesting and another pair of slots not I mean there are 4 slots.

Then what you do listen carefully. So, this is the stator iron. If these are open spaces and what you do now you place one conductor here one. I was writing x 1 y hence forth I will write one the front side. And, it is return side is 1 dash and this 2 coils I will join at the back understood. Earlier what I was doing here as a conductor; here as a conductor this 2 at the back I was join joining to have a series connection. Now, am telling slightly different. Suppose, we have 4 slots 90 degree apart, this is one this is 1 dash and they are joined at the back. So, it gives you a coil and this symbolically I now for the first time I draw like this ok.

You have a coil whose 2 terminals are 1 and 1 dash distinct. Similarly, you have another coil each front end is 2 and it is return end is 2 dash. Electrically it is a separate coil it has got it is own identity it has nothing to do with 1 1 dash no way a physical coil here a physical coil there, but for a change 2 is not the return conductor of 1 1 dash is the return conductor. Similarly 2 dash is the return conductor of 2 and just a simple way this 2 coils I can draw like this ok. Now, what I will do is I will connect them in series this 2 coils that I can do because those terminals are available externally to me I will connect them in series.

And, I will connect a DC voltage. So, that current I flows. So, how to show these currents here through the one of this coil 1 1 dash current is entering. So, it must be shown cross through the one dash current is leaving for this coil. So, I must show a dot here for the second coil 2 to 2 dash current is entering through 2. Therefore, I once again show it cross and through the 2 dash current is coming out I will show it dot so, cross dot cross dot. Now, what is the implication of this implication is very interesting. See this cross this cross current will produce lines of forces like this.

This dot current will produce lines of forces like this. This cross current will produce a lines of forces like this I am just drawing 2 representatives, and this 2 dash will produce this is dot current like this. So, it produces lines of forces like this is dot this is the thing. Now, see the, this portion on the iron lines of forces are entering.

So, this one quarter of this total iron will behave like a south pole the, this inner phase of course, inner phase ha south pole. Look at this quarter lines of forces are coming out from this inner iron of this stator. Therefore, this can be this must be a north pole created put it SS 1 NS 1 this is similarly this one this quarter here

So, that there will be NS 1 here and this quarter it will be once again SS and let me call it SS 2 second south pole of the machine and here once again lines of forces are coming out. So, this quarter will become a north pole therefore, I have now been able to produce 4 poles. So, ultimately what I have done is this quarter is your this south pole SS, this is NS, once again SS and this is NS. If, you want to distinguish between 1 2 you can SS 1 and SS 1 SS 2 NS 2 that will not be necessary.

So, this is how I can make a 4 pole. So, I will continue with this next time this is the conditions, that the number of poles must be same of poles of stator. What you have learnt that any iron body stator iron body. Similarly, this is proof for rotor iron body why not, that I can create any even number of poles if I wish by having appropriate coil display on the slots and passing current through them.

Thank you.