Electrical Machines - II
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Lecture – 48
Introduction to Cage Induction Motor

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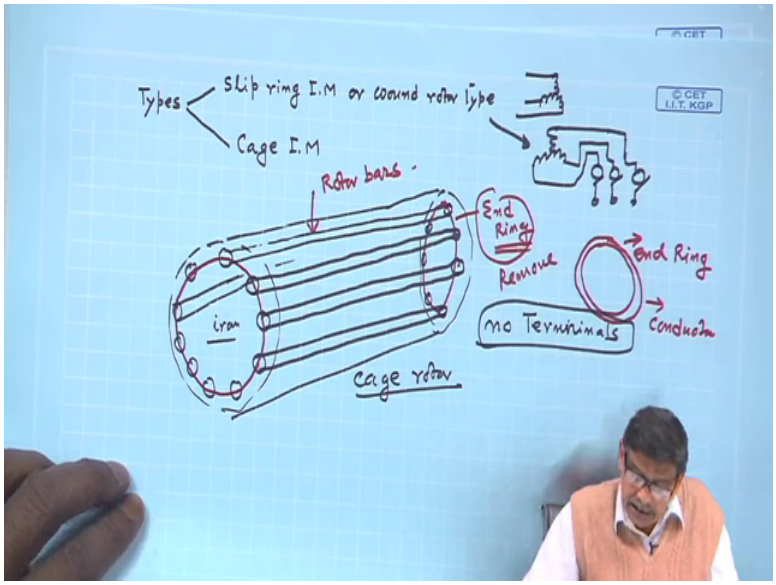

Welcome and we were discussing about the types of induction motor. These are one is called slip ring induction motor or also it is called wound rotor induction motor, because real three phase winding distributed are used wound rotor induction motor, wound rotor type. Stator windings are of course, same in both the types. Another is cage induction motor and wound rotor induction motor I have told you, it will be represented like this; three phase winding on the stator, three phase winding on the rotor, and these terminals are terminated in some copper rings which will rotate. And the fix brushes are shown by these lines and these are the rotor terminals. This is slip ring or wound rotor inductor, rotor is also wound like a.

Now what is a cage induction motor? [FL] Before I tell something about cage induction motor, another interesting fact I must share with you, before I go to the cage induction motor which will be helpful to understand how a cage induction motor works.

We know by this time that to produce torque in any rotating electrical machines, there should be poles created by stator currents on the stator body. There should be poles

created by rotor currents on the rotor body. And the number of poles must be same that is very important. And relative angle between these two should not be time variant, delta should be fixed that we know.

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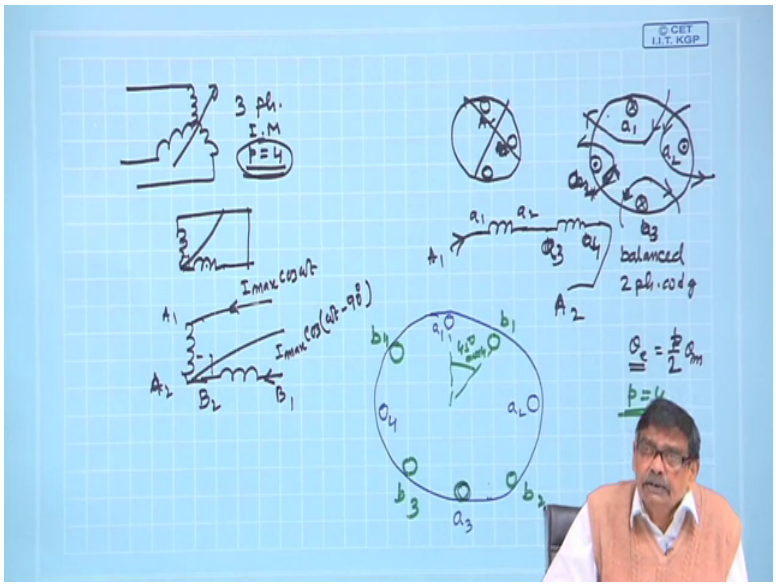

Therefore just as a academic exercise, if I say that I have a three phase winding on the stator of any machine, three phase winding which say p equal to 4, I create one three phase winding. On the rotor, suppose I will say I will make winding, the way three phase winding has be made, but suppose I say it is a two phase winding, balanced two phase winding ok. So, stator has a balanced three phase winding and rotor is balanced two phase winding. The phases are different in the winding of stator and rotor.

Now what is a balanced two phase winding? In its simplest form in the rotor if you have four slots and if you place, suppose four pole I want to create, I will say this is say rotor A phase, rotor B phase and similarly here. No I am sorry what I want to tell, to create four poles you know this is one coil 90 degree mechanical is 180 degree electrical.

So, this is the starting off say a 1 a 2 of the rotor phase. And another coil and this coil can be spread, symbolically I am just trying, this is b 1 b 2. So, it is a balanced two phase winding, in its simplest form to get the idea balanced two phase winding. How it is? It a this is a 1 a 2, this is there is another coil called b 1 b 2 and I am. So, sorry this is a 1 a 2 and this should be a 3 a 4. This is the a phase and so and so, is that clear, two coils are needed; a 1 a 2 and a 3 a 4. So, this is a 3 and a 4.

Now, if you connect them in series such that you pass current here to understand how many poles it creates, so we discussed it earlier. So, it is cross dot then once again through a 3, current is entering cross and dot. You can easily see there is four poles created, because this, this will be this way; lines of force and this will be this way; lines of force, and cross dot cross dot hm. So, this is the I am sorry, this will be the lines of force here dot and this cross will have lines of force like this, and this dot will have this we know this, and four poles are created south north south north etcetera.

Similarly, you have another four conductors. What is the balanced two phase winding? It will be marked as b 1 b 2 b 3 b 4, two coils will be necessary. And these two coils will be shifted from the a phase coil in space by 90 degree electrical, which means mechanical angle 45 degree, 90 degree electrical and electrical angle is 2 by p by 2 into theta mechanical. So, if theta mechanical is, theta electrical is ninety degree it will be 45 degree.

Therefore you have, then I will write nicely here. This is suppose your a phase coil a 1 a 2 a 3 a 4. This is a phase coil and b phase coil start will be 45 degree after this, and this I denote it by this. So, here it will be b 1, here it will be b 2, 45 degree apart and here it will be b 1 b 2, and here it will be the 45 degree b 3 and b 4.

Therefore, same pattern shifted by 45 degree mechanical for four pole is not, this will be the pattern. Therefore, A phase and B phase fields will be 90 degree apart. So, it is a balanced two phase winding. And such a balanced two phase winding, if it is excited from balanced two phase current then also it will produce a rotating magnetic field.

See any balanced poly phase winding B two phase, three phase, six phase excited by balanced poly phase currents of equal number of phases, will create a rotating magnetic field. How many poles it will create? Four poles. Stator is a balanced three phase winding; four pole. See if you have an induction motor. Essentially what I am trying to tell, if the rotor is balanced two phase winding like this and, if they are 90 degree apart stator field is created.

So, it will create balanced two phase voltages, if the stator field moves open circuited it will move like this. So, 90 degree apart voltages will be created and if these rotor terminals are shorted. I mean a balanced two phase current will be flowing, is not balanced two phase current will be flowing. And balanced two phase current if it flows a

2 will produce a rotating magnetic field. I leave it as an exercise to you to prove that a balanced two phase winding like this, say A 1 A 2. This is A 1, this is A 2 this is A 2, and the axis are, and this is A 1 A 2 and this is B 1 B 2. Their spatial angle is 90 degree electrical, if it is excited by balanced two phase currents

You assume this current to be I max cosine omega t and this current to be I max cosine omega t minus 90 degree, because balanced two phase voltage I will connect. What is the balanced two phase voltage? Phase voltages are equal in magnitude, 90 degree apart in time. So, such a voltage if you connect the currents will be like this, and these two also create a rotating magnetic field. Now since the condition for producing steady electromagnetic torque, never talks about phases. It only tells that the number of poles of the stator and number of poles of the rotor they must be equal, and the angle between them at any time should be time invariant.

Therefore one can, for academic exercise say that I can develop an induction motor whose stator will be balanced three phase winding, because supply is three phase, but rotor could be either two phase or six phase, multiphase rotor that balanced and wound for same number of poles that is important. Then stator will fail to understand whether on the rotor there is a two phase winding or three phase winding or a six phase winding. It cannot distinguish, whether. it only sees how he reacts to the rotor, because rotor creates a rotating magnetic field of a, of same number of poles as that created by the stator currents; that is all is needed to produce steady electromagnetic torque.

Therefore for rotor it, stator it does not matter, whether on the rotor there is a balanced two phase winding or six phase winding, no. Of course, while constructing a machine we will always see that three phase winding, wound rotor induction motor also wound the rotor for three phase winding, because otherwise for a given rating of the machine this winding rating has to be made higher; that is the thing only. Therefore and why unnecessarily make three phase stator, six phase rotor, short it, but the machine will work.

No problem at all. This background is necessary to understand the operation of cage induction motor. So, we have learn this that rotor winding could be of any phase [FL]. Now coming to the cage induction motor as I must telling. It is very interesting, see cage induction motor. First see the construction, what is done is this. it is like this. This is

suppose the rotor, rotor iron rotor iron. And what is done? There will be slots in which there will be conducting bars, they called bar, bar of the copper. And several such bars will be there, a number of.

Understood in this slots either aluminium or copper bar and that will run on along the length here. This is one bar; this is another bar like that. I mean, no point in continuing with this, this way this can be also done. So, several parallel bars, I mean around this perimeter of the rotor is there. And what is this? This is iron, iron. And there is as such, you do not require to manufacture this rotor a skilled winder. You tell so many slots are there put just bars.

And then what they do. This, this bars, each bar has got its own identity that is you can say coil sides, but I am not going to make a coil, what I will do is this. I will short circuit all these points here. That is I will take another copper which are called end rings, continuous copper or aluminium ring end rings of appropriate diameter. Of course, such that this fits into it, so I will push it here. So, that all the ends of these bars on this side, they will be shorted. Similarly end ring this is called, conducting end rings and conducting copper or this thing.

So, these are rotor bars. So, arrangement is like this. And here once again take another end ring and push it from this end so that all this free end of these bars they are shorted. there are several these I have not drawn, but you understand what it is. So, these bars also continue like this, I mean and so on. So, all the bars are there are bars here the projections of these; all are shorted from both the sides. And now it looks like a cage. If you imagine that this thing without the iron it will be just like a cage, squirrel cage they call it and that is why the name cage rotor is here.

So, this is the cage rotor and it can be done like this. And for this what I am telling you, do not require a skilled winder. A skilled winder is necessary for the stator winding, because he knows for how many poles you are winding, then mechanical angle, electrical angle, if for a given coil if one coil side is put in this slot where the returned coil side will be in which slot. So, lot of things are to be seen and that is why a skilled winder is necessary.

But in cage rotor it is not like that. It is simple, slots are given, you just insert the brasses one after another and take two end rings, put it like this and your rotor is ready. And of

course, in this type of construction no point in asking for rotor terminals, because everything is shorted, this side that side which point to take. So, no rotor terminals, no rotor terminals, this is very important, unlike a slip ring induction motor, where rotor terminals will be available to you to connect something.

So, in cage induction motor this is out of question. I mean no point to connect external resistance in a cage rotor, because I do not know where to connect, everything is shorted at both the ends. So, these are the end rings, end rings end rings ok.

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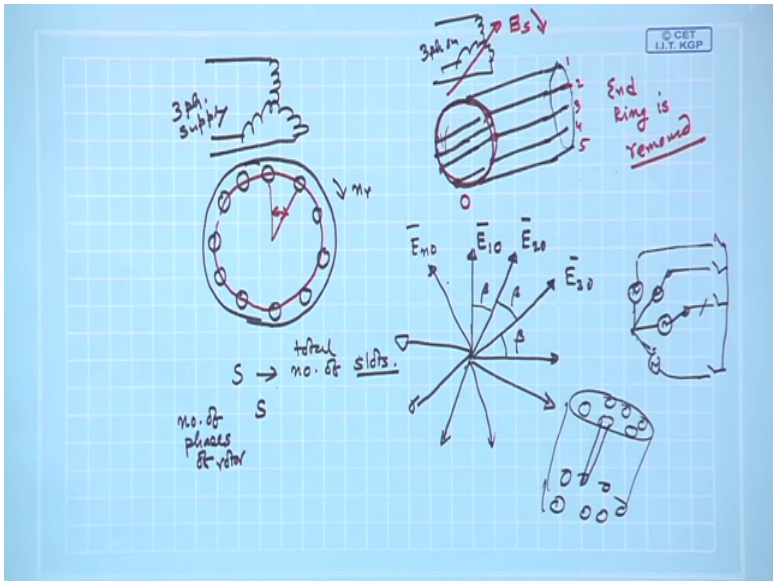

So, this can be also just drawn as a section sectional view like this from the end view of this machine will be just like this then several conductors to I mean some conductors and these are shorted and that shorting is shown by a circle touching all the ends on the other end also it is like that. Now, the question is, if for this machine stator is first the observation I will tell suppose stator has a balanced three phase winding rotor is like this no question of external short circuiting is necessary. Now, it is already shorted and here suppose, you give three phase supply balanced, three phase supply you will find whole rotor is rotating that is the observation I mean lab, if you just energize, you will see, it is rotating as a slip ring induction, motor will run.

Now, the question is why is it is doing, because how to explain these things it is of course, not a distinct poly phase winding, not a two phase three phase. What to do, see to understand this. What I will be doing is that first imagine. So, the simple way the rotor

looks like this, this is end ring, these are the bars is not, it goes on the other end [FL] to understand what is going to how things are working and suppose I name the bars and this ring, you imagine it is first taken out then this will be an incomplete end. This in end ring you imagine, I remove it, remove it.

So, that how these things will look like several conductors equi spaced in the in the 360 degree mechanical angle and the other end, I have removed the end conductors. So, these ends will be free with this end ring is present and this end ring you removed, end ring is removed, removed understood and suppose these are the terminals, one the free ends of these conductors 1 2 3 4 5 like that so many will be there and each one is a conductor of equal length, but their space from the other by this angle, the angle between them is the space angle by which they are separated.

Now, in this machine if you imagine the one of the end rings is removed other end ring is there and therefore, the potential of all these points, where the end rings I am imagining it is present this will be all of equi potential is not and on the stator I have got this three phase winding and here if I give a three phase supply then I know the consequence of this.

There will be a stator rotating field created say b s whatever it is and it moves. It does not depend upon rotor structure, what you are doing? You have energized a three phase winding with three phase supply, a rotating magnetic field will be produced., but nonetheless this rotating field will move fast, this conductor, which is now stationary, because there is no rotor current. So, no question of torque the other end ring I have removed then I must say that there will be induced voltage in each of the conductors in this conductor 1 0 in the conductor 2 0 3 0 there will be induced voltage and if I cage this induced voltages it will be suppose, it is e 1 0 this voltage rotating field is moving like this, then e 2 0 that is b l v this voltage the phasor of this and that will be a time varying voltage, because b is sinusoidally distributed.

And b 0 will be here somewhere, it will be lagging, length will be same like that e 3 0 what is this angle? If you call this angle to be some beta or whatever, it is each voltage will be lagging this voltage by an angle beta and this way I can come back here, some nth conductor. This voltage will be here depending upon e n 0. How many slots are

there? It will be something like. So, everywhere this voltage is there, getting the points hopefully.

Therefore, if you take a voltmeter connect between across each bar the magnitude of the voltages will be same r m s voltage b l v, but the voltages of the conductors will be displaced in time by some equal angle ok. So, over a two pole it will be like this, if it is a four pole machine. Anyway, this will be the phases. Now, the argument is so, in the rotor circuit I have generated a balanced poly phase voltage. It is no longer a balanced three phase voltage created in a slip ring induction motor rotor R phase Y phase V phase not like that, but nonetheless the voltages created in this conductors, they become seat of emf and it looks like it will be like this. There is a voltage here, there is a voltage source here, there is a voltage source here and this voltages and these voltages and so many.

So, it is a poly phase balanced voltage which will exist in the rotor now you imagine the second end ring I am now closing that is now equivalent to a normal induction motor operation what we do we short circuit this with the help of a switch and. So, on.

I think you have got the idea you short it now, with this second end ring. You now imagine it is now inserted then in the rotor circuit what is happening? There is a balanced poly phase voltage. How many phases it will be, we can easily work out, but nonetheless a balanced poly phase winding the circuit is closed therefore, the currents in the conductor will be balanced, poly phase current and if a balance poly phase current is flowing then the then it will create a rotating magnetic field ok.

And once that rotating magnetic field is created well stator does not know who created this rotor magnetic field, whether a balanced three phase slip ring induction motor or somebody has made a rotor like this. Everything is shorted here this side, that side with end rings and that rotating field is created if s is the total number of slots, in the rotor s is total number of slots then a we will discuss in the next class, that the number of phases, number of phases of rotor will be of how much do you think, it will be the number of slots per pole pair.

And this I will continue next time, but this is very interesting development, what is the advantage of this kind of motor? It looks like there will be no maintenance necessary, because there is no slip ring and brush. In fact, rotor is very strong and steady no maintenance is at all necessary and this rotor construction can be done. I mean mass

production of rotor conductors can be done that I will also tell you, that is some metallurgical process and that is what they do they take a structure like this. Rotor slots are there, you pore this holes are there, cylinders like this ok. You pore molten metal ok, molten copper or aluminum in it is slot and.

So, conductors you allow it to cool and your rotor is ready and only two end rings you make that can be also manufactured in large numbers; put one here, put another there and your rotor is ready. Anyway, we will continue with this next time.

Thank you.