Electrical Machines - II
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Lecture - 49
Cage Motor Can Operate for Different Stator Poles

Welcome to the next lecture. And if you recall we were discussing about types of induction motor. We know there are two types of 3-phase induction motors, one is called slip ring or wound rotor type induction motor and the other is called cage squirrel cage type induction motor. In fact, we are discussing cage type induction motor.

In cage type induction motor what happens is this, it is in the construction of the rotor which is different from that of the 3-phase slip ring type induction motor.

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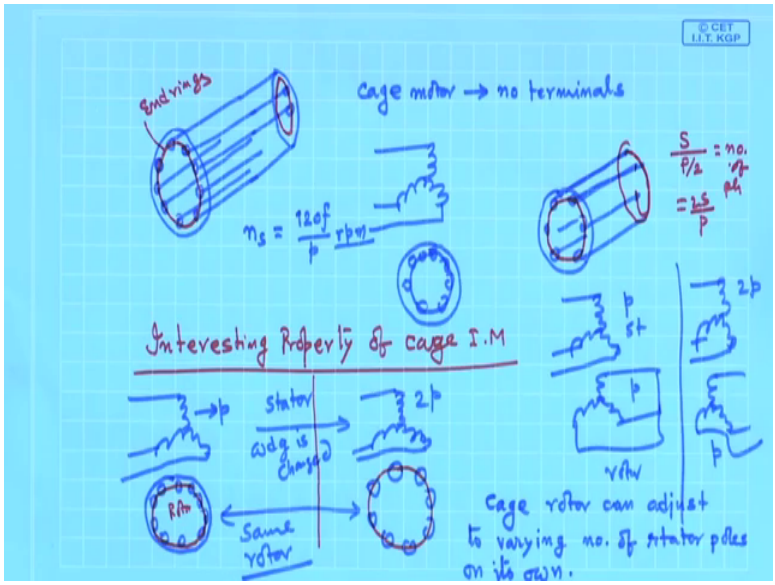

In the cage rotor as you know I will quickly tell the there are enough rotor bars, large number of rotor bars will be there and they will be like this; in this slots the. This is iron and it will be embedded with this bars rotor bars they call it. And on the other side also they will be terminated here or each one of them they will find an end, but all these terminals are short circuited, at both the ends by what is known as end rings, end rings, end rings, this side and also this side all are short circuited. Therefore, in the cage type induction motor no rotor terminals available, cage motors no rotor terminals.

So, that you will not be able to connect an external resistance to improve starting torque etcetera no slip ring, no brush like that. Therefore, this is how physically looking at a given induction motor you can easily see if you at the end cover, if you remove you will find in cage type induction motors, there are 3 slip rings and 3 brushes. But in cage type induction motor nothing available only rotor and that both ends it is shorted.

I was telling about how to then deal with this and such a cage induction motor will be represented in this way. Stator winding is of course, our traditional 3-phase distributed winding and cage rotor it shown like this, like this symbolically and they are shorted, that is all, no rotor terminals.

Now, what happens is this as an observation I was telling you if you supply the stator coils you will find a rotor is started rotating. Now, the question is how it starts moving. The answer is not difficult to obtain because of the fact that, in normal slip ring induction motor you have to keep the rotor terminals are shorted here also rotor terminals are kept shorted. So, to understand I told you like this you think in this way that these are the caged bar you first imagine that one end ring is removed, that is these are the bars here like this you consider this bar is removed fast. Therefore, it is like a open circuit induction motor and in each conductor there will be induced voltage, although with one end ring open the things cannot move because there is no rotor current and hence no rotor poles.

The important point is rotor should produce same number of poles as that of the stator no matter what kind of winding you will use. For example, you could have a 3-phase a induction motor whose stator is wound for 3-phase on the stator rotor is wound for 2-phase with two slip rings etcetera and things will run, provided these two windings are wound for the same number of poles that is the most crucial point. Because stator does not know what kind of polyphase winding rotor is having it is only interested to know whether it is developing same number of poles or not, based on that stator draws extra current from the supply when rotor current flows.

So, I told you last time very quickly I am telling that this bars can be shown to have a polyphase balanced polyphase winding and when the other end rings now you imagine other than end ring is also put, so that all terminals are shorted here. Therefore, this cage induction motor it was shown to be of number of phases number of phases can be

thought off 2S by P, 2S by P the balanced polyphase winding and therefore, it too will produce same number of poles. So, that is the idea.

Therefore, in cage induction motor the advantage is the construction of rotor is very simple, no maintenance because no slip ring brush etcetera. And cost of this machine will be higher compare to a slip ring induction motor because there are no copper slip rings, neither brushes, maintenance problem will be also least so far as the rotor is concerned.

However, it suffers a disadvantage if you say that the starting torque cannot be improved by inserting some external resistance as we were doing in case of slip ring induction motor. Nonetheless this cage induction motor has got another interesting property, that is the thing that if your rotor interesting property yeah let me write; those are obvious interesting property, of cage induction motor, cage type induction motor. What is that interesting property? It is like this.

Suppose you have a fixed rotor, with all bars number of bars are there, and these are shorted, this is how I show a cage induction motor. This is the rotor. On the stator I have got a 3-phase winding and it produces p pole, 3-phase winding wound for p poles. Now, what I will do is this I will have the same rotor, I will have the same rotor, but suppose the stator winding I change, balance 3-phase winding nonetheless and it is suppose number of poles is suppose 2 p, suppose it is 2 pole it is 4 poles stator windings. Rotor, same rotor, rotor I will not change same rotor, stator is changed, stator change means stator winding is changed, one for p pole another for two p poles.

And once again you energize this machine and this machine in both the cases the machine will rotate. In other words what I am telling and this is not going to happen if it is a slip ring induction motor. For slip ring induction motor we know both stator and rotor is to be wound for same number of poles and then you short circuit it is not, this is stator this is rotor. But for this machine if you do not do anything with the rotor keep it as p pole and stator winding rewind it for two p poles energize the supply and machine is obviously, not going to start, not going to run simply because the number of poles are different produced by stator and rotor.

But the interesting point is if it is a cage induction motor stator winding you change two in general any number of poles still it will work. Now, the question is why it should? The answer to this is not very far to seek that I will tell right now, but this is another

interesting advantage of a cage induction motor. In fact, in as I told you a induction an induction motor is maybe considered to be roughly a constant speed motor like DC shunt motor because variation of speed from no load to full load is only very little is not if it is a 4 pole machine synchronous speed is 1500 rpm. Therefore, variation of speed will be little, from no load it will be close to 1500, then full load maybe 14 30 rpm. Therefore, change in variation of speed is only 70 rpm as a percentage you can calculate, very little change maybe 2 to 5 percent of the synchronous speed that change will occur.

So, in general it is considered to be rather a constant speed induction motor. In fact, in earlier days few decades back also it was considered like that. So, to control the speed of the induction motor, one method suggested. See, we have discussed many a times that the that the rotor will settle down to a speed very close to synchronous speed under no load condition and slightly below synchronous speed even when it is fully loaded. Therefore, it is the synchronous speed which is going to decide about the about the speed at which induction motor is going to run.

For example, if it is a 6 pole induction motor 50 hertz is this supply. I will tell, machine will run below 1000 rpm and close to 1000 rpm without much workout I mean I am sure it maybe 950 rpm, 940 rpm like that. If it is 8 pole machine, similarly for 8 pole I can calculate synchronous speed and I am sure machine is going to run whatever is that speed synchronous speed close to that, but below that.

Now, synchronous speed ns is equal to 120 f by p so much rpm we know that. Earlier days in order to therefore, supply frequency is fixed machine number of poles are fixed therefore, it looks like you cannot control synchronous speed. The indication was that from this equation I note that if by any chance by hook or by crook if I could change the value of synchronous speed then I would expect the rotor speed to vary also accordingly so that the stem that it is a constant speed induction motor could be removed.

So, one way was that, you on the stator you use two stator windings, two separate stator windings, suppose one is wound for 2 poles and another is wound for 4 poles. Two completely separate 3-phase distributed winding in the stator slots you accommodate. And at a time, I will either energize that 2 pole winding or the 4 pole winding, and my rotor will be a cage induction motor. Therefore, when the 2 pole stator winding is energized the synchronous speed is going to be 3000 rpm and therefore, I would expect

the motor speed will be close through 3000 rpm maybe 2000, 950 rpm or so, but close to that.

And if I want to run at 1500 rpm therefore, I will de energize the windings corresponding to 2 pole and energize the 3-phase winding on this stator which is wound for 4 pole supply frequency is fixed then the synchronous speed will be 1500 rpm. And I would expect machine will run close to 1500 rpm. Therefore, we can say, this induction motor having two stator windings, two separate stator windings, one will be energized at a time can give you had best two level of speed, one is close to 3000 rpm another is close to 1500 rpm.

And that is possible provided the rotor is cage that is what I am trying to tell. So, cage induction motor also became popular because of this. People say, the cage rotor, I will write that statement “cage rotor can adjust to varying number of stator poles stator poles on its own”, you do not have to change the rotor, ok.

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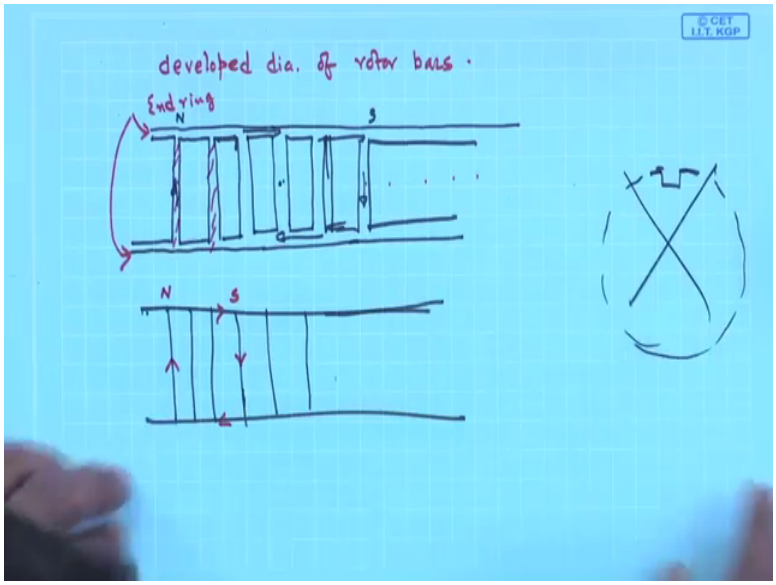

Now, the question is why? Why it should it is like this? It is because of the fact if you draw the developed diagram of the caged bar, it will be like this. Let me draw a few at least, like this, top view, you have developed it and looking from the top. I am sorry it is going to be left like this it moves. Whereas, the bars these two are end rings end ring also this one, and these are the bars copper bars which are short circuited at both the ends and it continues like this.

Now, suppose number of stator poles a is 2 pole or 4 pole whatever it is, suppose this conductor is under the center of the north pole, then under the center of the south pole there will be a bar present. And that is all because after all north and south pole dictated by stator decides the induced voltage and current in the rotor bars, because rotor bars induced voltage of this bar will be blv. And that blv in whichever weight has been decided by this stator coils we will have that polarity of the voltage etcetera and there you will find another bar which is 180 degree electrical apart after the south pole another bar exist.

No matter whether the stator is 4 pole or 2 pole or 6 pole wherever a bar is there you can find out after a distance of 180 degree electrical apart decided by this stator poles a bar is present and you can consider this to be a turn, and current will flow like this. Therefore, it will produce as many poles as produced by the stator coils. That is the beauty, it is already shorted. But in slip ring induction motor, no, that is not possible because the return conductor of a particular turn is already decided by meaning and I have taken all the care, that if one bar one coil side is under the center of the north pole generally other coil side will be under the center of the south pole and they have got their own identity a separate coil.

But here because of the fact that all the coil ends are shorted. No one knows whether this fellow will act as return conductor of this fellow or not. It will be decided surely by this stator of poles if this is under the center of the north pole you will find a bar exists where this bar will be under the center of the south pole. Both of them will have same induced voltage additive voltage and current will return like this.

Now, what I am trying to tell if the same I will now draw just like this, this is end bar end ring and these are your bars number of bars are present like this. If somebody says he is accommodating more poles created by stator winding you have changed on the stator, if suppose this fellow is under north pole the next peak of the south pole is suppose here, once again north south. Here this conductor will fill oh my return conductor is here I should circulate current like this. That is why people say the a cage induction motor can adjust itself to any number of poles I mean in general any number of poles has produced by this stator. So, it is a very nice thing. In fact, this was one of the reasons that cage induction motor you can have at least two speeds provided you have got two state of stator windings.

I will to have a complete type of statement on this ground I told you have two separate stator windings, ok, but it is possible. Which I indicated while discussing about my winding layouts etcetera that it is also possible sometimes not it is also possible that you use same winding which is wound for say 4 poles and reconnect the winding groups such that it will produce 2 pole.

That is what I am telling new thing now. You can have two separate stator 3-phase coils, energize one at a time, obviously, the utilization of the machine space available for copper you are reducing. Is it, can it be possible I will use the single 3-phase winding distributed? But by reconnecting the groups in a particular fashion is it possible to get a 3-phase winding which will sometimes behave like a 2 pole I change the interconnection of those coils and it will be behaving now like a 4 pole. Yes, it is possible. For example, suppose only r phase I am showing simplest thing. Suppose you have 4 slots I mean stator I should draw. So, it will be like this.

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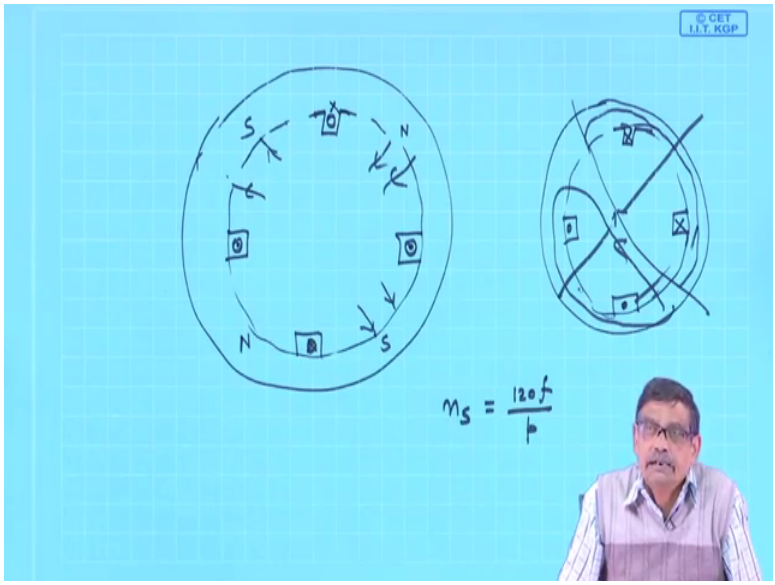

So, suppose you have a slot here, you have a slot there, you have a slot there, you have a slot there for say r phase, and these are the coils. Suppose I have wound the machine for 4 poles. So, this is cross you pass some current, it is written is here dot it is cross and it dot and you get 4 poles created this will be north, this will be south, this will be north, and this will be south because lines of forces etcetera will be there it will come out.

Now, I will change the connection of this coil such that the current distribution pattern I can change it like this. This is, this slots are there, windings are there. Can I use this same conductors to have 2 poles? Yes, you can have. Only thing you make sure that when it carries cross, these also carries cross, and these two carries dot and dot then it will give you only 2 poles. This half one quarter I mean this half will be north pole that half will be south pole. So, it is possible.

We will not go much into this simply because earlier days these were very nice methods which were proposed by after doing lot of research work this that is you have is one 3-phase winding, but some terminal should be available to the user. So, by interconnecting those group phases etcetera you can generate 2 poles in the ratio of 1 is to 2 like that,. But obviously, once again so many terminals we have to bring out from the machines, not simply two terminals for r phase, two terminals for y phase or two terminals for d phase. To carry out this kind of operation you require many terminals to be brought out, maybe from the groups of a particular phase. So, it was cumbersome that way, and you have to change that interconnection only to get two level of speeds that is all and having of course, a cage rotor.

But you know passage of time those methods are nowadays no longer used. Simply because we will at least highlight those points, because with the advent of fast switching, with solid state switches, we can make good inverter and you can vary the frequency of the supply to control the synchronous speed of the induction motor. Hence its speed, which is much more elegant and easier to do then to ask for two separate stator coils or one 3-phase stator coils with some extra terminals brought out which are to be always reconnected in a particular fashion to give you different level of speeds. Because ultimately as I told you this is true, synchronous speed is equal to 120 f by p.

So, earlier it look like supply frequency you cannot control, because it is the bus voltage that is only we are getting. So, people thought, with the same windings whether p can be changed hence n, n s and this cannot be done continuously, no continuous speed control is possible. Only two discrete level of speed you can have from one of the induction, from the same induction motor. Anyway, we will continue our discussion from this point.

Thank you.