**Electrical Machines - II**
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**Lecture – 62**
**Speed Control Using Two Motors**

Welcome. So, we were discussing about Speed Control of Induction Motor, as it is done in modern days. Now, I will also discuss about some in this class another method which I just pointed out, but because of academic exercise it will make you understand induction motor in its better way. I mean it will strengthen it your understanding how that control was done. But before that one point I want to tell.

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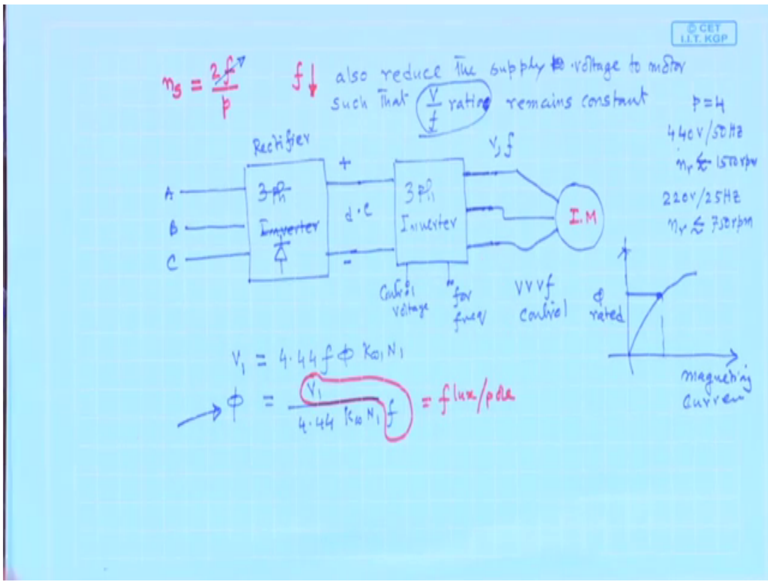


See, the moment somebody is making a connection like this that is he is now no longer fed by a constant frequency supply, that was the problem in earlier days; people use to say, induction motor it cannot really replace a DC motor where speed control is so easy. Here only at discreet level you can control some speed that too with complicated things by changing number of poles because frequency of the supply was fixed 50 hertz, but nowadays those things have gone and you can control the speed nicely. That is the numerator is a better option very frequency and that can be done easily by modern day inverters.

Another interesting thing is in this type of this thing it is it has to do it some starting. See in the starting also we adopted so many thing direct on line starting, direct on line starting on small motors you can do as I told you. But then you can have reactor starting you have to purchase reactor this, then auto transformer starting or then start delta starting some switching is to be done from delta to star and so on or start to delta, at the time of starting star switch over to delta after machine has picked up speed.

But here if you have an inverter you can also think of starting the machine in this way, do not apply full voltage supply it from an inverter like this and increase the voltage and frequency slowly with this control such that v by f ratio is constant so that machine is never saturated and go up to the rated voltage and frequency. There is no question of any large inrush current coming in. So, this point I am telling because of this that nowadays induction motor starting problem can also be reduced with the same inverter, with some proper I mean this control of voltage and frequency will be some you will be writing some codes here and there and get the get pulses of the inverter switches.

So, as to make v by f constant during starting process and so on; so, the way you look at induction motor should be also based on these understanding that is very important, ok. So, that was the thing, ok. One just method as I was telling, so this is the speed control of induction motor and it is it can be also done. That is why nowadays you will at least read the newspapers and the development of see traction in India, people use induction motor drive not DC series motor with this inverter and then converter all the controls will be there and you can use it in traction as well they are slowly replacing these old DC series motor.

DC motor the problem is major. What is the problem? Competitor segment and brush you have to replace this that, ok, but in case of induction motor and particularly cage induction motor. No matter, whether it is cage wound everything for every motors you can vary the frequencies, to vary the speed of the machine. Nonetheless, as I told you just this an interesting, earlier days also people thought because at that wound those days there were no variable frequency supply you was available no inverter fast acting inverter was there. So, this method is there listen it, and see how the concepts of induction motor was used.

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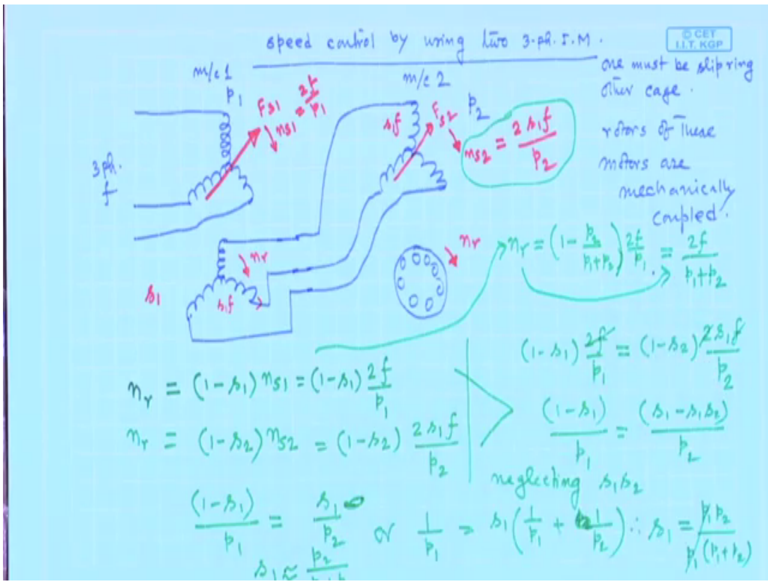

So, it is like speed control by using two three-phase induction motor of which one must be wound rotor, one must be slip ring type must be, one must be slip ring type and slip ring motors are costly because slip ring are there brushes are there. And other maybe slip ring or cage because the cost is reduced. What is done is this is the one motor this is the another motor, ok, it is rotor, no this is the stator and rotor of the first motor and these are the terminals I am not drawing the slip ring and brush arrangement. And you have another induction motor we will say like this and this is suppose a cage induction motor.

Now, what is done? And these two motors rotor some mechanically coupled. So, these two motors, I am not showing it here another line I have to draw, this rotors this motors are mechanically coupled which means that rotor can only rotate the rotor speed of both the motors are same it has to be if they are mechanically coupled. Now, what is done is this idea is very interesting and as I am telling you give the first machine, machine 1 and this is machine 2. First machine you supply with rated voltage rated frequency and suppose the number of poles of this machine is p 1 and number of poles of this machine they must be different, different number of poles p 2.

Now, now what is done? The rotor of the first machine will supply this stator of the second machine that is how it is connected, ok. Now, suppose let us assume the supply phase sequence is such that the stator field of or resultant field of the first machine moves in the clockwise direction n s 1, and this is this must be equal to 2 f by p 1 because its stator is supplied with frequency f. And suppose the rotor speed is also in this direction n r because speed of this rotor is dictated by n s 1 I draw it like this, and the slip of this machine is this one, ok.

Now, the look at the second machine, second machine is supplied with some balance three-phase voltage definitely because these are all balanced machine, but frequency of the supply of the second machine is how much. What is the frequency of the rotor currents? s times the supply frequency here, so s 1 f is the frequency here of this currents. Then the second machine I will say it is supplied with a frequency s 1 f. Therefore, this second machine stator winding will also carry a balanced three-phase current, but of frequency f 1 into f.

And thereby it will produce a rotating field f s 2, and suppose the way it is supplied the phase sequence supply to the second machine is such that it also rotate in this direction, with a synchronous speed n s 2. And what will be the value of the synchronous speed? It will be 2 f, but f is s 1 f by p 2 this will be this speed, ok. Now, the rotor speed of course, because they are coupled they are same, they cannot change. So, this will be the situation, that is from the rotor of the first machine you supplied the stator of the second machine both this machines are coupled mechanically coupled, so speed is n r like this.

Now, you we write down what is the value of n r from these machines. n r will be equal to 1 minus s 1 into n s 1 and this is equal to 1 minus s 1 into 2 f by p 1. And also from this machine n r same rotor speed will be equal to 1 minus s 2 suppose this second machine is running with slip s 2 into n s 2, and this will be equal to 1 minus s 2 into n s 2, n s 2 is this that is 2 s 1 f by p 2 and because these two are coupled therefore, these two must be equal. So, that is 1 minus s 1 into 2 f by p 1 must be equal to 1 minus s 2 into 2 s 1 f by p 2, where p 1 p 2 are the number of poles of the machine. Now, you can see this 2 f goals, from both the sides and you are left with 1 minus s 1 by p 1 here and here what you will be getting is s 1 minus s 1, s 2 by p 2, p 2 here

Now, the next step of simplification is centered around the fact that both s 1, s 2 slips are small therefore, neglecting s 1, s 2 the product of two slips because slips are small compared to s 1, s 1 s 2 will be small. If you neglect then approximately I can write you can get a fair idea of the synchronous speed as equal to is that clear s 1 minus s 1 by p 2, p 2 here or if you take this 1 by p 1 here and this side if you bring it will be s 1 by 1 by p

1 plus 1 by p 2. Therefore, s 1 will be equal to p 1 p 2 p 1 p 2 p 1 was there already by p 1 plus p 2 p 1 goes and slip at which the machine will run approximately is p 2 by p 1 plus p 2.

And once you get this then you say that this n r, n r rotor speed will be 1 minus p 2 from this one, 1 minus p 2 by p 1 plus p 2 into 2 f by p 1 which is equal to if you put it here it will be twice f by p 1 plus p 2. Is that clear? So, very interesting idea that is the rotor speed will be very close to 2 f by p 1 plus p 2. Now, I will not go further into it, but I will tell because see this problem also strengthen our understanding of three-phase induction motor that, it is supplied phase sequence is important, direction of rotation, then by simple algebra and knowing the facts we have learned earlier that is rotor speed is 1 minus s, n s 1 synchronous speed is 2 f by p 1 etcetera we find that this speed of the induction motor is 2 f by p 1 plus p 2.

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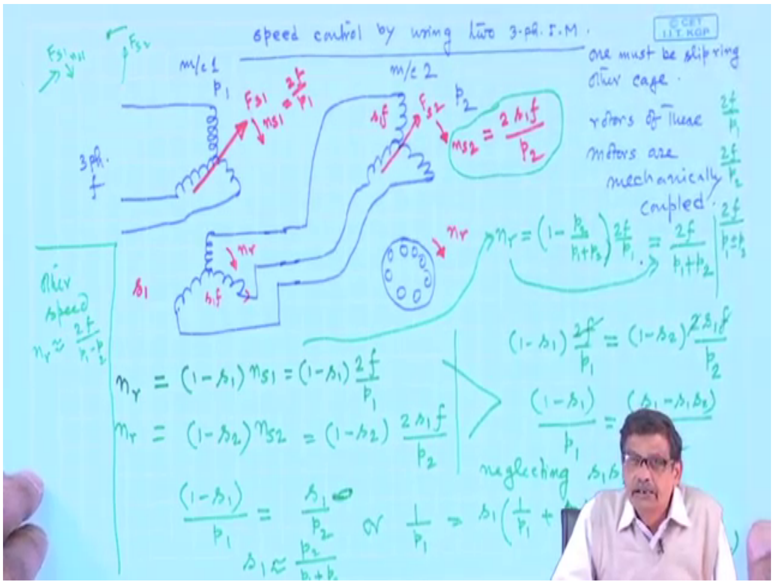


It can be shown I will just write down only these facts. If you supply the second machine with two terminals, here I have assumed they are supplied in such a way the stator field is rotating in the same directions, but you have another option. You supply the second machine stator with phase sequence reversed compared to this machine such that what I am telling if F s 1 is moving in this direction, F s 2 is moving in that direction, you do it then you can show that the rotor speed once again with this same type of argument you this I leave it to you to mathematically show the other speed. When the phase sequence supplied to the second stator is changed then such that F s 1 and F s 2 move in opposite direction, then it can be shown n r is close to 2 f by p 1 minus p 2. It can be similarly shown.

Therefore, it looks like I can get four discrete level of speeds, one is you only run this machine alone second machine it is coupled let it be there then you can get a speed of 2 f by p 1. Use the second machine only, first machine do not connect anything then you will get a synchronous speed of 2 f by p 2. And connect this two in cascade so called ok, that is the stator of the second machine supplied from the first machine rotor then you can get another to speed p 1 plus minus p 2, so force s.

But nonetheless, these speeds are discrete as I told you to control the speed of your load you would now require two induction motors then a costly motor slip ring of similar ratings and it will supply the load. So, nowadays no point I have in applying this in practice it looks like. Although, these where once upon a time they were used very much. See this is how people fought with the how to control the speed of a induction motor and make it a very good drive, making it a real competitor of dc motors that is with the advent of rectifier and inverter set those can be very nicely done, ok.

So, this is the what is called I just told at least gave you idea how to start an induction motor that also has changed as I told you. But those are traditional method go through it nothing run it wrong in it and then speed control I talk. And then what is the third thing which is important for any rotating machine, I told you electrical braking. Any motor one must ask how to start it, how to control the speed and how to electrically brake it.

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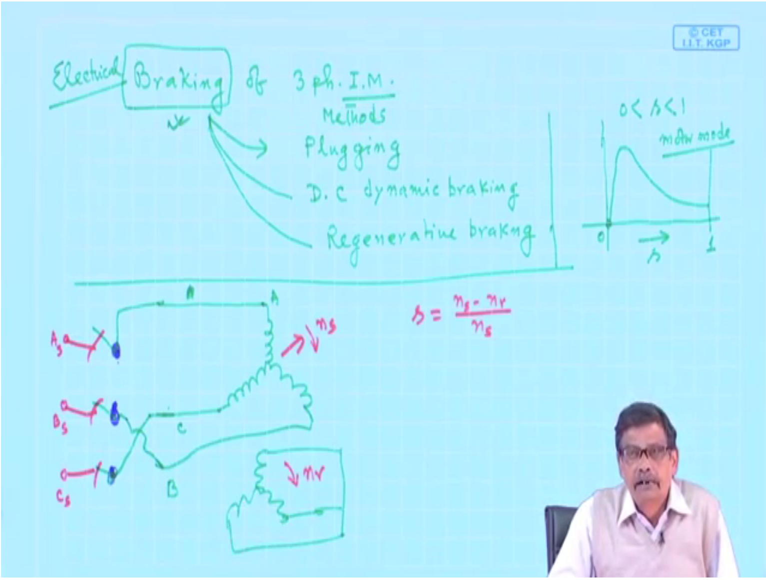


So, braking of three-phase induction motor; what is this? You know braking is very simply to understand if you go by this. When we ride a bicycle I want to stop quickly what do I do? I apply a mechanical brake, that is some brake shoes will touch the wheel and may your cycle will come to a stop, or what you can do, you are riding a bicycle you want to come to a stop you simply stop pedaling it further then it will also come to stop after of course, travelling some distance not quickly you can put it brake. Therefore, the essence of braking is this one.

If something is rotating you want to bring it to a stop, one way of doing it you simply disconnect whoever is driving that rotating body, ok. Simply for example, if it is the motor disconnect it from supply scan there it will come to a stop eventually because no flux, no current in the motor it will eventually come. So, that way it will come. Now, what is the essence of the thing? Essence of the thing is how a rotating system when it comes to stops what has happened, whatever was its kinetic energy that must have dissipated somewhere that is why that fellow has come to a stop.

Therefore, to bring a rotating mass into a stop you must see that how the kinetic energy stored in the machine is evacuated from the system. When we apply brake what you are doing, that kinetic energy is dissipated as heat in the brake shoes and of course, in the road and tire friction all the kinetic energy will be dissipated there your brake shoe will become hot. Put you your brake hard it will come also stop very quickly, but all the energy will be dissipated fast in the brake shoes it will become much hotter. Therefore, the essence of the thing is that if you have a rotating thing and the question of braking means, that disconnecting I want to bring that motors come to a stop very quickly, but I want to do it also a fast, so you can use a mechanical brake is not to do it. But mechanical brake once again maintenance problem will be there it may not be I mean you cannot control the braking torque all this things will come.

Electrical braking, we by braking of motor we understand that how electrically it can be brake it. So, to brake the induction motor there are three popular method, one is called braking is called by plugging, methods plugging, then another is DC dynamic braking, DC dynamic braking and another is called regenerative braking, ok. This method these are traditional methods. Nowadays, all the brakings can be done also with that inverter units, [FL].

Before I discuss this see, so far I have drawn the torque slip characteristics as a motor mode and told you that slip can be between 0 to 1. You recall, this is the thing you whichever way you draw I think you are now habituate either you draw this way or that way where to put s equal to 0. So, this is slip, and this is 0 slip synchronous speed and this is this is the torque slip characteristics and I told you this is the motor mode, motor mode, fine. And I say motor is operating a machine is operating as a motor is slip is positive like that [FL]. You now imagine this circuit, and induction motor is there and I have drawn a slip ring machine, motor mode it is running fine. A this is supply to be A, this is machine B, and this is machine C, ok.

And these are suppose supply terminals supply A s, supply B s, and supply C s. What I do here is this supply A, I take once again a triple pole double throw switch. I am sorry this is the thing, triple pole double throw switch. And bring it here this is A, machine terminals I bring it here, this is C and this is B. And I connect it like this through it this side the other side I will discuss, but the point is if you connect it like this the machine is supplied with a phase sequence A B C rotating field will be moving like this and rotor will rotate at some speed n r, and suppose it is running steadily and the slip is n s minus n r by n s.

Now, what I will do is this, the this machine I will at some time I feel I will change the supply phase sequence to the machine, that is supply as will be A s, but B s and C s I will interchange here. B s I will connect to C and C s I will connect to machine B. Then what do you think is going to happen? Motor was running fine slip s, but suddenly I change the supply phase sequence of this motor. If you do that then I know the rotating field produced by this stator we will move in the opposite direction compared to the situation when it was supplied with supply phase sequence A s, B s, C s.

But rotor speed cannot change instantaneously therefore, when you execute this switching at t equal to said 0 then at t equal to 0 plus, what you have done is the rotating field produced by this stator is moving in the opposite direction. Frequency has not change with same synchronous speed it will rotate, and at t equal to 0 plus rotor speed can also change instantaneously because it has got inertia. Therefore, the slip at which the machine is running we will calculate and show it that it is equal to 2 minus s. We will continue with this.

Thank you.