Electrical Machines - II
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Lecture - 68
Torque – Slip Characteristic of 1 Phase I–M Runnin on Single Winding

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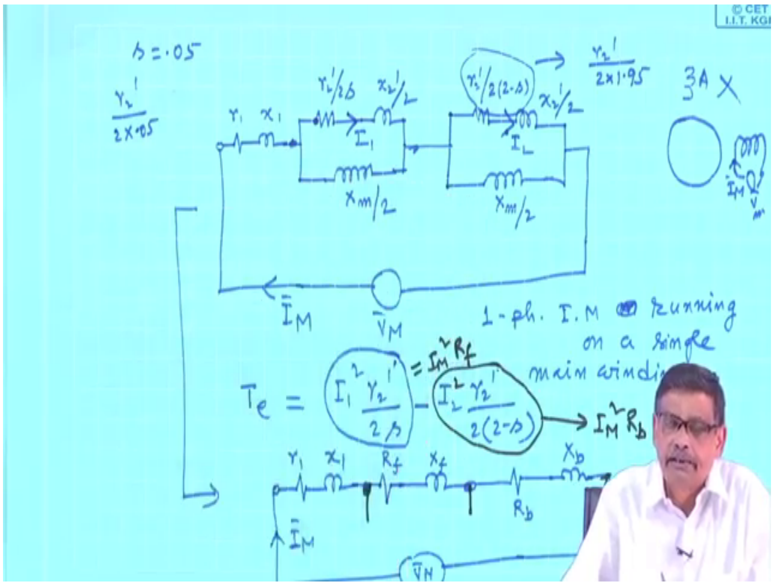

Welcome. So, this is the final equivalent circuit of the induction motor that we have derived and it is I am now happy. I have applied voltage V bar M, current run is I bar M, experimentally I can determine and it has got a meaning. No question of positive sequence, negative sequence those things I have taken into account already and then considering this I am just telling you calculate this current whatever it is and calculate this current whatever it will be after a it is circuit problem now, you know the value of this slip. Then the total torque will be this current square into r 2 dashed by 2 s minus this current square into r 2 dashed by 2 into 2 minus s will be the total torque.

It is I have no point in telling per phase equivalence, this is the equivalence circuit of the machine. One phase after all it is there and it is for which machine? The machine which is running on a single coil; mind you, that auxiliary winding this thing it was some cricks I did to translate this two currents has balanced two phase current. It is not there at all. Thats why I have assumed I bar M equal to 0.

So, this is I bar M, this is I bar M and this is V bar M. So, this is the equivalent circuit of a single phase induction motor on running on a single winding, running on a single winding, single main winding. And the expression now I will just call this current as I 1, this current as I 2. So, that that I a pi bi defined something to I a b becomes let us call this current I 1 this current I 2.

Then I will say torque will be I 1 squared into r 2 dashed by 2 s minus I 2 square into r 2 dashed by 2 into 2 minus s in synchronous what and the problem is solved. Sometimes it is interesting to note that this circuit is somewhat involved. So, how to solve this circuit? Some people do it like this r 1 x 1 is there, what you do; this parallel combination you find out, equivalent that will be ultimately between these two points there will be a resistance and reactance. Call this resistance to be R f, call this resistance to be X f, f for forward motor. Similarly this impedance also can be written as R b and X b and then this is the applied voltage V bar M and this is the current I bar M, no I have I bar M by 2. So so this is the thing.

Now, what I am telling? The moment you do this, it is obvious that I 1 square into this one I 1 square into r 2 dashed by 2 s this will be nothing but equal to I m square into R f because they are equivalent. Similarly this current square into r 2 dashed by 2 into 2 minus s is nothing but I M square into R b. I mean you can do like this or you can also do like this. This is the as if the voltage applied across the forward motor, this is the voltage applied across the backward motor.

So, this way also it can be done. I mean if numerical problem is there with some slip then better calculate this one, calculate this resistance. So, I M square R f minus I M square same current I M square R b, no I 1, I 2 now. They are same because copper laws will be same.

So, this way.

Student: (Refer Time: 05:27) x 2 prime by 2.

Sorry, these are divided by 2, important point ok. So, this is the thing. Clear? So, this way torque can be calculated. Now you notice one thing. Suppose has staring condition, s equal to 1. If I put, I will just verbally tell, I will not draw any circuit. What the equivalent circuit tells me, is it correct at least I can verify s equal to 1. If you do then it will be r 2 dashed by 2 here, this is x 2 dashed by 2. If you put s equal to 1 this will be also r 2 dashed by 2, this is the x 2.

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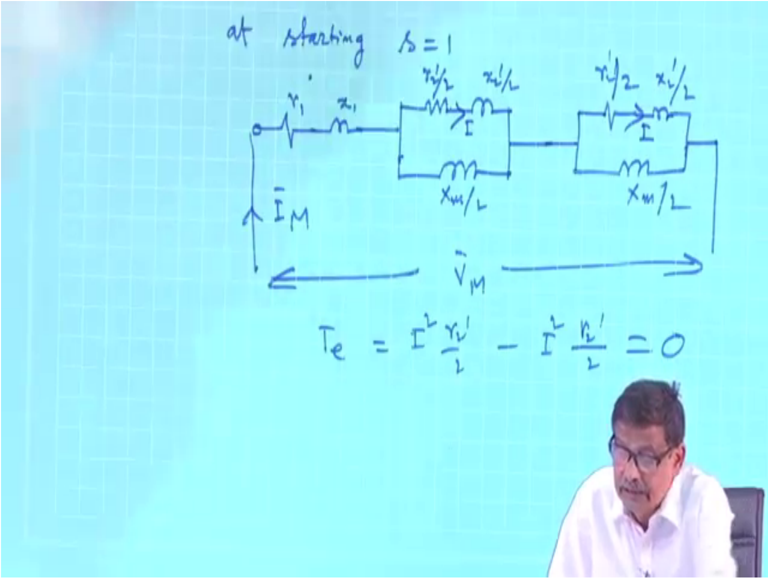

Or let me draw at s equal to 1 at starting, that is s equal to 1, equivalent circuit looks like r 1 x 1 and let me draw visual impact is necessary. So, this is the thing; this will be r 2 dashed by 2 only.

This is x 2 dashed by 2 and this will be also r 2 dashed by 2 and this will be x 2 dashed by 2 and these are of course X m by 2, X m by 2. Is not? This is the thing. This is V M and this is I bar M. Do you think this current and this current will be different? No, this current the way it divides because these impedances are all same. Therefore, during this time torque will be this current if I say I, this current will be also I and I square into r 2 dashed by 2 minus I square into r 2 dashed by 2, that will be 0. Therefore, machine is unable to develop any torque at s equal to 1 which of course physically I knew earlier, but equivalent circuit also tells me that. Now the question is what happens if slip is other than 1?

This is the equivalent circuit now. Suppose you say slip is 0.05. Put some number because range of variation of slip value is 0 to 1. It is balanced 2 phase motor from that s was derived. Is not? Therefore, if you put s equal to 0.05, s equal to suppose 0.05, see only this impedance is changes, what will be this impedances? It will be r 2 dashed by 2 into 0.05 and what will be this impedances? r 2 dashed divided by 2 into 1.95. These two impedances resistance values will be different. Therefore, at that time I 1, I 2 may not be same and not only that, that is this expression of the torque if you put, better come straight here s equal to other than 1, this difference will give you a result, electromagnetic torque.

Therefore it looks like machine will develop some running torque. Is that clear? This is purely from mathematical point of view. So, it is correct, as the things were observed the machine will be having running torque, but no starting torque is once again established here from the equivalent circuit.

So, we now know what is what and that is why at s equal to 1 machine will not start, although there will be primary and secondary current, rotor bus will carry current it will become hot. You must understand like blocked rotor, but nonetheless motor will not run because the fields are aligned along the same line. But when the machine is running that is why I told, if you give a twist I mean try to help the rotor a bit by some external agency, if you in the clockwise direction you run, you will see even if you remove your that external agency it will continue to accelerate on its own because at that time machine will have some slip between 0 to 1, not equal to 1 and therefore, I now know from this equation yes, it will develop a torque and when that torque balances the load torque it will continue to run at a constant speed over. After doing this let us try to draw the torque slip characteristics of the motor.

To draw the torque slip characteristics of the motor we ensure to this equivalent circuit first, after all I now know this is a balanced 2 phase induction motor, is not?

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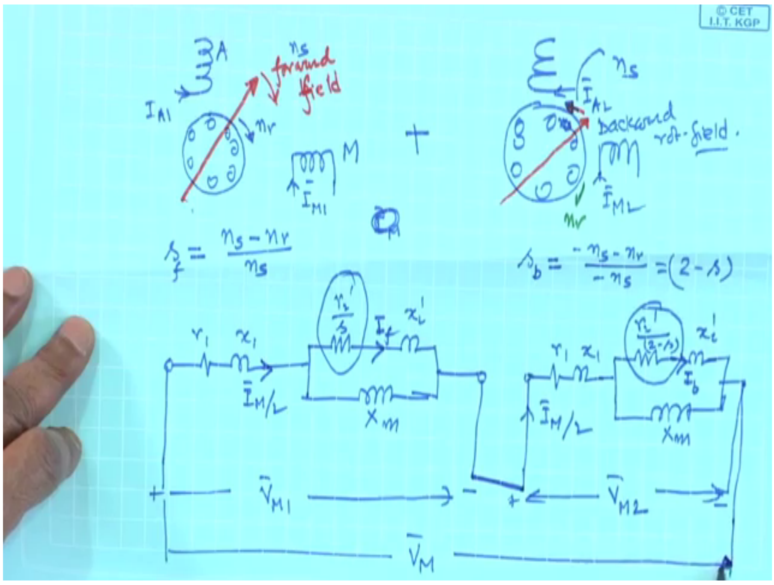

These two motors are at work, balanced 2 phase motor balanced 2 phase motor. I mean go back to that primary thing and it is a balanced 2 phase motor, its torque slip characteristics will be same as that of a 3 phase induction motor. Similarly this is another balanced 2 phase induction motor. Its torque slip characteristics why it will be other than we what we obtained for 3 phase induction motor; same. So because each one of them is a balanced 2 phase induction motor in this case.

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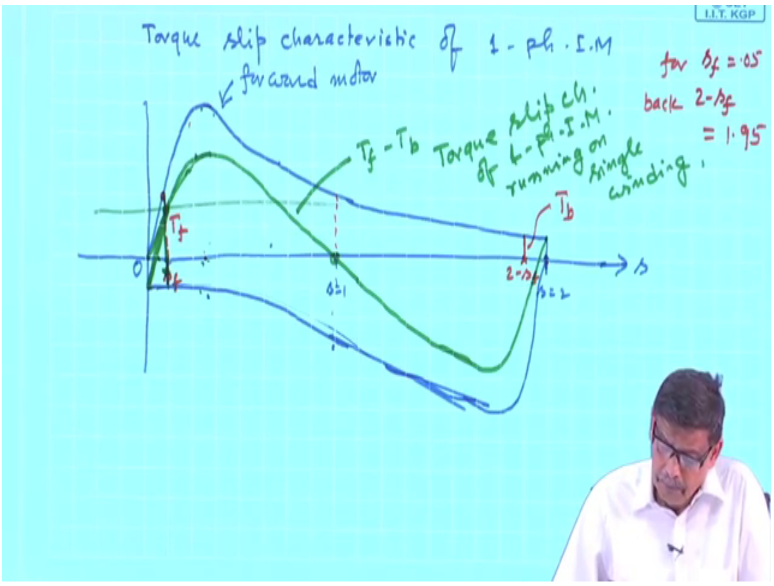

Therefore, torque slip characteristics of single phase induction motor will be like this. Suppose approximately this is s equal to 1, this is s equal to 2, suppose for the forward motor, the torque slip characteristics will be just like that of a single phase induction, a 3 phase induction motor and slip I have varied from 0 to 2. Why it is varied from 0 to 2, you will easily understand.

Suppose this is the for forward motor which is a 2 phase balanced induction motor, this is the torque slip characteristics. Suppose machine is running at some slip s, forward motor is running at a slip s. What is a forward field? Forward field is the one which moves along the direction of the rotation I define that way the forward field and its slip value is n s minus n r by n s.

So, some number you get, say 0.05, then what will be the slip of the backward motor? Backward motor slip is 2 minus s. If it is s f, this is 2 minus s f. So, forward motor torque slip characteristics is this. Suppose machine is operating at this forward slip s f, how much torque it has developed? This much, but there this story does not end. You cannot say that this is the net torque because in my mind there is another field rotating in the opposite direction and this slip corresponding to the backward motor is 2 minus s f. For forward motor if it is s f, it will be 2 minus s f.

For example, if s f is 0.05, the backward motor this is backward motor, this is forward motor its slip will be 1.95. Now, the question is what is the torque of the backward motor? Same curve can be used. Only thing that value I have to read from here 1.95. So, this is the backward motor torque, this is the forward motor torque and then the net torque is T f minus T b like that I have to do. If it is operating at this slip, this torque, then whatever is this slip 2 minus s come this side, slip is now greater than 1 for the backward motor, read this one and the difference of this two will give you the torque.

So, torque slip characteristics will be just like that of a 3 phase induction motor and you now understand why it is necessary to draw the torque slip characteristics over a range 0 to 2. Because I can then read the value of the torque from this curve due to forward field as well as due to backward field. For a given value of forward field s f, backward field it will be 2 minus s f.

So, I will come here read this. So, this is how one can. If s equal to 1 suppose at starting, what is the torque developed by the machine by the forward motor? This will be the torque developed by the forward motor. What will be the torque developed by the backward motor? 2 minus s, that is once again 1, same value and the difference of this two is 0. Any way this one curve will do, but people nicely a because reading this one, taking the difference always you do. So, what you do, you draw this curve, take the mirror image and flip it. By that what I mean is this one. Are you getting? Instead of going there reading this. So, if you do like this, then at any slip this is the forward torque, this the backward torque. This is the forward torque, backward torque. Getting? This is a good idea.

That is graphically. I mean you reverse this because for a given slip you have to go there 2 minus s f, read it. Instead of that do a trick that backward business bring it here and you have to take the difference of these two. So, this is T f, this is T b. This is also T b minus T b, T f minus T b.

So, what you now do is this, go to any value of slip this minus this, you will get a point here. This minus this you will get a point there. So, the resultant torque slip characteristics then will be somewhat, I mean I am sorry it will start from this negative value, it will go there, it will go there, T f minus T b if you go on doing, it will be like this. This is the resultant T f minus T b. That is the Torque slip characteristics of single phase induction motor running on single winding, running on single winding, running on single winding.

And it now it is now clear to me starting torque is 0. So, this torque slip characteristics of single phase induction motor must pass through s equal to one point and this will be there then the point of operation, operating point will be decided by the interaction of the torque slip characteristics of this single phase induction motor with the low torque, those things are known and it will be there.

Therefore, this is the full torque slip characteristics of the induction motor running on single winding that is very important. This is the starting torque, 0. Therefore, it looks like a single phase induction motor has a got a running torque, but no starting torque. It is not a good practice. I mean there is a motor you say somebody switch on the supply and ask somebody to rotate it giving a rotation by hand, not a technical solution. Starting torque must be somehow developed in such motors, if one wants to use it for practical purposes that is I will give this apply motor will automatically run.

But the problem is there is only a single phase supply and your motor has got a single winding whatever field will be produced will be a pulsating standing wave which is broken up into a forward and backward field and things like that. So, staring torque however will be absent ok. I will come to this starting problem and we must do something to the machine now so that starting torque is incorporated. Before that just I have really done in this way. I brought some auxiliary winding mentally, I mean nothing like physically that auxiliary winding is not present only main winding was there, that is what a single phase induction motor I will be looking forward there is single winding only.

Auxiliary winding was my thought process told I assume some auxiliary winding, assume that current will be 0 then it is equivalent to a machine which is got a single main winding excited from a single phase source. Now you can easily see that there will be as I told you 2 rotating field ok. One will be rotating in the forward direction one will be rotating in the backward direction. Now what will be this strength of the field? I mean the question comes like this.

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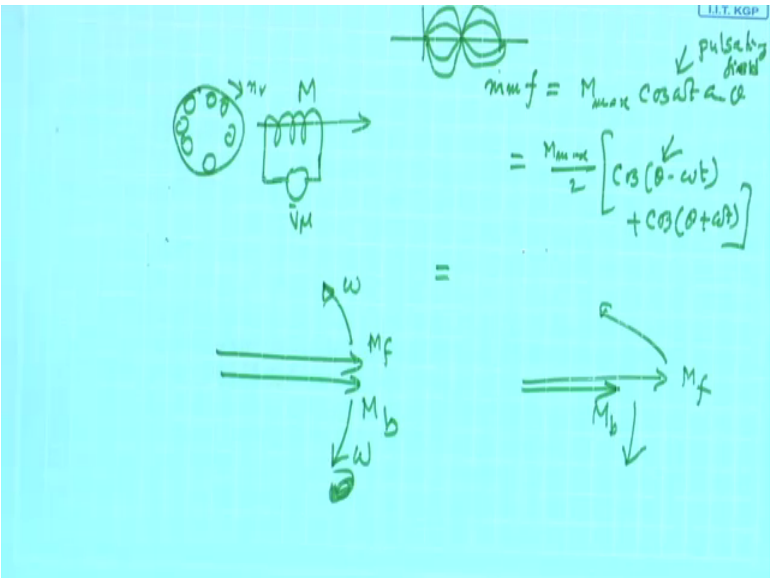

Suppose this machine only I am considering this is the rotor this a point to be noted what I am telling, single winding thats all. Here is V bar M and I now know and also explained that if you excite this at starting no torque machine will never start up, but if it is already rotating n r, it will continue to run that is what the conclusion was.

Now, the question is that while explaining that I mean physical consideration I am telling, mathematics is fine we have satisfied our self, but somehow still it looks like during running condition, it is also connected to a single phase source and it is also carrying a single phase current. What was the explanation that the motor will not have starting torque? Because this single phase current will produce a single phase mmf, pulsating standing mmf. For example, what will be the expression of this one? I will, quickly do it. Suppose the mmf will be some M max. It could be b max also, it could be b max, but M max mmf into cos omega t suppose into cos theta. You recall, at a distance some theta angle you get this values.

This can be just broken up by 2 and then 2 cos it is the pulsating field please look at the lecture pulsating field, standing pulsating wave that is the mmf distribution will be like this. You recall? No rotating business, but if you just manipulate it mathematically divide by 2 and multiply by 2, you can write it as theta minus omega t plus cosine theta plus omega t. Is not? So, here also I find what is the individual terms? This term cosine theta minus omega t is a rotating magnetic field individually and cosine theta plus omega t is the another rotating magnetic field, but rotating in the opposite direction.

Therefore, a single phase winding carrying a sinusoidal current will produce a standing pulsating wave, but I now know that stand that standing pulsating waveform can be thought of as two rotating field of equal strength moving in the opposite direction.

So, that is fine. Now the question is if that be the case, during running conditions still this fellow is carrying a rotating magnetic field, sinusoidal current, it will also then produce two rotating field of equal strength moving in the opposite direction then why it should produce torque? Torque will be produce somehow we have seen, very concrete evidence we have got, but here lies the problem.

Now what really happens is if the machine is rotating there will be two rotating field no doubt in the opposite direction, but the strength of the fields will be different. That is at starting what will happen? Two rotating field’ one is say M f another is M b both rotating in the opposite direction which equal strengths speed supply frequency decides this speed.

But what I am trying to tell when the machine is running with some slip or some n r, the forward field strength will be greater than the backward field strength. They will move in the opposite direction.

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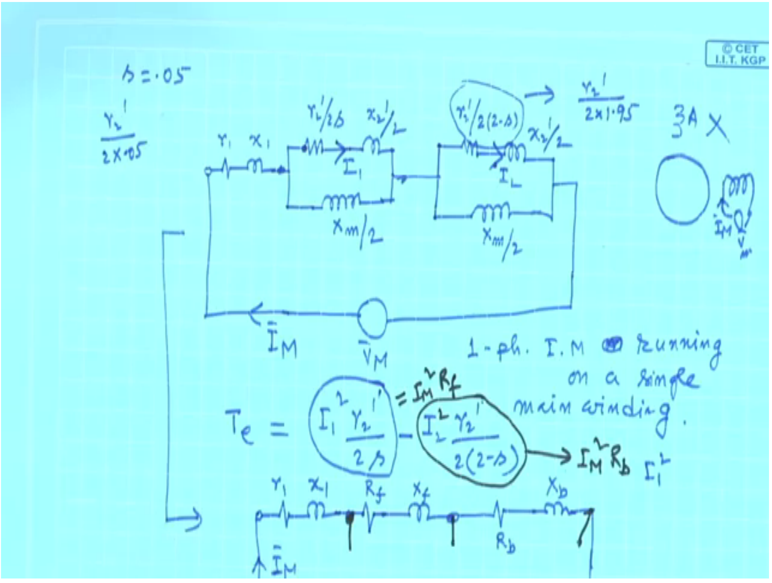

Why? The answer is not for to seek. Strength of the field is decided by magnetizing current X m. What is the voltage applied to this forward motor, what is the voltage applied to the backward motor. For a given value of slip, these two voltages when the machine is running at some slip other than 1, this two voltage drops will be different. So, magnetizing current of this machine and that machine will be different. It is the magnetizing current that causes that strength of the field. Therefore, at starting of course the voltage between this two points, this two points are same, magnetizing currents are same in the forward and backward motor and therefore, fields strengths will be same. More on this after some time.

Thank you.