Electrical Machines - II
Prof. Tapas Kumar Bhattacharya
Department of Electrical Engineering
Indian Institute of Technology, Kharagpur

Lecture - 71
Resistor Split 1 - Phase Induction Motor

So, welcome; we were discussing about the how to incorporate starting torque in a single phase induction motor.

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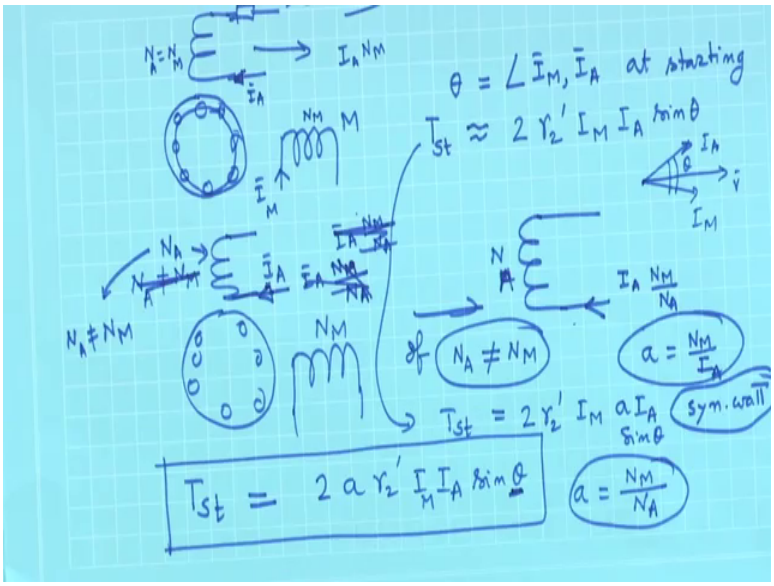

So, here was the result see, what I have assumed is this one this is the rotor of the machine which is sketch type always. And here is the main winding and here is the auxiliary windings and this current and this two will be eventually connected in parallel. And these two coils are having suppose same number of turns N A is equal to also N M. Only thing is you they are not identical otherwise. For example, it is impedance will be different from the impedance of the other machines of the other coil. That I can always do by connecting some external impedance in the circle. N A equal to N M and then this current I was calling I bar A and this current I bar M; recall that these two are connected in parallel across a single phase supply, but I A, I A matters.

So, that is all. So, this is the; this may be some external impedance like this. Or it may not be external impedance you simply use very thinner wire to wind the auxiliary winding. The reason of that I will tell you later; if you use thinner wire r 1 of this coil

and this coil will be different, is not? So, anyway this is will be the general thing. And then what I got is the T starting torque is 2 r 2 dashed into I M I A sin theta. What is theta? Theta is the angle between I bar M and I bar A at starting; all this analysis is true only during starting nothing else.

So, this will be thing. Now if I say that this coil in general what will happen is this. This main and auxiliary turns may be also different. For example, this is N M apart from the fact this turn is N A which is not equal to N M are you getting this is I A this is I M when N A equal to N M. So, how this thing can be then incorporated and we are discussing about the single phase induction motor and primarily about the starting torque.

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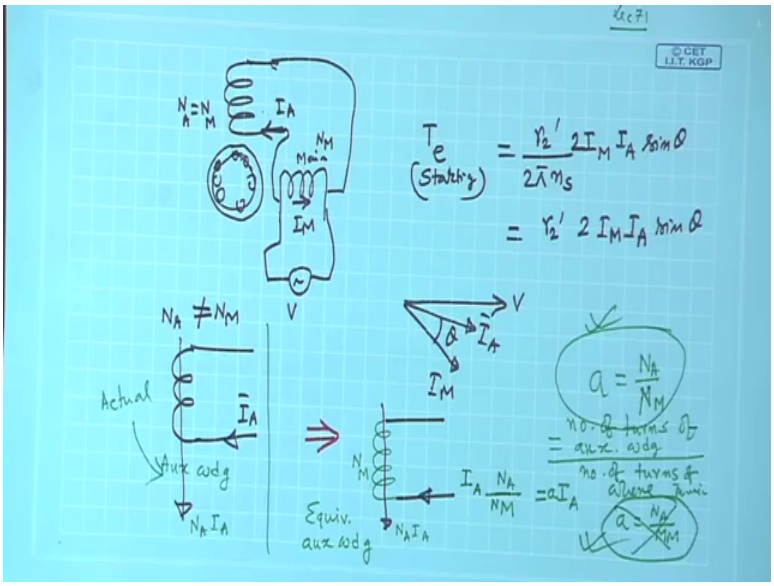

And we have shown you that in a single phase induction motor, there is a rotor like this cage rotor and there will be a main and auxiliary winding.

Because without auxiliary winding you cannot start the machine on it is own. So, a single phase induction, motor running on a single winding has no starting torque we have seen that. Now the question is how to incorporate starting torque and to identify on what factors that starting torque depends so that we can we will be then able to maximize the starting torque and other things. So, this is your main winding. And we have found that these two windings are connected in parallel. And here is your supply and this is your main winding current and this is your auxiliary winding current. And we have shown that this starting torque is will got as r 2 dashed by 2 pi n s into 2 I M I A or I M I A sin theta.

Where theta is the angle between 2 and another 2 is there. In Newton meter and in synchronous what it will be r 2 dash 2 I M I A sin theta. And what is that this is supply voltage V the main winding current is this, auxiliary winding current may be here may be leading also we do not know and this is theta angle between I M and I A. Now in this expression we have assume that the main and auxiliary winding turns are same, that is N A is equal to N M. And based on that this starting torque expression was found it can be used, but only the problem is the auxiliary winding turns or it is also sometimes call starting coil, the number of turns of starting and main winding may not be same.

For example, it is N M, it is N A and N A not equal to N M. The question is how then this equation gets modified. They idea is very simple. For example, this is a machine I am drawing only auxiliary winding. It is having N A turns which is not equal to N M and it is carrying a current of I A it is carrying a current of I A. And main winding has got a turns equal to N M. Now the idea is this whole thing very simple can be written as the same auxiliary winding, it is auxiliary winding. This is also equivalent auxiliary winding. And I am telling that I will replace this coil with the same turns as that of the main winding N M.

Then the question is what should be this current such that m m f produced here and N M a produced here remain same. After all it is the m m f which decides everything what is the flux distribution, how much is it how the induced voltage will be in the rotor of the induction motor is not. Now the obvious answer to is that this auxiliary current if I modify it was this current this is the actual machine mind you; actual auxiliary winding.

And this is an equivalent auxiliary winding. And I will say that ok this current is I A into N A by N M. Then you see the same m m f what is the m m f here; N A I A what is the m m f here N A into I A. Therefore, we can transform this actual auxiliary winding whose number of turns is different from main winding number of turns with this that is an auxiliary winding equivalent auxiliary winding having we will pretend it is having N M turns and then main winding is also having N M turns.

But then I say this current must be modified by I A into N A by N M. Or we say that it is I A into a where a is N A by N M. Mind you sometimes I also make mistake in future, even if I do that wherever a is there sometimes in flow of words I say N M by N A please this is the correct one, mind you and go through the notes also. Therefore, it is not N M

by N A; n a by N M this is suffix N M, I will write it a is equal to N A by N M number of turns of auxiliary windings auxiliary winding divided by number of turns of the main winding. Got the point? This is important.

So, in through my utterances or this that if I ever say N M by N A please do not take it seriously, this is the correct thing ok. In future slides there may be I am not sure. So, I always N A by N M auxiliary starting winding turns divided by main winding turns is this one.

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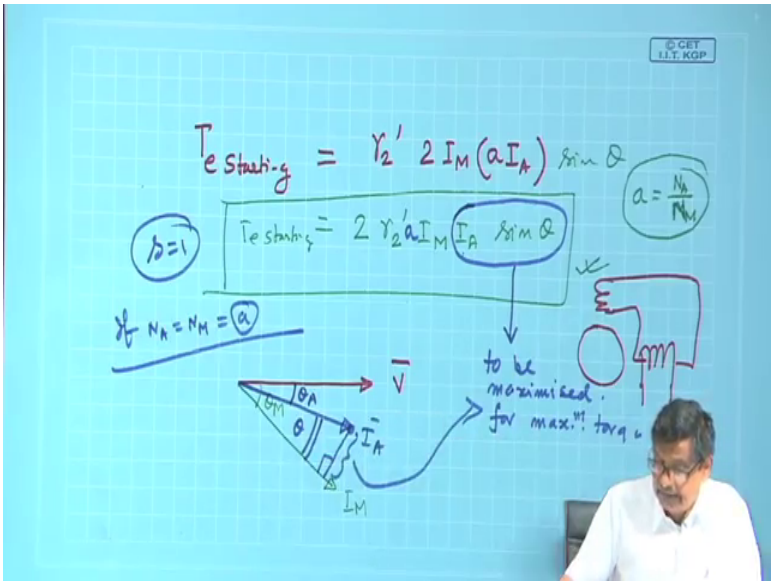

If that be the case then this expression of starting torque that is T e starting will be this r 2 dashed into 2 I M, but this auxiliary current I will write a I A into sin theta where a is N A by N M. In synchronous what that is that will be the expression of the torque starting torque. Or this is equal to 2 r 2 dashed r m s value of main winding current r m s value of actual auxiliary winding current and sin theta.

That is the thing. See what happens is this auxiliary winding circuit parameters may be different. In fact, auxiliary winding if it has to run truly as a single phase induction motor. Auxiliary winding is provided only to give you starting torque machine torque accelerating and when it reaches close to synchronous feet there will be a centrifugal switch here, which will disconnect the auxiliary winding. Therefore, auxiliary winding is designed as a short time rated coil. It is not that it will carry current continuously is not. Whereas, main winding will carry current continuously. Therefore, these wires are also

thin or less or lesser current it is designed and for a not very long time it has to carry that current. Therefore, auxiliary current, but here our purpose of study is this equation why it assumes importance is there if I want to maximize this starting torque.

What should I do? for example, if this is your supply voltage and this is your main winding auxiliary winding what happens suppose I have not connected any external thing, but I know auxiliary winding will be much thinner. Because it is short time rated things like that. Therefore, main winding current and it is power factor angle theta M and the I M they are designed based on their running performance. Because main winding will decide how the machine will behave in the running condition. So, this is I M. And since the auxiliary winding current is much more resistive it will be here I A. And this is the power factor angle of the auxiliary winding theta. Mind you this angle is theta. So, I M I cannot do anything.

Because main winding impedance is fixed. I should not add something extra in the main winding to improve this starting torque, I will not do that. Main winding main winding. So, to maximize this starting torque and these are all at s equal to 1; T starting. So, to get maximum starting torque sometimes people say theta should be 90 degree. No it should be I A sin theta to be maximized for maximum torque. What is I A sin theta? From the tip of this drop a perpendicular here, this length is to be maximized to get the maximum starting torque

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Oh a; if N A equal to N M a is equal to 1; if N A thank you, N A equal to N M. So, this is how things will go. Therefore, this will utilize in our next slides to have different types of phase splitting of single phase induction motor.

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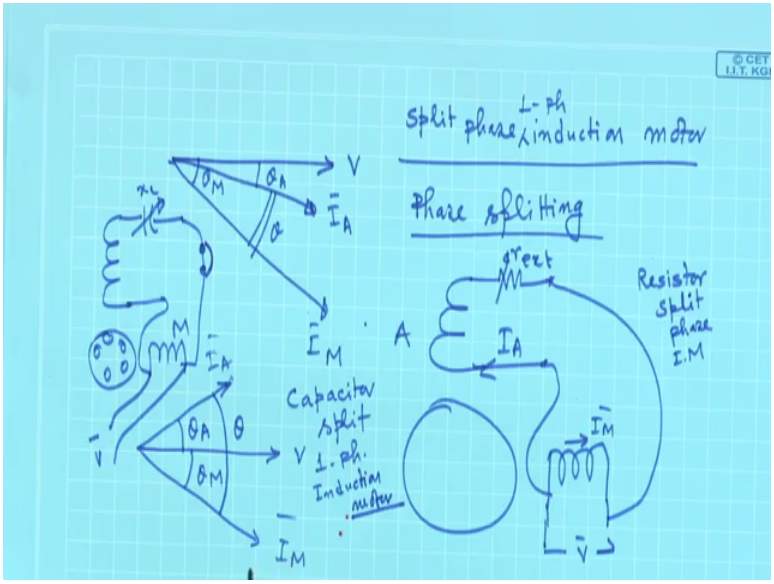

If you apply a voltage I M will be lagging because after all lagging theta M that is fine. Now this theta M power factor angle of the main winding I will should not disturb because the ultimately the motor will be running on single winding expected to. Then I A auxiliary winding I have brought in and the I A may be here because auxiliary winding resistance is higher it will be moved toward supply. This is theta Aa and this is your theta what matters so far as this expression is concerned. Therefore, I M I A sin theta will be the torque. One of the way of starting the single phase induction motor and this is called phase splitting.

For example, I could do like this auxiliary winding I will connect some r external here. This is the machine and this is the main winding. Main winding, I am not going to connected a thing. And this r external and this thing I will do connected to the supply. Then this is I A, I A will be much closer to V because I have increased the resistance and this is I M. It is impedance I will not touch. Then this is called resistor splitting, resistor splitting. Split phase induction motor they call it, split phase this term split phase induction motor ;split phase single phase induction motor.

And this split phase means to create to make theta A and theta M different. You are splitting the phase. So, resistor split phase induction motor means in the auxiliary winding I have connected external resistance. Similarly, it could be. This is supply voltage this is I M, I M I am not going to touch as I told you can connect a capacitor in

series with the auxiliary winding. So, that theta a will be leading by that angle I A. And theta M as usual remains like this. And this is theta angle between them, that matters. And how this such a situation can be obtained provided you connect in place of resistance, if you connect in the auxiliary winding some capacitor. This is the motor. This is the main winding and you connect a capacitor whose value I will be varying.

For example, this r external also I will vary. And then this is supply V. This is your rotor. If you do like that and suppose this x c external connected is higher than inherent inductive reactance, then truly if this circuit effectively across the supply will become capacitive and current will be leading. And then in that case it is called capacitors split capacitor split. These are two popular methods split induction motor; single phase induction motor. Therefore, we have learned now. And of course, to incorporate the idea if you want to run the machine as a single phase induction motor, in series with the auxiliary winding. I will connect a centrifugal switch which remains on which is a; which operates which is otherwise on as the rotor speed increases.

Suppose 70, 75 percent of the synchronous speed it will be out from the circuit. In that case it is called a capacitor starts single phase induction motor. So, when a capacitor split induction motor; the auxiliary winding gets disconnected, when the speed reaches close to synchronous speed. Then it is called a capacitors start single phase induction motor. Sometimes what happens because the moment you connect a centrifugal switch its maintenance becomes a botheration.

So, sometimes for example, our ceiling fans. There is this no centrifugal switch connected. Although it is a single phase induction motor; capacitor is left in the circuit means auxiliary winding and main winding both carry current. Also during running condition. Then it is called a capacitors start capacitor run induction motor. May be the value of the capacitance during starting and during running I will connect differently. There is a wrong notion to say that in case of a capacitors split single phase induction motor, what should be the value of the capacitance so that maximum torque will be developed.

It is I mean very tempting to say the angle between them should be 90 degree. Then only maximum torque will be developed, but the answer is not that. Because if you look at the expression of the torque what thing I am changing I am changing the impedance of the

auxiliary winding. The moment you change the impedance of the auxiliary winding both theta and I A will change.

Therefore, maximum torque will not we are not sure whether maximum torque will be occurring when the angle between them is 90 degree. It is when maximum torque will occur when I A sin theta will be maximum. Then only maximum torque will occur otherwise not. Therefore, from starting point of view the value of capacitance you will get which will depend on if you want to maximize this starting torque.

And there is another factor. First of all, you decide whether you will go for resistors splitting or capacitor splitting. Then decide what should be the value of the external resistance or capacitance so that maximum torque will be developed. There is another interesting criteria. They say that is this so far as starting is concerned. And you get some value of the capacitance. We will discuss at length in the next class.

But what I am telling you must understand that if certain value of capacitance is chosen so as to maximize the starting torque fine. And suppose I say I do not want to go to use any centrifugal switch in the auxiliary winding, I will keep the auxiliary winding alive also during running condition. Then the; should I change the value of the external impedance that I have connected at the point of starting? The answer looks like perhaps we have to change. Because then I will say during running condition perhaps I would like to see the currents are sort of balanced or 90 degree. Starting torque those equations are now invalid; are you getting? Perhaps at that time I will ask I A and I M are at quadrature. Therefore, single phase induction motors are also available.

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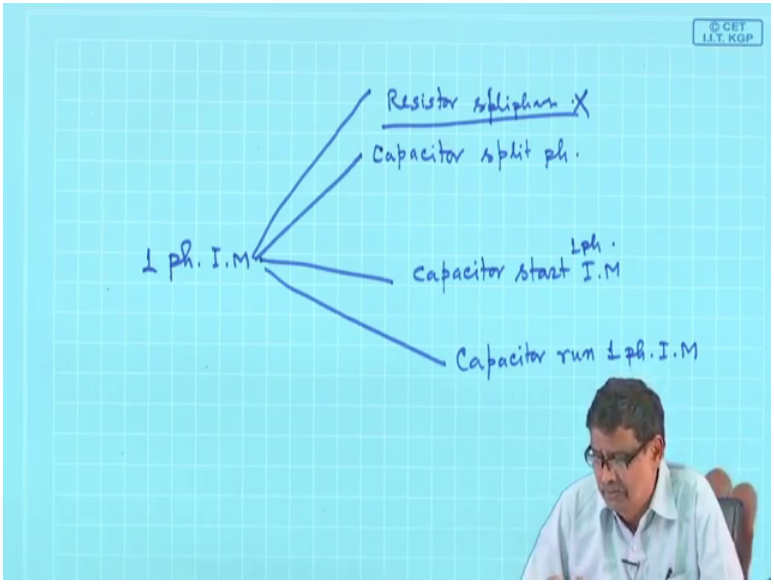

So, I will write this one see. Single this is this in the note also I have written you please single phase induction motor now can be of various kinds. One is capacitor split phase, resistors split phase. And once you of which resistor split phase people do not use. Because starting torque can be marginally increased it cannot be vary so much low starting torque. Then I can also classify this capacitor start induction motor single phase induction motor. And another is capacitor runs in a single phase induction motor, capacitor run; that means, auxiliary winding will be present all throughout single phase induction motor so that way and the value of the capacitance at the point of starting.

And at the time of running condition may be different. The value of the capacitance should be chosen during running condition based on the running performance, capacitance at the time of starting should be selected based on this starting performance. So, that is the thing.

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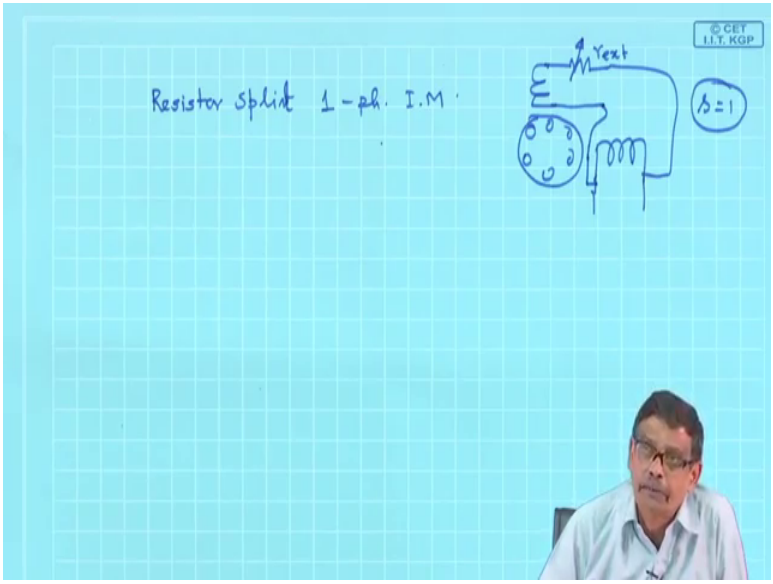

Now what happens is this now suppose let us try to understand resistors split how to chose optimum value resistors split single phase induction motor. That is the goal will be it can be shown like this auxiliary winding. I will connect some r external. All things are happening at a s equal to 1.

I want to select what should be r external such that starting torque will be maximum. That is what the question we ask ourselves. Similarly, if you imagine it is replaced by capacitance; what capacitance I should connect so that starting torque will be maximum. So, we will continue with this in the next class.