Electrical Machines – II
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Lecture – 72
Capacitor Split 1 – Phase Induction Motor

So, we were discussing about the starting torque of a single phase induction motor having an auxiliary winding.

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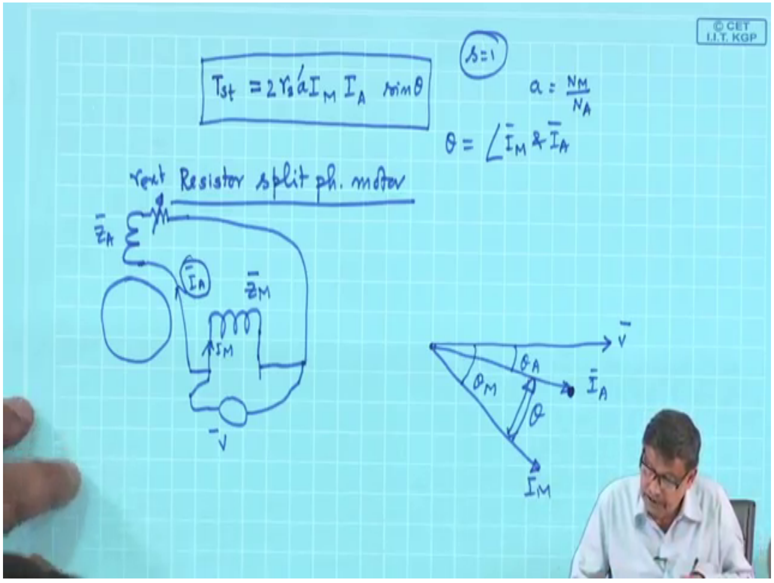

And we got the starting torque to be is equal to in synchronous watt, it is equal to r 2 dash that was 2 one just 2 r 2 dashed I M I A sin theta into a term a; a is N M by N A if there is a number of terms difference you have to incorporate that factor also. Now this is the starting torque and we conclude that theta is the angle between I M and I A between these two phases this angle and everything is s equal to 1 standstill condition. Now the point is suppose I have decided to use a resistor split motor; resistor split phase motor.

That means this is the rotor in the auxiliary winding I will connect an external resistors r external and main winding I will not disturb. So, these two we are connected in parallel and connected across a supply fixed supply v c supply. So, this is I M and this is I A ok. So, in general a it will be like this, this is your supply voltage your I M let z M bar is the impedance here and it is z A bar impedance offered to the supply at starting. So, v by z M bar will be z bar M will be the current here and this will be theta M. And theta I bar A will be somewhere here perhaps I bar A and this is theta A.

Because it is more resistive compared to main winding current will be their magnitude may be different and this angle is important this is theta that is to be used here. Now, therefore, I want to select a optimum value of r external auxiliary winding resistance so, that starting torque I want to maximize. Now to find out that obviously, you now know that what I have to do is this, I have to find out the locus of I bar A as I vary resistance in the auxiliary winding. So, auxiliary winding z A bar it after all inductive r l will be there always and therefore, if you vary the resistance the locus of the tip of the circle of I A bar will lie on a circle and we are we know what is to be done.

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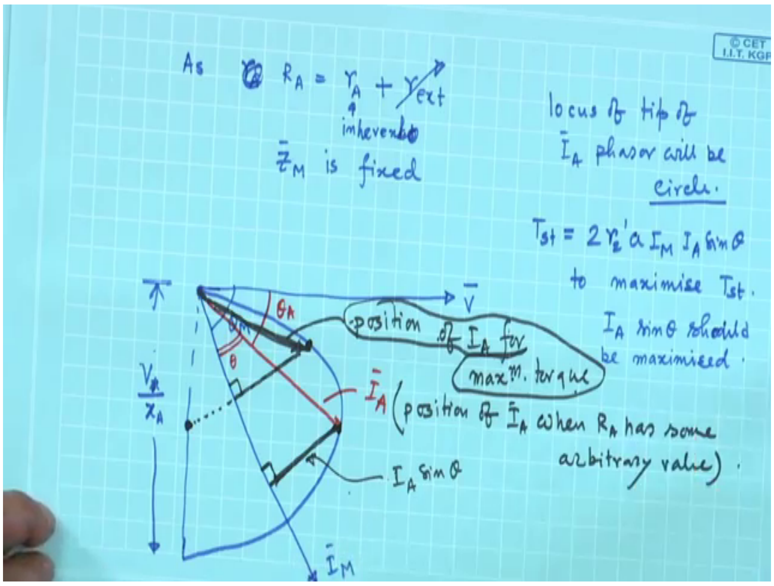

Therefore, as auxiliary winding resistance r auxiliary now, becomes equal to r auxiliary inherent that I cannot change; inherent e r e n t inherent resistance plus this r external whatever I have done I can vary these r external. But anyway the thing is that this is suppose your supply voltage phasor, then your locus of the tip of I A; locus of tip of I A phasor I A phasor will be a circle will be a circle. What will be the diameter of the circle? When this whole r is, it will be v by x a and at that time the current will be lagging therefore, it will be like this is it. So, it will be something like this because lagging it cannot. What is this? This is V by v by x A total inductive reactance which I am not changing this will be there this is the center of the circle.

So, I can draw this circle it is the I A; however, I M will be fixed I M will be fixed I M will be fixed I M cannot change z M is fixed is fixed decided by running condition thing I will not change. So, this will be your theta M ok. Now I will draw the I A phasor. Suppose I A phasor since resistance is higher, it will be somewhere here I do not know this is I bar A arbitrary position for some value of r external it will be here. And this angle will be theta A. Mind you and this angle is theta therefore, torque will be maximum T starting torque which is equal to 2 or 2 dashed a I M I A sin theta. To maximize torque, to maximize T s t other things remaining same I A sin theta should be maximized sin theta should be s h o should be maximized. Now the question is what is I A sin theta? I A sin theta is nothing, but this length

Drop a perpendicular to I M axis, this is I A sin theta. If you have chosen arbitrarily this length is to be maximized. Now the question is where this point should be so, that this intercept I A sin theta will be maximum? It will be maximum provided this line passes through the center of the circle, that is you take a you draw a line perpendicular to this I M line wherever it touches, if your I A position of I A position of I A for maximum torque. This is the position of I A of I A when R is arbitrarily chosen when R A has some arbitrary value arbitrary value. In other words what I am telling this should be the position of I A or for maximum torque.

Because it is this intercept which is to be maximized and that is this length will be maximum when if you drop a perpendicular from this point to I M axis and that passes through the center that is the whole idea. Therefore, the simple geometry rule can be found out in this way.

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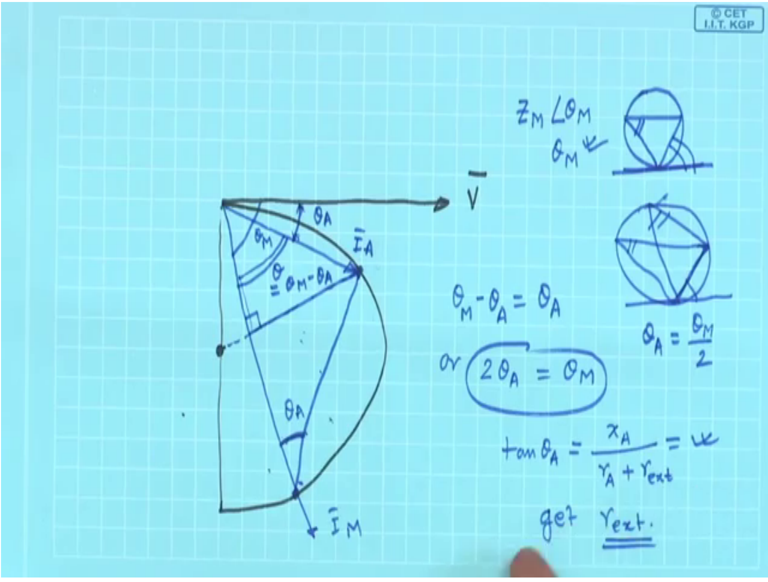

So, I will draw this characteristics for maximum position only V bar M, and first I will draw the circle this is suppose the center and I M is suppose here this is I M, and you drop a 90 degree there to this arc 90 degree wherever it cuts this circle, they there you say this is your I A I A: what is the diameter of the circle? V by x A anyway.

So,. So, this angle is theta A we are looking for, and this angle is theta M and this angle is theta, and then this length will be maximized. Although this circle is not drawn very good I mean what I mean to say, if I join these two points this will be also theta? No this is you know this rule if you have a circle, and if you have a tangent here this angle is always equal to this angle. Therefore, here it is a tangent there and here is a triangle whose tips are like this. So, this should be also theta A, because this is a tangent this is a circle. So, this angle theta A must be the internal opposite angle theta A because of this.

Student: (Refer Time: 13:23) tangent is parable to the base of the triangle (Refer Time: 13:28).

No not necessarily it could be anything this angle it can be easily shown, because angle on a chord are always same no matter where it is. In a circle on a definite chord all the angles subtended are same therefore; if it is theta A this has to be theta A I will not go to that level right now. So, this is the thing and theta is theta M minus theta A therefore, it looks like that and then this angle theta M minus theta A must be equal to theta A. These two angles are same because it is a chord and it passes through the origin bisects. So, it is a equi I mean these two sides are equal and then or 2 theta A is equal to theta M.

In fact, we are done now what I am telling is this if you have a calculator, you know z M suppose z M value is known z M theta M. So, this value is theta M is known suppose the parameter values, impedance, offered to this supply by the main winding is known completely then theta M is known if theta M is known I will say I know theta A which is theta M by 2, and then I will say tan theta A tan theta A is equal to x A divided by r A inherent plus r external and this is now known this side because theta A is known and then from this I will be able to calculate get r external; that can be done.

Graphically you just simply z M is known, this relation is known, I will calculate theta A and tell tan theta A is nothing, but reactance of auxiliary winding divided by this plus this. From which I will be able to calculate r external and say that that will be the value of r external chosen and then with that r external you calculate I A and use that torque expression that is r to t is equal to 2 or 2 dashed a I M I A into sin theta theta M theta A are known.

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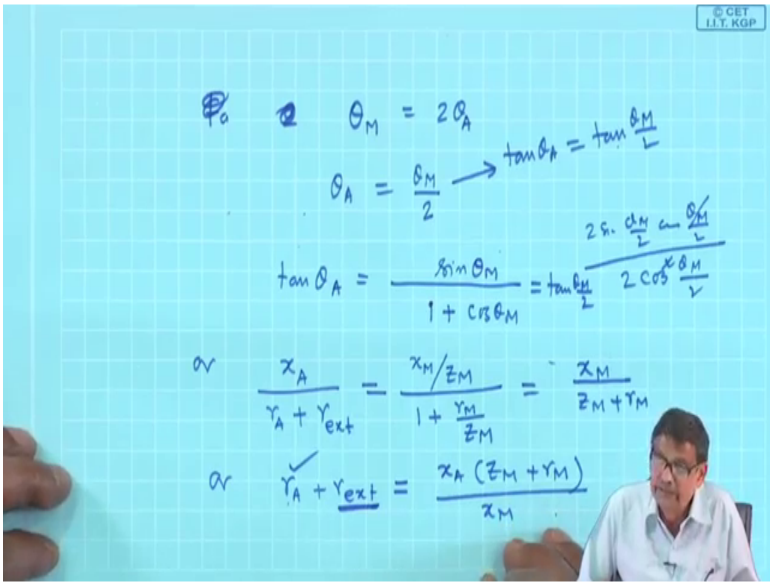

But, I will go just a step further and only for this one I will do; because see the moment you get this tan theta A we have got this relation some earlier books when computations were difficult, you have got this one theta M is equal to 2 theta A you have got. Therefore, it can be written as theta A is equal to theta M by 2. You are not. So, tan theta

A this is I do not know whether it will come like that, is it equal to sin theta M by say 1 plus cos theta M.

Because this is 2 sin theta M by 2 cos theta M by 2 numerator and denominator is 2 cos square theta M by 2; so, this cancels this is indeed tan theta M by 2. So, this is nothing, but tan theta M by 2 you not; so, it is actually what I am doing is this tan theta A take tan of both sides tan of theta M by 2. And, then tan theta M by 2 can be written like this I mean trying to get a closed form expression for that r external instead of going graphical. So, tan theta is this, then I will say or x A divided by r inherent auxiliary winding resistance plus r external optimum must be equal to sin theta M is nothing, but x M by z M.

And this is 1 plus r M by z M and which is equal to these are pure mathematics x M by z M plus r M here or you can write r A plus r external I mean do not memorize this, I am telling you although I am doing it is no point r A plus r M is x A plus z M plus r M divided by x M. I mean some people multiplied with z M minus r M do whatever you like, but then r external can be found out because r A is known inherent.

So, this is how this can be found out. I am also not finding out for example, maximum torque will be this length proportional to I A sin theta. I mean one can find out also expressions like this but this you see I will send you a note where you can find these things. But the whole idea is this that you try to find out the angle of the ability winding by using the concept of circle diagram and fix up the point ok.

Now, after resistors pleat I have done, but resistors pleat what happens is this the starting torque all it will be maximum if somebody sticks to resistor split what best he can do is to choose this value of r external. But the starting torque obtained will be in compared to capacitor start split phase motors split phase motor there will be much less and so, people this is only little bit of starting torque compared to capacitor split phase motor is obtained.

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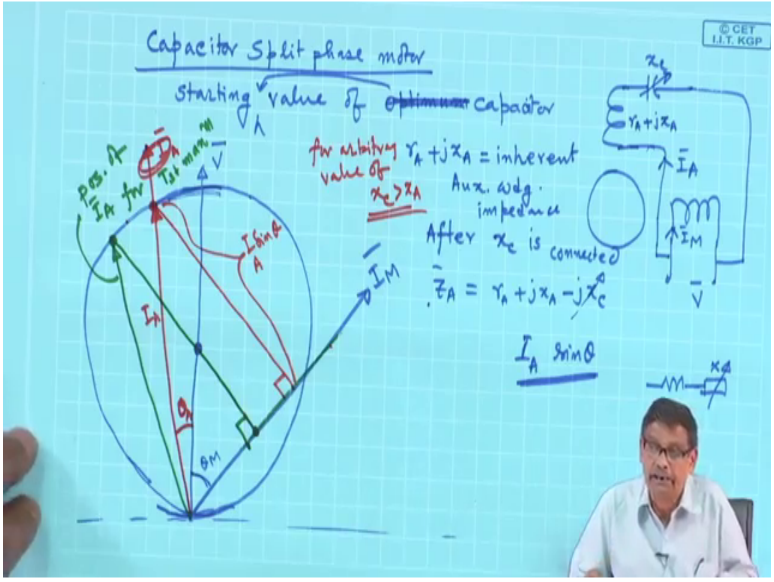

Now, let us see what happens to capacitor split phase motor how to. So, capacitor split phase motor capacitor starts starting torque; starting value of optimum capacitor optimum starting I think optimum should be here starting optimum value of capacitor ok. How to do it? In same way I will do what is the thing now? Thing is it is better you draw this circuit, here you are connecting an x c and here is your rotor, here is your main winding instead of r external now some capacitance and here is this 2 are in parallel and here is the supply v bar this current is I bar M and this current is I bar A for a arbitrarily chosen hexing. Such that this I A bar will lead I bar M I will chose such a value of capacitance.

So, this capacitance value must be at least greater than inherent impedance what is the inherent impedance? This is having r r A plus j x A r A plus j x A this impedance I cannot do anything r A plus j x A is the inherent auxiliary winding impedance all at the time of starting auxiliary winding impedance. After you connect this x c after x c is connected x c is connected our z a will become r A plus j x A is there minus j x e is not that will be the total impedance. I am telling if you make x c greater than x A it will become capacity current will be leading starting. So, it is this fellow I am varying ok. Now that is I M remains fixed as I am telling repeatedly.

Now, what I will do is this, I will draw once again this circle diagram suppose this is your supply voltage like this. Then the circle diagram will be my god like this will be the locus of the tip of circle diagram why I have shown 2 hops because when x c is 0 this circuit will be inductive. See this is the circle diagram if you have x here which is varying reactants, it could be inductive as well as capacity. So, for the whole range of variation of x this is the circle diagram that is fine.

Then your I M will be lagging this and that angle is fixed; oh this time I have drawn v vertical it does not matter it wrong horizontal or vertical. So, this is theta M and depending upon this value of x, the position of this one will be vary. Next equal to 0 will be somewhere here lagging bar factor x c 0; but x c greater than x A the current will be here that is what I want to tell and this is the center of the circle center of the circle. Therefore, for large value of x c or whatever it is some arbitrary value of x c suppose this is I A I have drawn I A this much do not worry about that, it is about this scale it will be less perhaps, but the angle is important here this will be then theta A it is for arbitrary value of x c.

But arbitrary value x c greater than x AI have chosen because leading current it is like this; so, what I have to do to. So, what will be the torque now produced? Torque is proportional to I A sin theta; I A into sin theta. Therefore, from the tip oh I am sorry I cannot play with this length it has to be here I A tip of I A lies on the circle I M of course, fixed theta M. So, I A is this one the length and I A sin theta means I have to drop a perpendicular from this point to I M axis. So, I will draw. And then this will be equal to your I A sin theta and this I A sin theta I M will be proportional to the torque, it is for any arbitrary value of x c.

Now, the question is where this point should be so, that I A sin theta will be maximum; it will be once again it should be somewhere here you drop a perpendicular passing through the center and this should be the position for I A for maximum torque position of I A for maximum torque. For T starting maximum, is not just like that resistance one position of maximum torque I A sin theta to be maximized then through this entered you drop a perpendicular to the chord I M to this length I M, and it will be there. So, what should be then the relation? So, now, I will draw only for this maximum torque.

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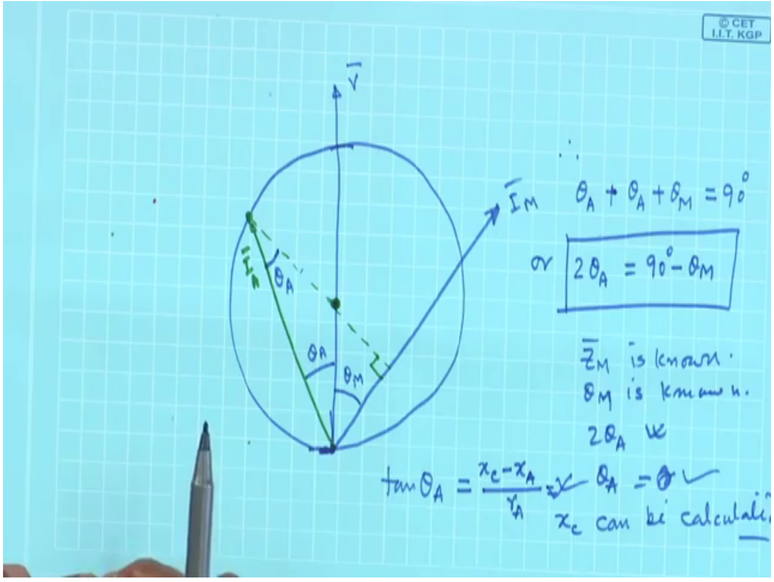

So, we have first I will draw the circle this is the thing this is my v and this is your I M I M did not lie on this circle and this is suppose the center of this circle. So, drop a perpendicular there 90 degree wherever it means that should be then your I A they should be your I A, now what are the things I know? This is theta M and this is theta A this will be the thing and it is a right angle triangle and since this is center it is a chord. So, this will be also theta A is it not theta A because this 2 are radius. So, what is the condition from this right angle triangle theta A plus theta A plus theta M must be 90 degree because this is 90 degree.

Therefore they therefore, the condition is theta A plus theta A plus theta M is equal to 90 degree or 2 theta A is equal to 90 minus theta M this is the thing this will be got the point. Now so, I will be if with the help of if z M is known if z M is known then theta M is known is known then 2 theta A is known then theta A is known, then I will say it is known then I will say tan theta A here you should be a bit careful it is equal to x c minus inherent auxiliary winding resistance x by r by inherent this time I am not connecting any external resistance only capacitance, this value is known then from which x c can be calculated I leave it to you to find out in like the previous one a closed form solution of x c by playing with this equation clear.

So, you take tan of both sides or things like that and try to find out. So, today I stop. So, we have discussed in this class very important topics that for starting you have to do some phase splitting and the starting value of the capacitor if it is a capacitor split phase motor we have discussed provided you know z bar M you can ultimately find out theta A after constructing this phasor diagram and the whole thing is this length is to be maximum not I A sin theta. So, merely telling theta I will make 90 degree will not guarantee you maximum starting torque in most of the cases; similarly for resistors split phase motor ok.

Thank you.