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

**Lecture - 55**
**Circle Diagram Slip line**

Welcome. And as we know we are discussing about the Circle Diagram of three-phase induction motor. Circle diagram approach of a analyzing a three-phase induction motor performance is very popular that is you do not have to calculate anything, once for all you just have this circle diagram for that motor drawn, then you can estimate, estimate mind you whether it is very exact or not. There are so many approximations. So, you bring the parallel branch in forward and things like that, but a very reasonable estimate of the performance of the three-phase induction motor can be then very easily done.

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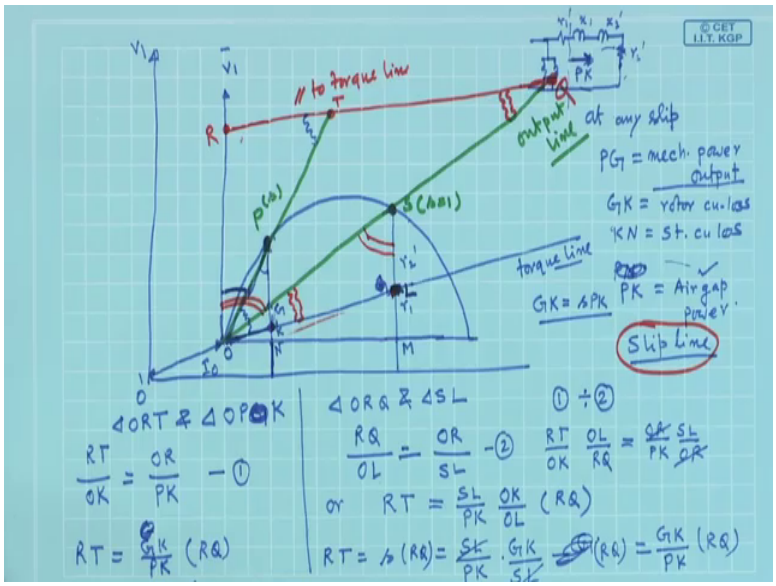


And last time we showed you that the circle diagram of the motor will be somewhat like this. This is the no load current, two branches are there parallel, and one is that side of the parameter where all the series parameters are added up and the circle diagram was like this. Circle diagram was like this. Then as usual and this is your voltage V 1.

Similarly, here is also if you draw a line parallel to this; this also is V 1. So, this current is that I 2 dashed reflected current and at S equal to 1 it was like this, there were two

points operating point we considered one is that S equal to s which means at stand still condition and another is the actual operating point which could be lying here P, ok.

Remember, in the RL circuit circle diagram, when r changes I told you this is r equal to infinity and this is r equal to 0, but here r will vary from the inherent resistance which is at this point r increasing this way no doubt that is correct and up to the full load point. That is a segment of this whole circle will be of interest anyway will come to this slightly later. So, this is the thing, this is S stand still condition, this is at any slip S.

Then what I told that just recollecting very quickly this length vertical length if you drop a perpendicular here this length in some scale will represent the constant losses of the induction motor. And this will be at s equal to 1 the total air gap power, not total air gap power if you divide this resist this segment in the ratio of r 1 is to r 2 dashed, in this ratio if you divide this line r 1 is to r 2 dashed then if you draw a line passing through this point then this length will represent this stator copper loss at stand still condition. And remaining power is the air gap power at stand still condition of course, that total air gap power will be lost as rotor copper loss, ok.

And then at any slip S when it operates if you drop a perpendicular once again the total input power is given by this length of which this length will be that constant losses, this length will give you stator copper loss, this length segment will give you rotor copper loss and the remaining power is the mechanical power output of the machine. So, this, this to this, this length that is say if I name them as I named previously P GK, P G K and this point is suppose N. And here I named it like this S, L, M; S, L, M.

So, at any slip mind you P G is the mechanical power output power output. The length GK is rotor copper loss rotor copper loss, and length KN is stator copper loss copper loss and PN is the power inputted into this series part of this circuit. This is r 1, this is x 1 and this is x 2 dashed, this is r 2 dashed. So, P N is the power in this branch of this circuit. PK or PK I will write it like this PK is the power here this length, not this length the after this, after stator resistance loss this is the power and therefore, PK is the air gap power air gap power, ok.

Then it is ok, fairly complete. Only thing I have to tell you what, how to draw the circle diagram that I will do, but before that for completeness sake another interest because how to fix up the operating point. Maybe I will be telling that the motor is operating at 5

percent slip, then corresponding to that 5 percent slip I have to fix up this point P and for that also you have to calculate then something where it should be you may be asking what are the parameter values. But another interesting thing can be done that is called slip line and that I just indicated in my last lecture at the last moment that you can draw a slip line in this way. What you do is this, you take any point on this axis, let this point be called r and also note that I called this to be my torque line. Why torque line? Because this power air gap power is a measure of torque GK is a rotor copper loss. So, PK is air gap power.

Therefore, this is the torque line and that is the air gap power this intercept PK is gives you a measure of the torque because air gap power in synchronous word gives you torque divided by 2 pi N S you get the torque, ok. And this P G is the mechanical power output this length therefore, the intercept between this and this is called the output line, this is called the output line. Is that clear?

Now, what you do? You take any point any point r on this V 1 axis you could select it here, but it will become very clumsy. So, take it above and draw a line parallel to this torque line, ok, draw a line parallel to this torque line. So, this line is parallel to torque line. Draw a line that is this line parallel to this and then you extend this lengths, this one and this one. So, it will intersects at this two points this point I called T and this point I called Q suppose this point of intersection Q, ok. And then I it can be shown or I will show that this length RT will be a measure of this slip at which the machine is operating.

How this can be shown? Once again by considering some similar triangles and call this is as O, this is suppose O dashed. So, consider two similar triangles, triangle ORT that is this triangle and the triangle OPG triangle ORT and triangle OPG you consider. This two triangles OPG or OPK sorry OPK, this triangle and this triangle.

This two are similar. Why? Because this angle must be equal to this angle, this is parallel to the torque line, is it not. And also you know this angle of this big triangle is equal to this angle and the third angle this and this will be parallel. If that be the case then from this I can write you first take this big triangle side opposite to this angle is RT divided by this is RT divided by OK, is not. Big triangle I have taken first then you take side opposite to this curved angle that is OR, OR divided by PK. In the same way you take

now consider the triangle big triangle corresponding to this line ORQ, ORQ and triangle OS OPK. So, OS this point may be called G. So, ORQ is this big triangle and OSG.

Student: G is already used. G is (Refer Time: 14:09).

The L say this point OL, I mark it. So, OSL; this two triangles are also similar. Why? Because OSL up to this I have taken. So, so this angle is equal to this angle, and also you know.

Student: S (Refer Time: 14:50).

And also this angle will be equal to this angle. This and the third angle will be equal. So, once again I do the ratios therefore, first the big triangle, triangle ORQ, this angle you take opposite to that is RQ divided by in this triangle it will be equal to OL, this point is LL, so RQ by OL. And this will be equal to OR divided by SL and we are done. I mean if we write this two, because this two triangles are also I mean what is called similar triangles.

Now, what you do? You divide this equation 1, this equation 2 divide 1 divided by 2 you do. If you do it will be left hand side will be RT by OK, divided by OL will go up RQ, left hand side left hand side divided and the right hand side will be OR by PK, PK into SL by OR. So, OR cancels out and you will be left with RT to be equal to SL by PK it was there, and all other terms from this side I will take it to the right hand side. So, it will become equal to OK by OL and whole thing into RQ this will be the thing. Now, what is SL, SL by PK? Is not is that clear? SL by PK is how much? SL is the.

Student: (Refer Time: 17:55).

And, OK by OL [FL], OK by OL [FL] this you can write it like this. So, this is equal to SL by PK and then, OK by OL this length by this length will be same as because this triangles are also parallel. So, that is this triangle and this whole triangle is parallel, so OK by OL will be same as GK by SL GK by SL because this two are parallel. So, this OK by OL will be also equal to GK.

Student: G in by (Refer Time: 18:52).

GK by SL, and then SL goes and you are let with into of course, RQ, RQ is there and this is equal to GK by PK into the length RQ. But what is GK by PK? PK is air gap power and GK is the rotor copper loss which must be equal to S into PK. Therefore, what happens is the you get RT is equal to S into RQ this is the thing. So, here the trick is here that is OK by OL is once again this are all parallel, so OK by K L will be same as ON by OM which is same as GK by SL that I have applied and I get this.

Therefore, the length RT; so finally, what we have got RT is equal to GK by PK into RQ, but GK by PK is slip it has to be because air gap power into slip that is s into PK is equal to GK; GK is equal to s into PK. So, so this will be s into RQ. Therefore, what I have done; you have taken a point any point R then we have drawn a line parallel to the torque line this line, then the point of intersections capital T and this is OQ.

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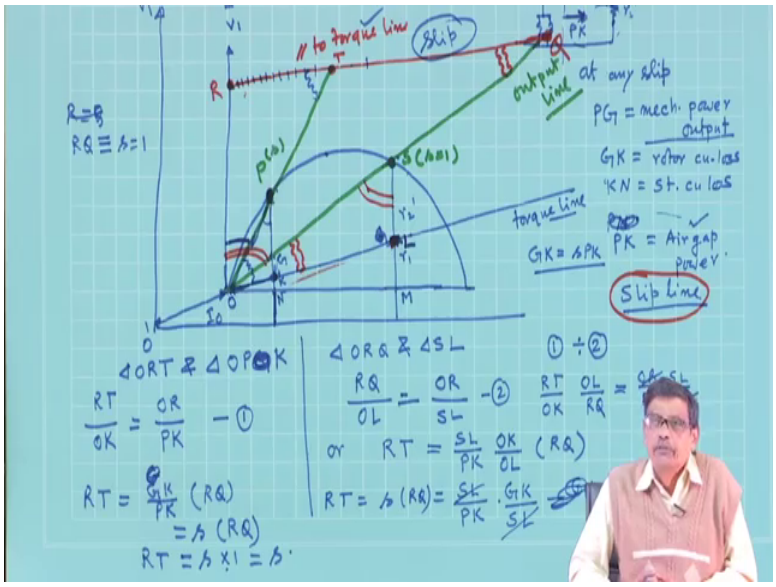


So, RQ is this length. Suppose I call RQ, sorry RQ suppose I say that is it is equivalent to slip equal to 1, this whole thing I will say slip equal to 1 this length represents. Then, I immediately know RT will represents slip.

So, the idea is you draw a line, take a point R, draw a line find out the point of intersections then this RQ you call S equal to 1 because it goes there arbitrary call, this length represents S equal to 1. If you do so, then RT must be the slip corresponding to this point here also it is slip corresponding to this point because s equal to 1. Then what I will do is, I will break this up N equals segments divide this line in 100 segments. So,

each segment will represent 1 by 100 slip or you say if somebody gives me a problem that at slip 0.04 I want to find out the performance I have this slip line all also drawn divided. So, I will this much centimeter represents slip 1, then 0.4 represented by which centimeter I will cut that length and join this point with this point, point of intersection will be the operating slip. And once I go that operating point, I know everything, total input power, air gap power, mechanical output power, torque developed by the machine and so on.

So, this is called the slip line. So, for a motor if you have this circle diagram drawn then you can estimate the performance of the machine for any value of slip which is between 0 to 1 and get the performance. So, that is about slip line. Of course, slip line it is not necessary you always draw slip line, but it is better for completeness sake and that is what a practical engineer can do or the given induction motor is working on once for all draw this circle diagram and then you can perform the prediction of the induction motor.

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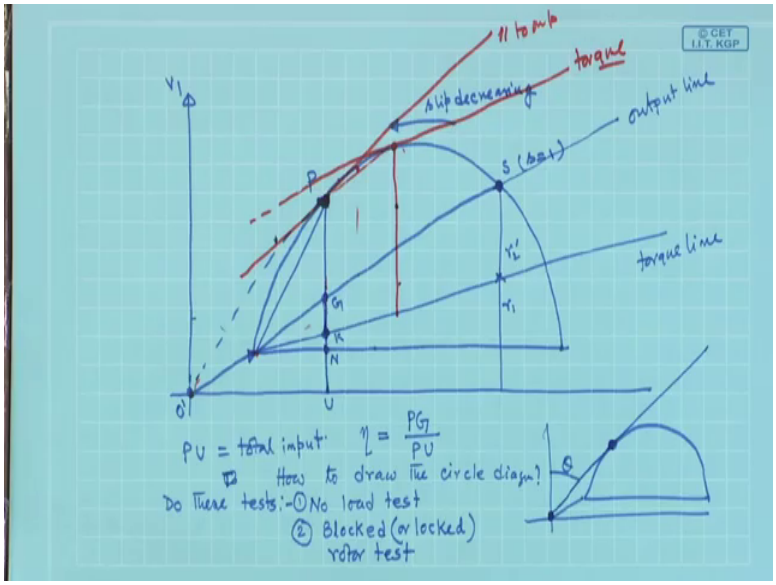


So, slip line we have done, now, let us just try to see. So, henceforth I will not draw this slip line to highlight many things. For example, I will I have got the circle diagram somehow, that somehow I will explain how to really get it.

Now, this is your no load current and this is this. So, this current is this current actually I naught and then this circle diagram has been drawn. And then this two points are crucial s equal to 1 points stand still points this is here drop a line and do not forget to divide this

line in the ratio of r 1 is to r 2 dashed. Then, draw another line and then this is torque line. I am repeating it is better so that you understand this is output line.

Now, either from this slip line or somehow if somebody says this is the operating point now, you simply join this. Current drawn from this supply will be then this length this is suppose O dashed, O dashed P will be the current drawn from the supply. What will be the power factor of the motor? Join this point cosine of this angle will be the power factor angle. What is the total input to the motor? Drop a perpendicular, this whole length will represent in some scale of course, the total kilowatt input.

What is this length? This length will be the constant losses. What will be this length? Stator copper loss, per phase, if it is per phase you have drawn. What will be this length? Rotor copper loss. And what will be this length? From this to this torque line, this also air gap power. So, air gap power is torque line divided by 2 pi N S to convert it to Newton meter. And this one will be the mechanical power output. So, this are named like this G in our earlier diagram also, N and let this be called some U. So, PU is the total input. And you as I was telling efficiency of the machine will be output power that is PG divided by PU and of course, I can find out also rotor copper loss, stator copper loss, input power factor and so on everything can be found out.

Suppose, somebody says that what will be the operating point corresponding to mind you slip is decreasing this way, slip is highest at this starting point then it is decreasing going towards full load slip which is very small. Now, suppose somebody ask me that what should be the operating point corresponding to maximum torque the motor has produced. Then what you have to do? Then you have to simply do this thing torque line is there take a set square parallel to this torque line, wherever this is parallel to torque line is there then only this interception will be maximum. It can be showed I mean like that.

So, this corresponds to maximum, this intercept will be maximum when the operating point through that if you draw a line parallel to this then only this segment is maximum. Similarly, if somebody says I want to get output power maximum. So, from this then I will calculate back this slip and tell the machine is operating at this slip. Similarly, if somebody says what will be the operating point corresponding to maximum output power, then what you have to do is this you have to draw a tangent to this circle find out

the tangent to the circle which will be parallel to the output line because output power is after all this length, this segment.

So, draw a line parallel to output line wherever it will be cutting it is parallel to output line and then wherever it cuts I say that is the operating point corresponding to maximum output power. If somebody says that what will be the operating point when the power factor at which the motor is operating is maximum then what he has to do is this. This line he has to draw a tangent I better draw it in a small version what I am trying to do, this, this. If somebody says motor find out the slip or operating point such that the power factor at which the motor is operating is maximum what you will simply do the total current drawn from this supply is this is not this dotted line.

So, draw a tangent to this circle. This will be the operating point corresponding to maximum power factor because you can easily see for any other power factor this angle which is the power factor angle theta that will become more and cos theta is there maximum value will have only at this point. So, several things can be done if you have circle diagram drawn for a given machine.

Now, the question is how to get this circle diagram drawn rather easily. The circle diagram can be drawn by doing this two simple test. You do not have to find out the parameters exclusively to draw the circle diagram, although it looks like, unless I do not know the parameters how can I draw, but we will see now by doing two tests one is called tests, I mean question is how to get the circle diagram. How to draw the circle diagram? The answer is do this tests, do this tests. One is called no load test and the other is called blocked rotor tests, blocked or some people call it or locked same thing locked rotor tests. And I will show you in the next class how from the readings of those tests circle diagram can be rather very easily drawn to scale.

Thank you.