Electrical Machines - II
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Lecture - 56
Circle Diagram from Test Data

Welcome and we were discussing about Circle diagram, and how to draw the circle diagram for a given machine. For that I told you last time that two tests can be performed, one is called blocked rotor test, another is called no load test. Before I come to that testing let us now we are we will be now able to understand this thing.

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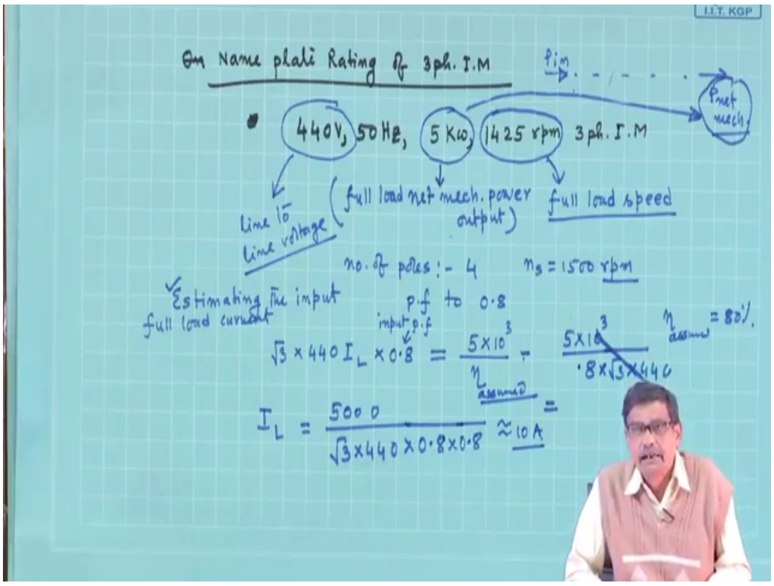

On the name plate rating of a 3 phase induction motor, name plate rating this is important to note name plate rating of a 3 phase induction motor. If a motor is there, every motor on its body it will be written what is the kilowatt of the machine? Say for example, I write 5 kilowatt 440 volt, 3 phase; 3 phase is 3 phase, 440 volt, 50 hertz, 5 kilowatt and what else will be written is say 1425 rpm, 3 phase induction motor, 3 phase induction motor typical name plate rating. Where you will note that on the name plate, there is number of poles of the machine not mentioned in general.

Now, the question is what are these things? This 5 kilowatt corresponds to what? This 5 kilowatt corresponds to net mechanical power, full load net mechanical power output that is what will be mentioned, not the input it should not be taken as input. This 1425 rpm, this is the full load net mechanical power output, this is the full load speed full load and mechanical speed it will be written full load speed.

Now, it is from this full load speed looking at this, I can decide about the number of the poles ok, because full load speed I know it will be less than synchronous speed is not and very close to synchronous speed. Therefore, the number of poles, number of poles of the machine, I can easily find out to be 4, because if the number of poles are 4, then only synchronous speed is 500 rpm, this facts are known to me ok.

Therefore, next highest synchronous speed; for two pole synchronous speed is 3000 rpm, but that cannot be synchronous speed, whose full load speed is 1425, because machine will be running even under full load condition at a speed close to synchronous speed, but just below that that is the thing 1500 rpm. So, this I can find out and 5 kilowatt is the net mechanical power output. And this voltage whatever, it is the line-to-line voltage always line-to-line voltage, these are the things which will be mentioned.

Another thing full load power factor may be mentioned in some of the machines, under this full load condition what is the power factor or sometimes if it is not mentioned, you will be provided or you can assume that to be some value. Now, you know a well-designed motor power factor full load power factor should not be less than 0.8 as simple as that I mean, no point in designing a machine whose full load power factor is 0.4, then your drawing excessive reactive power from the machine.

So, power factor if it is mentioned find full load. Generally, power factor you can assume if even if it is not mentioned to be 0.8, it may be 0.84 lagging power factor and it has to be lagging after all, everything is r l. Therefore, from this data what you can calculate is the full load current root 3 V L L; I L that is line current, I am not bothered whether the motor is connected in star or delta.

Line current is all that matters to me, root 3 V L L I L and power factor 0.8, but this is the input power factor. Estimation what I am discussing now, estimating the input current, input full load current that is if the machine is operating under full load condition, what current it is really drawing. Therefore, you know root 3 V L L I L this is input power factor I have assumed, even if it is not given input power factor. This should be equated to what, should it be equated to 5 kilowatt? No, 5 kilowatt is the net mechanical power output.

If you have seen the power flow diagram this thing P in, there were several stages and then you get P net mechanical power output, there were several things stator copper loss, rotor copper loss these that then you get and this is what is given what I am telling. Therefore, this P net mechanical power cannot be the input power, it must be higher than that ok.

Just to estimate mind you I am trying to estimate the full load current ok, this motor is given, how much current it will draw under full load, then I have assumed power factor, because I cannot, but assume it reasonable value. Similarly to get the input power factor, I have to assume this 5 into 10 to the power 3 divided by efficiency. Efficiency of a rotating machine induction motor, may be 82 percent, 84 percent, 80 percent, but it cannot be as I as 99 percent as it happens in case of a transformer because of so many losses present of similar type of similar rated transformer.

But nonetheless, this efficiency then also I should then assume reasonable. Only the assumption is that the motor has been designed by somebody, which has at least maintain this figures input power factor, the at least 0.8, efficiency is say at least I am take say 80 percent, assumed 80 percent efficiency. So, it is from these figures I will be able to calculate I L, why I am telling it is necessary to estimate the input current, because you have a machine and this current may not be explicitly written on the name plate, then it is this way you estimate the current. And I am telling you, you will not be perform the actual full load current this is the engineers approach.

Therefore, this full load current drawn from the supply can be estimated ok, this you just keep in mind. Then I come to the test, test is as I told you it is no load test and blocked rotor test. Induction motor what is no load test.

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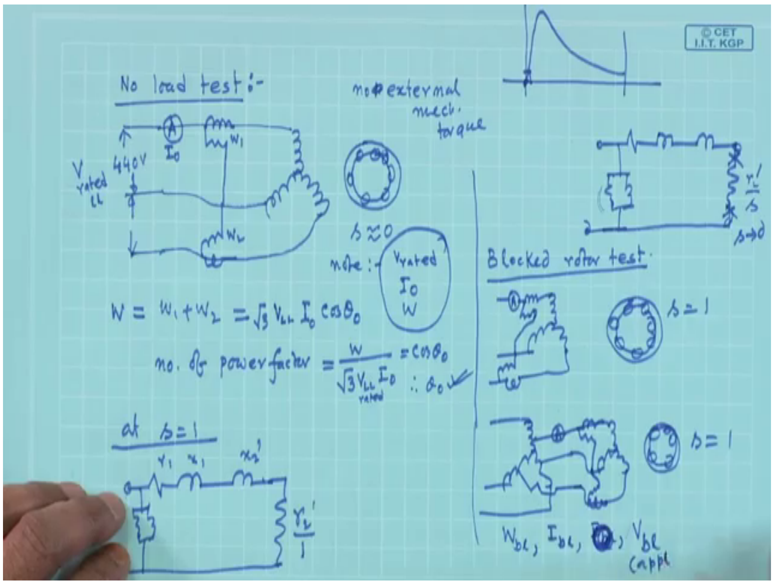

First let us come to no load test. In no load test, suppose this is the motor let us assume it to be star connected, and the rotor may be cage or rotor suppose cage this is the rotor here is your supply. So, under no load condition, you apply the full rated voltage that is 440 volt here line-to-line, V rated you apply line-to-line and give supply to this, and record the ammeter reading. And connect better 2 watt meters and W 1 plus W 2 gives you the total input power.

So, under no opposing torque, no external opposing torque, so no load means no mechanical, no external mechanical torque, external mechanical torque. Only thing may be friction is present that is not in your hand. So, under this condition, you run the machine. What will be the value of this slip under this condition, it will be very small as I have told you earlier always draw this curve corresponding to rated voltage, then at no load it may be running the if this is 14 1500 rpm, 4 pole machine it will be running 1480 rpm or 90 rpm very close to that.

Therefore, this branch impedance this branch or let me draw it this branch impedance. So, s will be can be assumed to be very close to 0, and this is r 2 by s. So, this branch can be thought of to be open that is this circuit practically it does not draw any current. Therefore, whatever power it draws W1 plus W 2 that power must be this stator copper loss, rotor circuit there is no current, because s is open. This side is open ok, s tending to 0, this will be infinite no current here.

So, the whatever power is drawn can be assumed to be this the power in this parallel resistance which corresponds to mechanical loss as well as core loss; core loss will be there because flux is there. And the core loss as I told you on the stator it is much had rotor iron body core loss can be neglected, because low frequency thing. Therefore, this will be the total power drawn. What I can calculates, and this ammeter reading will be the. So, let W be this; so W will be, then this if it is line-to-line voltage root 3 V L L no load current I naught and no load power factor is theta naught, ammeter will record this I naught.

Therefore, I can calculate the no load power factor, no load power factor to be W by root 3 V L L, I naught V L L is the rated value. So, no load power factor that is cos theta naught is known. Therefore, theta naught is known theta naught is known cos inverse that. So, this is the thing I will get from the no load test, and will be of interest to me so far as circle diagram is concerned. How? We will see.

The next test is the blocked rotor test. In blocked rotor test what you do? The same circuit diagram anyway let me draw s equal to 1 that is log the rotor by holding, do not hold by hand make some mechanical arrangement, so that the rotor is locked, it is not allowed to move. So, s equal to 1 is ensured that is what the blocked rotor means, then what you do in the same way you connect an ammeter and to watt meter. Now, the question is how much voltage should I apply, should I apply the rated voltage, no, why because under blocked rotor condition at s equal to 1, the equivalence circuit you no longer can neglect this x 2 dashed this will be r 2 dashed by 1 s equal to 1.

And here are this branches are there. If you apply full voltage, this always remember the winding resistance and leakage reactances at 50 hertz, these are very small. So, r 1, r 2 dashed, x 1, x 2 dashed are the series parameters which are very small. Therefore, if you apply full voltage huge current will be flowing will be drawn from the circuit as if you are almost short circuiting the supply that you cannot do, because machine may exceed its rated current by many times ok, maybe 15, 20 times higher than the rated current of the machine.

Rated current that is why I am telling you can calculate it by putting have this estimate of the rated current rated to calculate [FL]. You can calculate this rated current from this. And then what I am telling whatever is this number amperage, I am just calculating and telling you 5000 by 0.8 by root 3 into 440, you know I L let us calculate this in number. So, it will be 5000 by root 3 into 440 volt into 0.8.

Student: one is 0.8 (Refer Time: 18:42).

Student: (Refer Time: 18:59).

Into 0.8 efficiency. So, how much it is coming?

Student: 15 ampere approximately.

Approximately 10 ampere. So, for this machine suppose I am testing I know its full load current is 10 ampere. I am telling if you do not allow the rotor to move and apply full voltage, the currents order may be 10, 12 times higher than this rated current may be 100 ampere, 120 ampere, because the impedance offered to this supply is then the least. When the machine is operating at full load condition mind you this is s equal to some 0.04, this resistance increases many fold and full load current is 10 ampere, but now with rotor not allowed to move and you apply full voltage then this current will be excessively large.

So, what is done is this, this motor is supplied from an auto transformer. So, this supply here should be like this, this air is your motor stator; connect it here connect ammeter connect watt meter and so on. So, it is a must, do not apply full rated voltage for although 450 volt is the rated voltage. And this is the rotor s equal to 1, now slowly increase this voltage applied to the motor, motor in any case is not going to start because it is not allowed and you will find ammeter reading is increasing, watt meter reading is increasing.

So, increase this auto transformer voltage till rated current flows say 10 ampere for this machine, and then you further stop increasing the voltage. Therefore, it is like doing short circuit test on a transformer. While doing the short circuit test, we apply enough voltage to circulate the rated current; here also a situation like that prevails leakage impedance only limits the current. Therefore, I must apply very less voltage. How much less? Doing the while doing the experiment I will keep an watch on the ammeter reading. Apply such a voltage which will be much less than the rated voltage and you will find line current is 10 ampere, then you stop further increasing the voltage and note down this reading that is the whole idea.

Therefore, once again I note down, the watt meter reading which will be W 1 plus W 2. I am calling it W b l this ammeter reading is I b l. And what else I was noting here ammeter and voltmeter, and applied voltage. Mind you here also I am I noted applied voltage; so, note in this test note V rated you have applied here you are applying rated voltage not V rated I naught and W these are the three things. Similarly, here also note W total power note the line current I b l which is supposed to be rated current that much, and the ammeter reading I b l to indicate blocked rotor condition.

Student: Voltage.

And the applied voltage, I b l I wrote two times V b l applied line-to-line voltage, applied line-to-line voltage. you apply.

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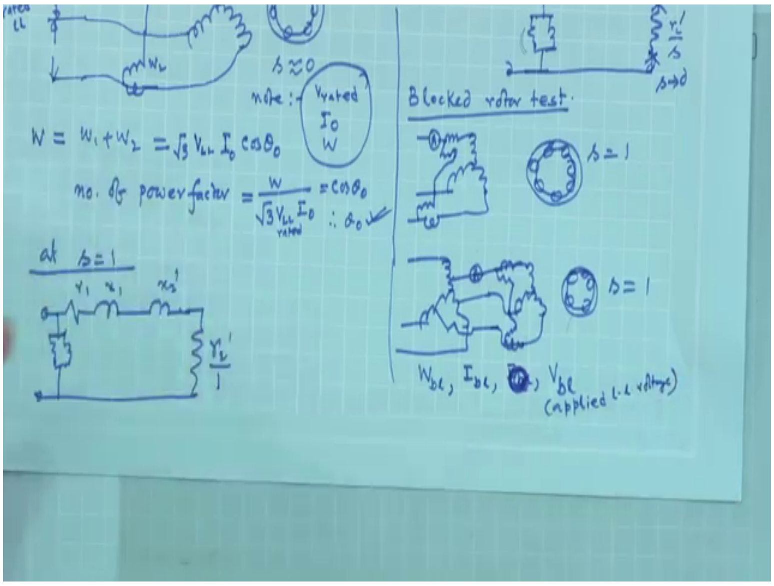

You have got your readings you have taken, then you can go straight away to draw the circle diagram. How? Let us see. What I will do is I will chose a voltage scale.

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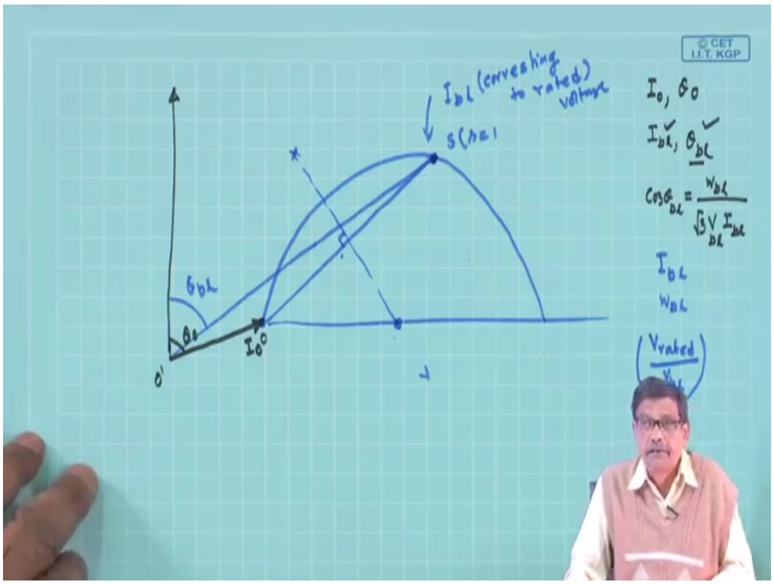

So, what I do? I chose a voltage scale or voltage of course, need not be drawn right now chose a current scale that so much centimeter represent so much ampere. Then from the no load test I know I naught and theta naught. So, I will sketch this I naught here to this scale now nothing left, this I can after choosing a length here.

So, in this circle diagram, if you look at I have got this point o, this is theta naught because so. So, this point is o dash suppose this is o I have got it. Then what I have done from blocked rotor test, I know I b l and theta b l, I can calculate in the same way I have done here all the thing you should note one important thing during blocked rotor test, this parallel branch can be neglected. Why? Because this current is so high this can be neglected that is one way physically also I am applying only a fraction of the voltage flux level will be less, cold loss will be less that magnetizing current two will be less.

Therefore, this branch can be neglected or even if it is there that constant business I have recorded mind you this current in any case I 1. So, from that I will calculate this, this current I 1. So, theta b l, I will calculate in the same way cosine theta b l is equal to W b l divided by root 3 V b l whatever voltage I have applied V l and I b l is not this will be the thing; so theta b l is known.

Now, what I will do and current scale already chosen so much ampere is represented by 1 centimeter. So, I b l is known, and theta b l is known. Mind you here where is that point that point is here s equal to 1, this is theta b l. Let me spoil this figure, but to understand what I am doing is it is s equal to 1, I am now looking forward.

Therefore, you draw a line and this is suppose I b l, this is I b l, and this angle is theta b l. And this is the point s equal to 1, s, s equal to 1 s point is it? No, not really. Because of the fact remember when you draw the circle diagram what thing I assume? I assume that the applied voltage is fixed, but here you have got this point from no load test by assuming apply voltage is 440 volt if that machine. And while doing block rotor test we have only applied a small voltage. So, this numbers I b l; theta b l of course, will not change, and W b l must be appropriately converted to the rated voltage; in a circuit if I know you have applied 10 volt, it is carrying 2 ampere current. If you apply 20 volt, it will carry double the current.

So, with the rated voltage divided by V v l; V rated by V b l whatever you have applied you must multiply this current I b l to get this I b l corresponding to rated voltage that work you have to do corresponding to rated voltage. Because I know I have not calculated out the block rotor test under rated condition, so that is necessary. So, theta b l and this corresponding to rated voltage modify and fix up this point. And once you do this, then rest of the thing is simple I know it is a point on the circle, I know this is a point in the circle.

So, I will join this two and this must be a chord, and I know diameter center lies on this horizontal line. So, I will bisect this chord something like this, I will do, I will bisect this chord. And this point will be your center of this circle and then circle can be completed like this. See drawing the circle is pretty simple, then I will tell you how to draw the torque line and output line in the next class.

Thank you.