Electrical Machines - II
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Lecture – 57
Starting of 3 Phase Induction Motor - Introduction

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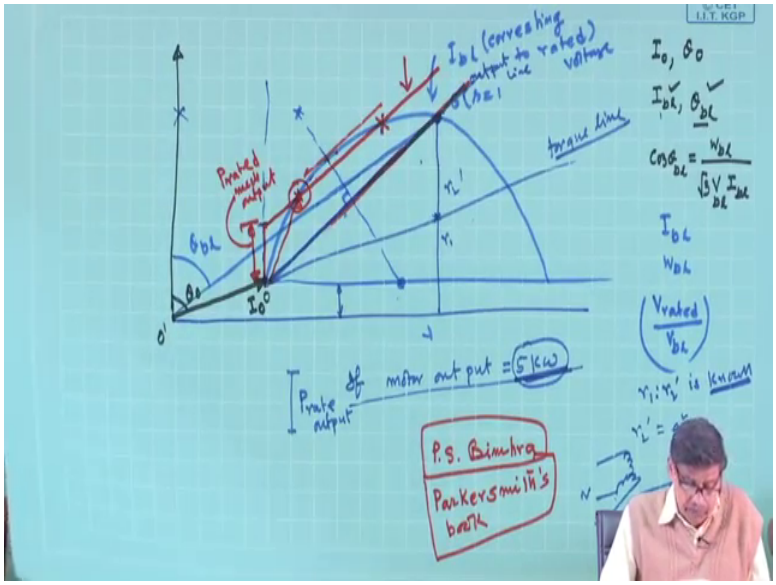

Welcome. And we were discussing how to draw the circle diagram of a 3-phase induction motor from two simple test; one is called no load test, another is called block rotor test. And only thing to be noted, no load test is carried out at rated voltage, and no load condition, block rotor test is also under no load condition, but a anyway s equal to 1, so no rotation.

Therefore, but you require a very reduced voltage to be applied may be 15, 20 percent of the rated voltage. Therefore, but circle diagram holds good for a constant applied voltage, and you are varying the resistance, therefore, this current value should be suitably changed line value of the current, and after changing that and manipulating this one.

Now, I told you, you choose a current scale, now where is the power scale. See power scale is already chosen in this way, because if you draw a horizontal line from the no load test, this is the power drawn, this length represents how much is the power drawn.

And therefore, I know the wattmeter reading. Therefore, this length represent so much watts is fixed.

Therefore, scale of power is to be after you choose the current scale, power scale gets fixed, how from the no load test you know. Either you calculate on per phase basis or on total power basis, it does not matter those things. But, whatever you do very clearly state ok, then this power scale is known, this thing is known, and drawing circle diagram is simple. This is the under block rotor condition, this much current will be drawn by the machine o dash s.

And at corresponding to rated voltage that is to be modified original I bl, this is I bl I mean corresponding to rated voltage not this I bl at reduced voltage that is to be modified theta bl etcetera is known. So, this then these two join, it is a cord divide it, circle rise here, point of intersection will give you the circle. But, still now I have to draw, where is the torque line and output line. Output line is of course this one. This is the output line, is not it, output line.

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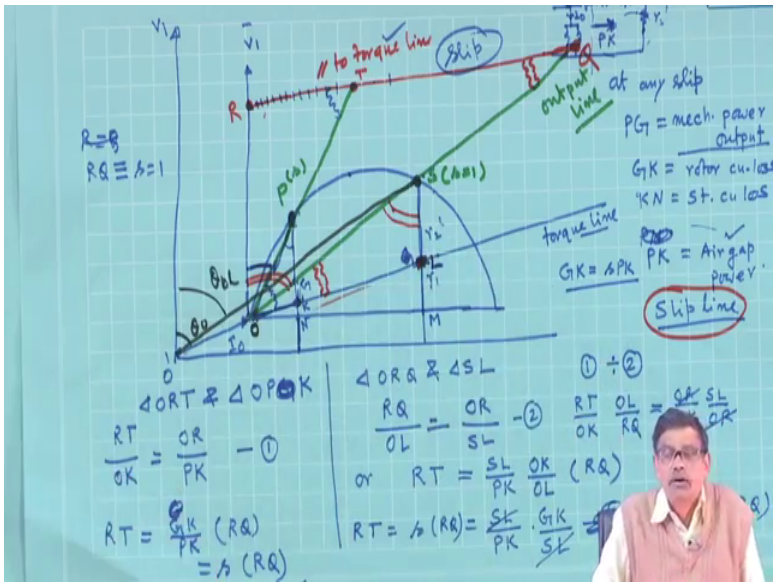

Now, r 2 dashed if it is one rotor induction motor, similarly I can excite the rotor winding from a DC supply get the value of r 2, but I need r 2 dashed, what to do; r 2 dashed is equal to a square into r 2. What is a? a is the terms ratio. So, for that what you do, if it is slipping machine, you can do it very simply, you measure this voltage and applied AC voltage here are you getting.

AC voltage you apply, rotor open circuit and measure this voltage, the ratio of these two voltages is N 1 by N 2, I am not going there, so it can be estimated. Cage rotor it is difficult, I mean cage rotor how to measure r 2 dashed. Separation of these two is difficult, but at that time what people either the designer will tell you what is r r 2 dashed expected or if no data is available, you assume 50-50 that is make it half, in case of data not available.

So, in any case you drop a line here, this ratio if r 1 r 2 dashed is known somehow, then you separate it also graphically. And then draw this line, and this will be your torque line torque line. Another way of estimating r 2 dashed, I am telling you if it is a cage rotor, you first find out r 1 ok. Then apply some AC voltage instead of DC, then r 2 dashed will appear. And from that equivalent circuit, it will not be that easy equivalent circuit only r 1, r 2 dashed, some leakage reactance will be there, because r 1, r 2 dashed after all small quantities. So, it can be some by some rules, it can be perhaps separated r 1 is to r 2 dashed.

And if it is separated, then only I can draw the torque line. In absence of any data, assume 50-50 1 is to 1. To estimate see these are the all I am telling is the estimates, nothing like very accurate no never, but it is a very simple means of doing these things. And after you have drawn the circle diagram, then draw the slip line also. And your circle diagram is now ready, and you cannot predict anything you like.

Now, I will tell you two thing. So, one is suppose I say that the machine rating is machine is how to fix up operating point, if motor output is equal to 5 kilowatt, for the motor rating I have written last time 5 kilowatt motor, how to fix up the operating point here ok. What you do? One way of doing this motors full load slip, I can calculate, slip line is drawn, you can do it.

Another interesting way of doing this, if motor output is 5 kilowatt; what is the output line? Output line is this line, these intersections are output. So, what you do, you

corresponding to this 5 kilowatt. If you are if you have drawn it on surface basis this circle diagram, then you take 5 by 3 or if you have drawn on the so far as power is concerned total power, either of this way you can do. You cut out a length corresponding to this rated output.

And here you cut out this length, then draw a line parallel to this output line. This length is supposed corresponding to the rated mechanical output rated mechanical output, from this point cut out this length through this point draw a draw a line corresponding to output line parallel to this, then you will get two point of intersection is not. One at a lower value of slip, and another at a higher value of slip, and this is not surprising. We have seen for a there maybe two operating point of which of course, this is to be selected is not.

And then you say machine will draw this much current, what is the total current drawn, this to this. What will be the power factor, cosine of this angle and so on. I do not want to further, I mean make this diagram very bad by drawing so many lines, but you have got the idea, this is what we have to do ok. Cut out this rated mechanical draw a line parallel to output line, and then this will be the operating point stable operating point. What is the maximum mechanical power output you can draw, as I told you draw a line tangent to this circle, corresponding to output line, and that will fix up. So, this is a very elegant way of so called estimating. Estimating is the word, I am using all the time, the performance of an induction motor, and efficiency I have already told.

Therefore, there are very nice problems in given in Parker Smiths, I will ask you those are long problems, but try to solve one of them or go through some text books. For example, P. S. Fim Bimhra, there is another machine book P. S Bimhra, I think I have written this spelling correctly nice book, Indian book. And go to there are lot of problem solved in that book including circle diagram problem, and problems based on equivalent circuits. So, please go through those problems, worked out example.

Of course, you try to do on your own, then compare the results that should be the attitude ok. And another go book problem book is there, Parker Smith you must have heard very standard problem books parker smiths book. They are very interesting problems on 3-phase induction motors are also given please go through that ok.

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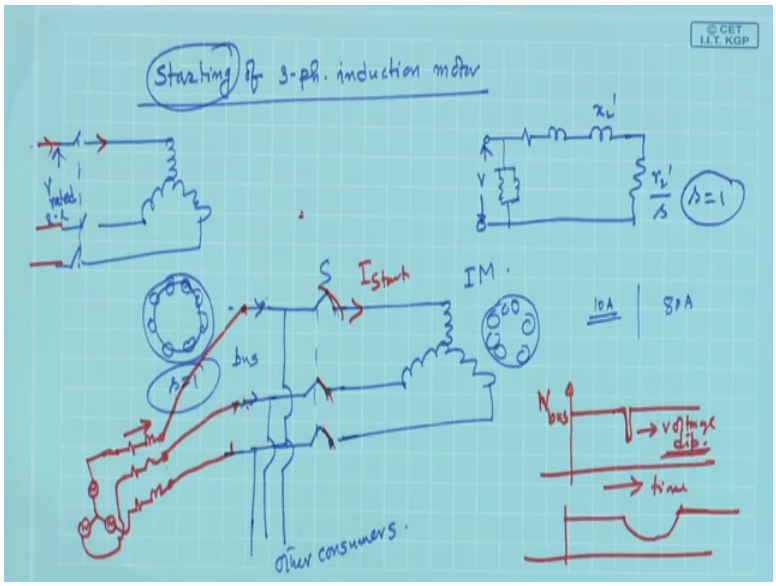

So, I will now do discuss about starting of 3-phase induction motor. We will come back to this tests later, if time permits once again to estimate the equivalent circuit parameters that we will see if it is possible. But, right now I will do starting of 3-phase induction motor, what are the method starting of 3-phase induction motor. First of all what is the problem, problem is like this. See I will refer to this equivalent circuit x 2 dashed, and this is r 2 dashed by s, and this is your supplying voltage per phase voltage.

Now, since I am interested to know, what happens at the time of starting that is machine is stationary, you have switched on the supply, how much current it is going to draw that is machine has not yet started running because of its inertia. At that time how much current it will draw, and things like that. Therefore, I will I can always put s equal to 1. So, starting means s equal to 1, at that time t equal to 0 plus etcetera, what is going to happen? And this branch as I told you, the impedance of this branch is lowest, when s equal to 1. And it will be very high, very high means higher much higher than corresponding to s equal to 1, when machine runs at full load.

Therefore, it is quite obvious that if you take an induction motor ok, and apply rated voltage at starting, suppose cage induction motor I am drawing. So, you apply here rated voltage line to line. Then when you close this switch, current drawn will be very larger. I was telling about block rotor test, nah block rotor test I told you that apply lesser voltage, because current maybe 10 12 times, 8 times higher than the rated current. For the earlier

machine, the rated current was 10 ampere. When you apply full voltage, it is going to take at least 80 ampere. If not more, I mean 8 times, 10 times, 100 amperes, now the it is not fair to pass such a large current.

Now, the question is it really a big problem to answer this question, you must understand this point. See a motor whose rated current is 10 ampere, and if you pass 80 ampere to the stator coils, because suppose 8 times the full load current at take, it takes when you apply full rated voltage s equal to 1 always, because starting I am discussing. Therefore, it is going to draw 80 ampere, so will the machine gets damaged.

If I pass see there is a tricky thing, if the motor is very small in the small size motor ok, then you switch on the supply full voltage, starting torque will be there, inertia is less, machine will pick up speed very fast ok, 80 ampere for small, but as time passes this speed rises rapidly. And therefore, it will take 80 ampere, but for a very big period. And you know that two spoil a winding, you require large current for considerable time I square RT, decides the amount of heat generated. Therefore, you should not be too skeptic. If you are in engineer, you will tell inertia is small, current 80 ampere, momentarily flows for break period, it does not matter. Because, after all the current will go down, slip is decreasing r 2 by s is increasing.

Therefore, it looks like full voltage with full of course during block rotor test what you do, you keep the rotor in block position for a long time, you will note down the readings. You should not keep this rated voltage applied for long that will be a real problem for the motor. And not only that that is the from the motor point of view, it looks like then if the motor is very large with large diameter, 100 kilowatt induction motor 440 volt, whose rated current itself may be say 50 ampere. You apply full voltage, then 8 times of that 400 ampere. And you know large inertia means, what it will slowly start turning, gradually speed will increase slowly.

Therefore, situation like s equal to 1 will prevail for a longer time that large that current 800 ampere, if it is rated current was 80 ampere, it is decreasing no doubt, but slowly it is decreasing. The level of the very high value of current will prevail for a longer time, and that may really spoil the windings, we will see smoke is coming out, and things like that above for very large motor with large diameter indicating that large inertia, motor if you switch on to a 3-phase supply full voltage, it will start drawing large current. And the

level of the current will remain fairly large for considerable amount of time and your there will be real problem, so that is from the motor point of view.

Now, see whatever current you draw has to come from the supply no doubt here, see this large burst of current this large current at the time of starting has to be supplied from the source. So, your source must be also capable of supplying that large amount of current, for sometime if it is a large for small motors does not matter, similarly to the source large current briefly, where this wires which are meant for less currents can perhaps will survive.

But, another problem is there, therefore the thing is if you look at this diagram carefully, this is the your motor, you want to start it, here is your supply, I am not drawing the fuses etcetera, this may be drawn. This is your bus from which you are giving supply, mind you in your bus where from this incoming supply is coming, other consumers are also connected is not, single phase, 3-phase consumers, other consumers.

Here is your induction motor, this is the switch and you have plan to switch on the machine with full voltage starting at s equal to 1. Now, what happens, when you close the switch, it draws very large current many times higher than the full load current may be 8 times higher. And this large current has to come from this, whoever is holding this bus alive, it has to come.

Now, you have read Thevenin's theorem and so on. So, this behind this three points, this source can be modeled as some Thevenin's equivalent with small resistance, internal impedance, reactance, internal impedance, these are the source 3-phase source. I mean you can think in this way is not, this three points at this three points, L nodes are connected ultimately.

Therefore, when such a large current will be drawn from this, there will be drop here that drop which is otherwise negligibly small for rated condition, we will now have some voltage drop here. Therefore, at this point the voltage will suddenly dip each time, you switch on the induction motor with full voltage. This voltage, where other consumers are connected will suddenly see a dip in voltage, rms value I am telling about.

And how long it will remain dip, depends on how much time your induction motor takes to reach the full load speed, I mean download speed that he is the bus voltage, it looks

like with time. It was maintaining some constant voltage satisfying all the consumer, suddenly at some time you switch on this motor close it, it draws large starting current, and voltage will dip.

And if it is a small motor ok, it will dip and it will come back like this, very small duration. If it is a large motor, bus voltage will dip remains dip, then once again it will come back, when rated speed is achieve something like this you picturized the thing, this is called voltage dip or voltage sag. So, there are two problems. One is from the motor side, whether a problem exist or not. Another is it will affect the other consumers is not, there will be a sudden voltage dip, this is called voltage dip, it will be a nuisance.

You must have observed, whenever in your house for example, whenever the freeze is switched on, there is an induction motor not a 3-phase, but single phase, suddenly there is a if you have lights, it you can easily see the fluctuation in the output luminance, suddenly goes down. Then once again the that motor is small quickly speeds up, and once again the light, I mean will be glowing at its normal glowing capability.

But, the important point is if that motor is making on and off in quick succession, I mean very rapidly in small intervals of time, then it will be causing irritation. So, for I your reading working ok, every time every 1 minute, there is a fluctuation and once again regaining a voltage, because that that is also an induction motor that you some how you can survive, but fortunately that temperature depending on temperature, there is a auto disconnection of the motor also connection, it happens rather not so frequently.

But, imagine there are critical loads connected to the bus a hospital, then such a dip in voltage frequent dip in voltage will not be allowed no, no way. There as induction motors used in industry which are to be switched on and switched off at regular interval of time, say a rolling mill to iron balls see what rolling. One beam iron beam comes, you roll it by roller with the help of induction motor suddenly full load, but motor is to be started there. And once again you restart with full voltage that is there you can think that ok, sometimes it is to be started switched off, after doing some operation in quick succession.

Then you really cannot afford to do this, because then you have to take permission from the supply authority. If you have a large induction motor, which is to be started at regular intervals of time, and then you have to add of some other means, so that such a nuisance

does not prevail at the terminals of the suppliant is not, so that is called a voltage dip, and another thing is the motor thing.

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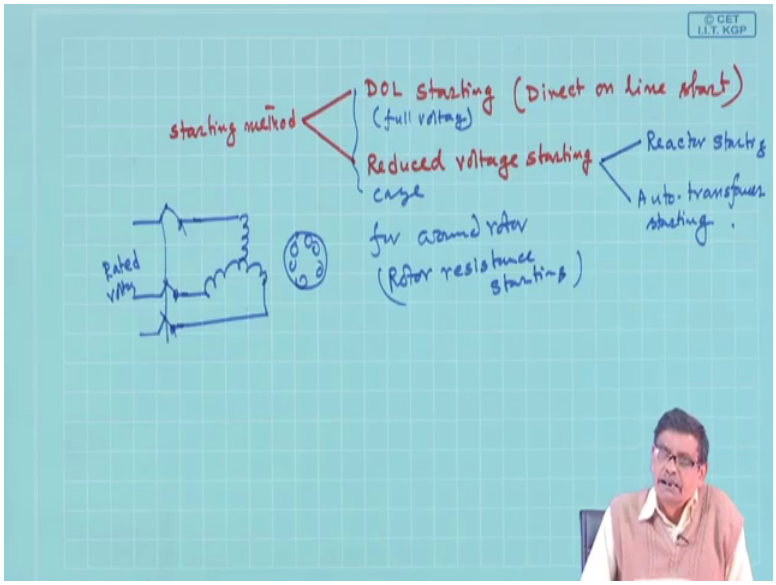

So, when you depending on the method of starting, I will just list out the method methods starting methods. I will discuss this three at least, one is called DOL starting DOL starting, which is called direct on line start direct on line start. For small motors, this can be adopted that is rated voltage you apply do not find ok.

Another is called, what are the other method should be reduced voltage starting do not apply full voltage, then reduce voltage starting. And this reduce voltage starting can a various thing, one of the thing is what is called reactor starting reactor starting. And another popular method is auto transformer starting. So, DOL starting means full voltage starting full voltage. Reduce voltage name is appears, you then because it is going to draw very large current better apply lower voltage, and gradually increase the voltage that is the whole idea.

So, in DOL starting means simply this, I mean in circuit point of view have a triple pole switch ok, you are sure the motor rating is not that high inertia is low, here rated voltage, and here is cage rotor close the switch that is all, nothing else straight. [FL] This you see I am drawing always just last word in this lecture cage rotor I am telling.

In case of wound rotor, the problem is less severe. In the sense that in case of wound rotor, rotor terminals are available. And to limit this starting current, I will connect external resistance r 2 per phase, and this will not only increase this resistance r 2 plus r external, but at the same time it will also improve starting torque. So, both way benefit you will be getting, so that for wound rotor motor, these are for cage for wound rotor, rotor resistance starting rotor resistance starting that is connect some external resistance per phase in the rotor circuit at the time of starting. So, it will not only limit this starting current. But, at the same time, it will also improve the starting torque. So, we will carry on with this discussion next class.

Thank you.