Electrical Machines - II
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Lecture - 58
DOL and Reactor Starting

Welcome. And we were discussing the starting of 3-phase induction motor, what are the problems, and how to avoid those problems. The thing is that if an induction motor, it has got a rated voltage as we know.

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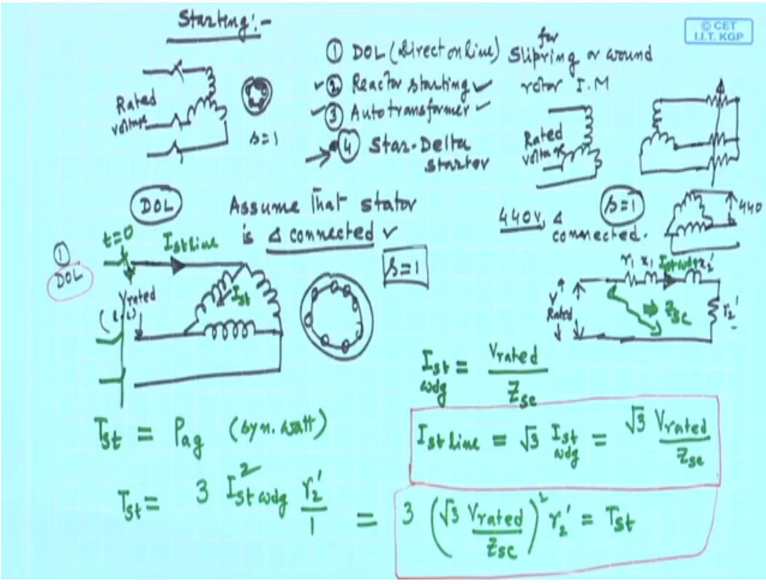

If you just directly connect it to the supply, then it is called full voltage starting or DOL starting Direct On Line that is the motor is there, and you straight away connect the supply. In simplified diagram, it looks like this rated voltage here rated voltage. And here is the rotor of the induction motor ok, the rotor say.

Because, in wound rotor induction motor, this is the motor can be started keeping in view that you connect some router terminals are available. So, you connect some external resistance in the rotor circuit slipring machine slipring or for slipring or wound rotor induction motor and rotor induction motor. What you do is this, this is the stator, and this is the rotor, suppose and in the rotor, you connect external resistances that we can connect, because the rotor terminals are available, gang resistance their values can be varied together.

So, initially put some apply full voltage across this stator full voltage rated voltage. But, keep this resistance to some value which will limit this starting current, because in the equivalent circuit r 2 dashed plus r 2 external dashed will come. Therefore, the current at starting and at starting you always remember s equal to 1. So, you have increased the impedance of the motor seen by the supply, therefore current drawn will be can be controlled at the time of starting. At the same time the starting torque is expected to rise also. So, it is called a rotor resistance starter for slip ring induction motor.

However, for cage induction motor you cannot do such a thing, because a rotor terminals are not available. And the methods the current drawn, if I apply full load supply at s equal to 1, current drawn will be many times higher than the full load current. In my last class I told, how to estimate the value of the full load current from the name plate rating of the motor. So, the starting current 8 to 12 times or may be still higher 15 times higher than the rated currents depending upon the machine, so that gives you an indication.

So, current drawn at the time of starting a full voltage is applied is very large, and which may be detrimental to the health of the motor. If it is a large induction motor as well as there will be problem, because certain suddenly if you are drawing such a large current from the supply, other consumers connected to the bus will also get affected, because momentarily there will be a voltage sag.

And once again of course, once the machine picks up speed to its normal value, then that current (Refer Time: 04:30). And once again the voltage across the terminals will be regained. But, the other consumers will be affected, each time you want to start a rather large induction motor, and tries to start it with full supply voltage, so that is called voltage dip problem, there is a sudden voltage dip and so on.

And this problem assumes importance, because if you have to because of your use of the induction motor, if you have to intermittently start and stop the motor every 15 minutes, then it is objectionable. Therefore, you must see that the current drawn at the time of starting of the motor is kept low ok.

And how I can do this? It looks like, if you apply a reduced voltage as at the motor terminals, and then as the motor picks up speed, then start increasing the applied voltage, so that rated voltage is finally applied across the motor that is the idea.

Now, how can I do this? One way of doing is called reactor starting reactor starting or better first I will put DOL starting that is a full voltage starting this is used, but for very small sized motors, whose inertia is less ok. DOL starting, then reactor starting, and then what is called auto transformer starting auto transformer starting. So, external equipment are necessary for this and this, you have to connect the reactors in the circuit.

So, the first is a DOL starting, and we will compare all these starting methods. There is another method I will discuss, I am not writing it now. This DOL starting compared to that, we will see how much is the starting current reduced. And once you do reduced voltage starting, one thing is clear, your torque starting torque 2 will be reduced, because torque is proportional to voltage square. Therefore, if you reduce the voltage by half it looks like, starting torque will become one-fourth and so on.

Therefore, we will compare the starting of 3-phase induction motor by reactor starting, auto transformer starting, and compare it with that of the DOL starting full voltage starting, then it will become meaningful ok, with respect to full voltage if I have applied, how much was the current drawn, how much was the torque produced, what are the ratios of this current drawn and torque produced in terms of other method of starting induction motor. So, this is DOL starting. [FL]

One thing is so far see I have told you that I am drawing always induction motor stator winding to be star connected is not. But, this stator of that induction motor can be delta connected as well no problem, what you ultimately need a balanced 3-phase current flowing through the windings. So, it does not, matter whether the winding is stator of rotor connected.

Now, to discuss about the starting of 3-phase induction motor, what I am going to do is I will assume that stator is delta connected. The reason for this will be clear, but I can only tell this much at the very beginning, because there is this forth arrangement of starting is called a star delta starter.

And I would like to compare with DOL starting, all of these starting methods including the star delta starter. And star delta starter can only be applied, if the machine is design for delta connection that is final connection of the machine with full voltage should be delta connected. The ideal is clear, if you connect those windings at the time of starting in delta star, then voltage reduced will be by 1 by root 3 voltage across the windings. Therefore, that is also reduce voltage starting.

And the advantage of this method is you do not require any extra thing, you need not purchase. Like in this method, you have to purchase some invest some money for the reactor or in this method some auto transformer, you have to invest. But, in star delta starter which can be only applied to the induction motors, which are designed for delta connected stator for its normal operation that is a 3-phase 440 volt delta connected induction motor that is in normal operation delta connected 440 volt.

Rating of each winding will then becomes 440 volt rated voltage, you have to apply line to line 440 volt for this kind of machine, so that I can do that it is not necessary that you have assume delta connected the stator to explain, what happens in reactor starting and auto transformer starting only, it is not necessary. Star connection also same conclusion, you will be reached.

But, if you want to then you have to but this method puts a condition that the normal operation must be with delta connected stator, and the rating of the machine based on that delta connection. Then to embrace all these starting methods under one umbrella, it is better you start with assume that the delta connector. So, your connection diagram will be like this stator is delta connected, I will assume. And it is suppose a cage induction motor rotor and I will apply here the rated voltage.

So, I am discussing first DOL starting DOL starting direct online direct online full voltage starting. So, I will apply V rated line to line I will apply. And I will estimate at starting that is s equal to 1, how much is the starting current taken by the machine.

See the equivalent circuit for phase suggest that at s equal to 1, the impudence offered is list. And that is that corresponds to block rotor condition as if rotor is still not rotating, and that impedance that is in the equivalent circuit if you see, it will be like this. This will be only r 2 dash, no external resistance only inherent resistance r 1 x 1, x 2 dashed ok. There is a parallel branch with high impedance compared to this value, we will also neglect that what is the point, because this current is with full rated voltage here applied per phase, which in this case is V rated itself line to line voltage is the phase voltage. And this is the starting current in the winding is not that will be the thing.

But, my goal will be how to calculate the starting current drawn from the supply, because this magnitude of current is important, because it is going to hamper the other consumers is not line current drawn from the supply.

So, anyway therefore you we can easily see, if I write this current, if I call it as I starting I starting winding or phase. This will be simply V rated, because per phase voltage is V rated divided by this impudence. This impedance let me call it Z sc. As I told you, it is like a short circuit case of a transformer that is why, it is called Z sc. We could write Z b l also like that, but it is not really blocked rotor is blocked, rotor is free to run, you are applying full voltage, it will quickly start running I mean like that. But, impedance offered at T equal to 0, I am closing the switch.

And my focus is at that time around that time, when you switch on motor as not yet started running, how much is the current drawn? Because that causes the problem with the supply and with the machine; so Z sc is this impedance, you can think of like that s equal to 1. So, this is I stator winding is this. Then I starting line, let us write a very big suffix to understand, what we are the really calculating, it will be root 3 times the I starting winding winding or phase whatever you call it. And this then will become root 3 V rated by Z sc, this will be the current clear.

So, I starting current will be this current, I note it down [FL]. How much will be the torque produced? Starting torque T starting T starting torque, we know it is equal to P ag in synchronous watt. If I like you divide by 2 pi n s that is ok, so it is air gap power.

And air gap power is nothing but this current square, this is the; I starting winding is not this current is this. So, this will be 3, this current square that is I starting winding squared into r 2 dashed by s which is equal to 1 that is air starting we know rotor copper loss is the torque produced. Therefore, this will be this magnitude total starting torque.

And this if you substitute this as 3 into this current square that is root 3 by V rated by Z s c whole squared into r 2 dashed is not, this will be the starting current torque starting torque 3 is because of 3-phase total power. So, this is the value of the starting torque. Starting line current is this one, current drawn from the supply, and what is the torque motor produces. So, this is the DOL starting summary.

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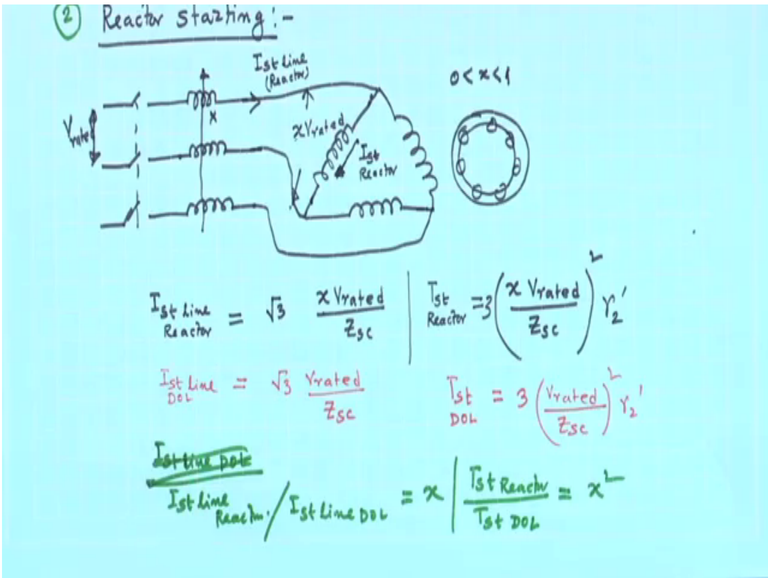

Now, I will say that I will adopt the second method that is the reactor starting. So, what will be this, this will be two reactor starting. What is done is this, these are the supply, after the supply in the three lines, you connect some reactors, and here is your supply.

So, in series with the line you connect this and this is your induction motor which I have assumed as you know delta connected. And here is the rotor of the machine, and these are connected here ok. And this reactors can be varied together so that it remains balanced all the time. And there is some reactance, you have connected in series with the line. And here is your V rated line to line V rated line to line voltage, it is present here.

Therefore, if you close this switch, V rated is here some current, so current will now be limited not only by the this equivalent impedance parameter whatever is Z sc, which is connected in delta. But, also by these reactance is not, I have simply increase the impedance in by the supply that is what I have to do, to limit the current drawn from the supply. And this current I am telling now I starting line current with reactor, and this is the current per phase which I am calling it as I starting reactor, this is the thing.

Now, if this is V rated x, you have connected some reactance here. The line voltage between across the machine terminal will be less than V rated let by which it is reduced is x V rated. Because, after all balanced reactance, I have connected, so rms value here, and rms value here will be different, magnitude of the voltage is important. But, none the less here there will be balanced 3-phase voltage, whose value is reduced is that clear?

So, x V rated is the line to line voltage applied here, here also it is x V rated. This small x is the setting of the reactor, it is it can vary from 0 to 1. When small x is 1 means, no reactor is connected is not. If small x is 0.5, I mean that reactor is connected in such a way that half of the rated voltage will come across the machine terminal. So, rms voltage applied across the machine is reduced by factor of small x. This x has nothing to do with this external reactor, I mean it has to do with that external reactors not the reactance value which may be denoted by capital X. x is a number between 0 to 1. And I told you x equal to 1 means, no reactance and so on. And x equal to 0 means infinitely large reactance you have connected, because it is open circuit then, anyway so this is the thing.

Now, I my target is to estimate, what will be the; I starting line, it is very simple algebraic calculation. And I can do it in one stroke reactor with reactor connected, I will say this connect will be this is I starting winding current no, this is winding current, so it will be root 3 times this current. And what is this current? This will be x V rated by Z sc, Z sc is the impedance.

Here it was V rated by Z sc, because you applied V rated voltage by Z sc, but here you are applying simply less voltage x V rated by Z sc, this will be the current is that clear? So, this is I starting line reactor current, this much current it will be drawing. And what will be the value of starting torque? It will be air gap power now. Air gap power means, this current squared into r 2 dashed, so this current square winding current squared.

So, this current square is how much is x V I am writing in one stroke V rated by Z sc, this is the winding current, this squared into r 2 dashed by 1 into 3 that will be the starting current in the reactor. Now, let me write just below it, here I starting DOL I starting line current DOL, we have calculated earlier. It was root 3 V rated by Z sc, and we also calculated starting torque DOL full voltage starting as 3; 3 I 2 dash squared r 2 dashed 1. And T starting DOL, we have calculated.

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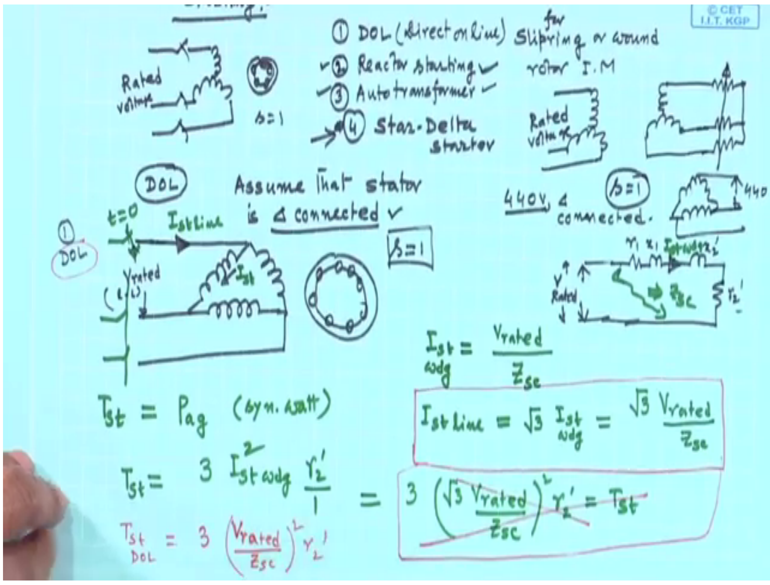

[FL] I will just correct it if something was see T starting DOL, I am re-writing there is some most probably mistake here. It will be 3 winding current square that is I starting winding r 2 dashed squared into r 2 dash, but I starting winding was only V rated is not. So, this was wrongly written. So, please previous page, so it will be V rated by Z sc squared into r 2 dashed is not. So, this will become T starting DOL is V rated by Z s c squared into r 2 dashed, this is the thing.

So, the last one is take the ratio, so I starting line by DOL method divided by I starting line reactor method. If you do, I think you make it other way round. I starting line reactor by I starting line DOL, this ratio simply becomes x. This by this, x remains and T starting reactor divided by T starting DOL will simply becomes this by this means x square.

So, the final conclusion is if you connect reactors, current will be reduced by factor of x, x is a number between 0 to 1 as I told you. And starting torque will be reduced by factor of x square. So, if you make x equal to half ok, current drawn from this supply compared to DOL starting will become 50 percent no doubt half, but starting torque also will be reduced by factor of 1 by 4 times it will be reduced, we will continue with this.

Thank you.