Electrical Machines – II
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Lecture – 59
DOL and Auto Transformer Starting

Welcome. So, were discussing with the reactor starting.

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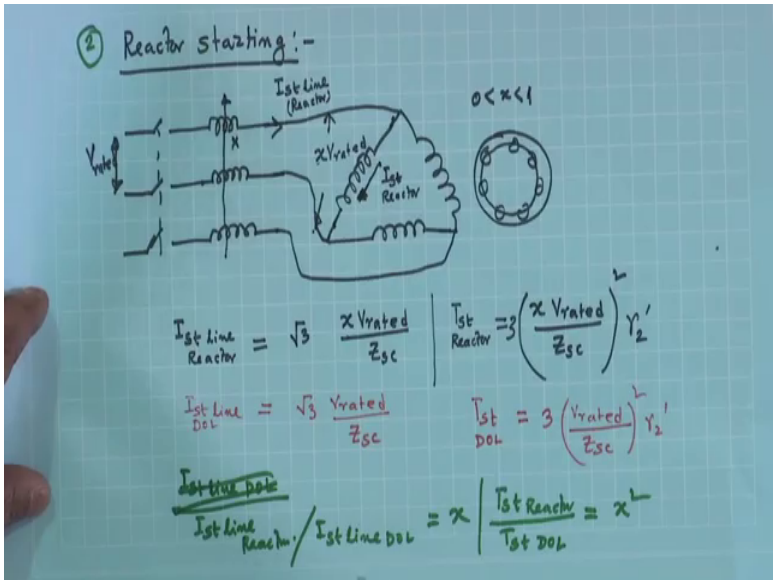

And, you remember that if we use reactor starting your starting current will be reduced only by a factor of x I am not writing that and starting torque will be reduced by a factor of x square and I am comparing these with respect to direct on line start, ok.

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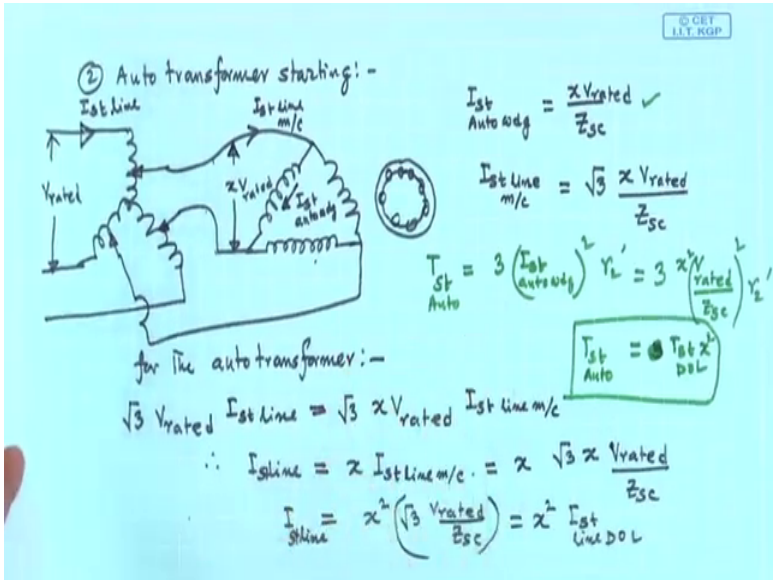

Now, the second method is let us do the same thing. The second method is called auto transformer starting auto transformer starting. In the auto transformer starting, same machine so, delta connected I have chosen for reasons I have told you. This is the thing; what you do? You connect an auto transformer three-phase auto transformer and here is your rated voltage. This is your supply bus V rated line to line understood? And what you will do you will take some from a fixed tapping here, here and here you connect it to the machine and here is the rotor of the machine, ok.

And, so if you apply V rated here, then depending upon where your this jockeys are they should be ganged together I mean equal tappings are taken so that the here the voltage available between the lines will be also balanced. And this voltage once again let us assume; it is reduced by a factor of xV at the machine terminals, I will assume this auto transformer to be ideal I mean for this large starting current no point in taking all the I mean considering auto transformer to be non-ideal;. so this is xV.

Here once again this current that is I starting auto in the winding if you want to write winding; I starting same thing here auto winding in this case. This will be simply xV by Z sc, the magnitude of the current is important.

I starting line machine that is this current is I starting line in the machine line not the supply line mind you the machine this will be equal to root 3 times xV rated if you are using V rated; xV rated by Z sc and this is also V rated you note this will be the I starting

line here. Now, but the point is this current we are interested in what is the current actually drawn from the three-phase source. So, this I will write I starting line supply line it is this correct and to calculate this current in a transformer you know the input volt ampere is equal to output volt ampere equate it; you can find out relate this current with this current.

So, for the auto transformer for the auto transformer input volt ampere is root 3 V rated; root 3 V I is the k V a into I starting line will be same as the output of the auto transformer that is root 3 line to line voltage is xV rated into line current that is I starting line machine. This two are same and therefore, you can see I starting line will be equal to root 3 V rated goes x into I starting line machine, this will be the thing.

And, I starting line machine is this one; so put it here. So, it was x here. So, root 3 xV rated by Z sc Z sc. Therefore, current drawn from the supply line current will become x square into root 3 V rated by Z sc, but this thing is nothing, but the line current drawn when you adopted DOL starting. So, straight away I am writing this is equal to x square into I starting line DOL, S is a number less than 1 and what about the starting torque? Let us calculate.

Starting torque will be 3 times this current square I starting winding that is I starting auto winding, phase winding current you have to take current square into r 2 dash by 1 in synchronous one ok, r 2 dash and this becomes equal to 3 times put this value that is this value. So, it will be x square V rated by Z sc. So, this will be this much, but 3 into V rated by Z sc square into r 2 dash is nothing, but 3 starting current DOL recall.

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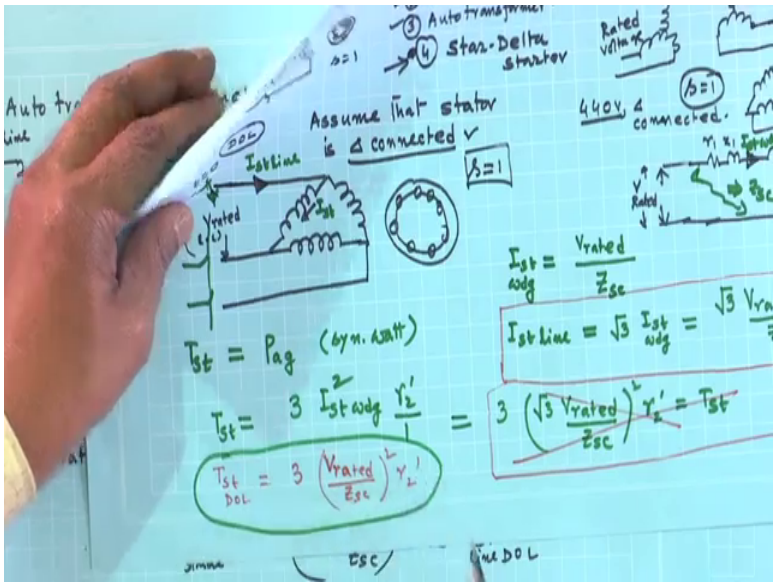

This is the T starting DOL 3 into V rated by Z sc whole square into r 2 dash. So, T starting auto transformer is this one, x square into this. Therefore, what we find in auto transformer starting that line current drawn from the supply is reduced by a factor of x square much less. Of course, this we also got for what is called the reactor starting current is reduced by a factor of x square. No, current was reduced by a factor of x in case of auto transformer starting. Now, current is reduced by a factor of x square; so it is an improvement.

However, starting torque is reduced by the same factor that was x square also here also it was x square, but nonetheless with respect to current you get some relief. So, you know that when we talk about the starting of three-phase induction motor. And we compare DOL starting with auto transformer starting and that of reactor starting with respect to DOL starting, it looks between auto transformer and reactor this will be good because this reduces current by a much higher factor; therefore this is the thing.

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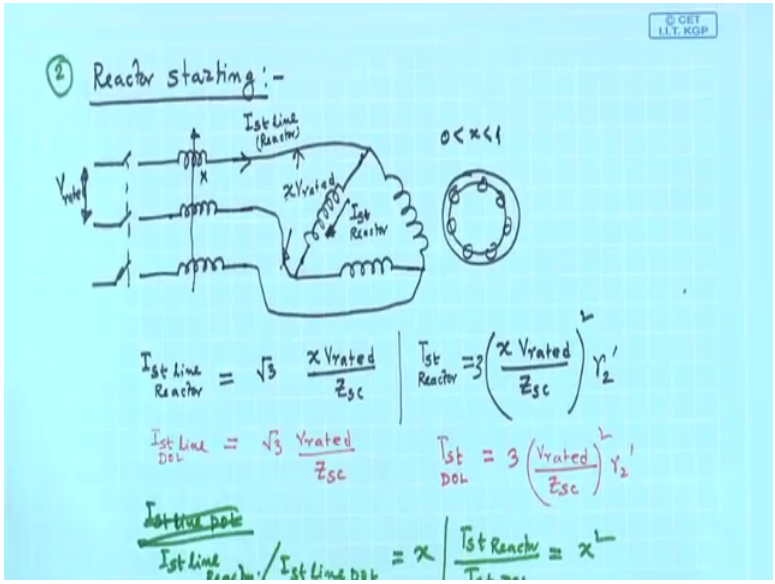

So, you note down that, but do not forget that in both this method you have to invest extra to purchase reactor or auto transformer. Auto transformer is costlier than plain reactors therefore, you have to invest money and also you are sacrificing torque by some factor x square and get some relief.

But, there is a nice method that is called the reactor this was actually number 3 number 4 is what is called the star-delta starting.

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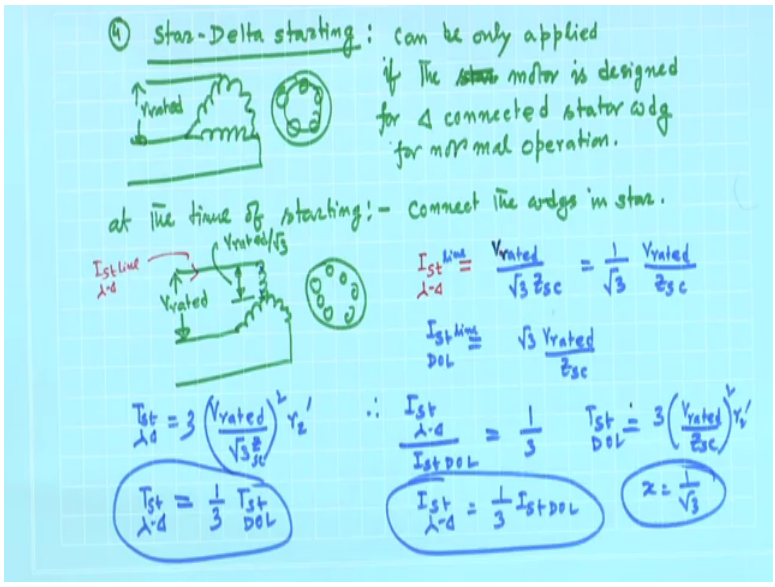

Number 4 star-delta method of starting three-phase induction motor; in this case and this can be this you now note down can be only applied if the stator if the motor is designed for delta connected stator winding; stator winding for delta connected stator winding for normal operation for normal operation, that must be understood.

If you have an induction motor whose stator is star connected for its normal operation as a motor supplying load, rated voltage you apply for that no it is meaningless to talk about star-delta starting of a star connected three-phase induction motor. Why, I am telling you? What is done is this motor is rated for idea first let us understand very quickly. This the normal operation delta connected, this is the KG rotor it is like this rated voltage is applied no problem normal operation things like that.

But, what you can do is this three windings at the time of starting at the time of starting at the time of starting what you do is this you connect this windings in star connect the winding stator windings in star, like this and applied it at voltage line to line which is here V rated this is at start. Then the applied voltage across the winding will be root 3 times less, you know, applied voltage will be root 3 times less that is I have been neither purchased or not to transformer not an reactor.

Simply at the time of starting I will connect the windings in star apply the full voltage, but this is not DOL starting for the machine. For the machine DOL starting is delta connected full voltage applied that is why I have taken delta connected winding which is for normal operation.

And, this will be this and then once again I can calculate the starting current as well as starting torque developed. The calculation in this case is pretty simple because I can say if you say that this current is I starting using star-delta starter line. So, I will write I starting star-delta starter using star-delta starter is equal to it will be how much here? It will be V rated this it will be V rated by root 3 by Z sc; Z sc is the winding impedance here reflected getting. So, it will be just like this.

In other words, this is equal to 1 by root 3 times V rated by Z sc and what was the I starting DOL? I will write there because I am comparing everything with that I starting DOL was here. I starting line here also it is line current I starting line DOL was root 3 V rated by Z sc you know, it was this. So, it is like V rated well same thing I am writing Z

sc it is like this. Therefore, I starting star-delta by I starting DOL will be one third. This two will cancel, it will become one third.

And what about T starting star-delta? It will be the winding current square into r 2 dash and winding current square is this one itself. So, V rated by root threes current square into r 2 dash into 3 into Z sc is not, current square into this. And this once again will be one third of T starting DOL because T starting DOL from the previous page you know it was 3 by V rated by Z sc square into r 2 dash. So, take the ratio it will become one third, is that clear. Therefore, T starting star-delta is one third starting DOL and T starting DO I starting star-delta is one third I starting DOL; this is current, this is star.

Therefore, we can say that a star-delta starter is equivalent to an auto transformer starter whose setting is x equal to 1 by root 3, is it not. So, star-delta starting is equivalent to an auto transformer whose setting is that x small x is equal to 1 by root 3 because in an autotransformer current reduces by a factor of 1 x square torque also reduces by a factor of x square; x in this case must be 1 by root 3, that is why it has become one third and one third.

Therefore, you see this way of starting induction motor you have to you do not have to invest any extra money, but at least you can get this service like an autotransformer which whose setting is small x equal to 1 by root 3. Only thing you will ask so that a star-delta starting can be implemented is there the machine must be designed for delta connected stator in its normal operation, that is, winding rated voltage is V rated and as delta connected it will operate like that.

And, second thing you will also ask for that all these stator winding phase terminals must be available to you because you have to make this because you connected in star at the time of starting then what you are going to do? Because your machine is designed for winding voltage winding is designed for rated voltage. So, you have to do some switching so that the star connected windings now becomes delta connected for its normal operation. Ok, at this time of starting there was some problem latch current you were talking then you try to reduce that current by a factor of one third and connect it in star, then once again you have to go to the delta connection for normal operation ok.

So, to this point must be noted, that is, after the machine has started and speed has gone up then once again switch over to delta connection. How this can be done? Very simply and nicely in the machine lab for small motors it can be easily demonstrated.

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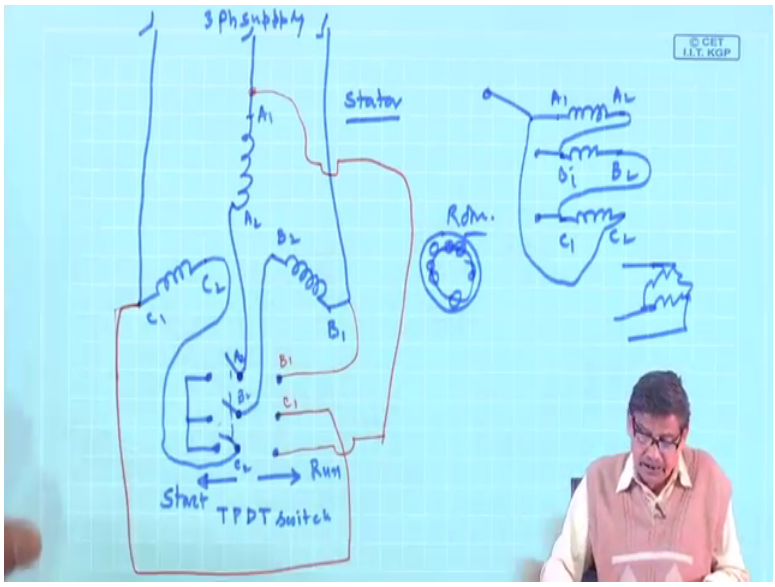

What you do is this suppose you have stator windings all the terminals now must be available to you A 1, A 2, A phase or r phase I am writing AB. This is B 1, B 2 stator and this is suppose C 1, C 2 what I will do is this three I will connect it to supply. Here is your three-phase supply with fuse, with unit etcetera, and this six terminals must be available to me in order to implement star-delta starter. At the time of starting what I am going to do? I will connect this A 2, B 2, C 2 together then it will become star. So, this can be easily achieved if you take a triple pole double throw switch what you do? You do a little bit of wiring.

So, from A 2 you do this is triple pole double throw switch. So, A 2, B 2, C 2 and this these are the triple poles and this side this three terminals you short it short it like this. So, if you close it here it will be star connected machine is supplied and delta connection about delta connection you should be a bit careful. But, nonetheless if process three windings which I am just drawing electrically I mean how you connect suppose this is B 1, B 2 and this is C 1, C 2 what is delta connection of this three elements?

Delta connection as you know essentially means they are connected in series and series and closed. So, you connect them in series and while connecting in them in series you

should be careful finish of a phase start of B 1 and so on and these also are closed then it becomes delta connection. And then what you do you from the junctions you take this three terminals; so it becomes delta connected. So, delta connected mind you of three elements means they are to be connected in series and the circuit is closed then the junctions at the delta point junctions that is we are drawing like this. I think you have got the point.

So, what you I will be doing on the other side of the switch once again I will do a little bit of wiring. See the; this points are the middle points I have brought A 2 here B 2 there and C 2 there. Now, I know what I have to do if I know want to connect it to this side to make it a delta connection then A 2 should be connected to B 1. So, I will do this wiring A 2 to B 1, then B 2 to C 1, then I will take a piece of wire here. So, this is B 1 this is C 1 and finally, it must be A 1. A 1, C 2; A 1 should be connected to C 2.

So, take another piece of wire connect it here and I will write it like this. This side if you operate start and if you move this side it is run a star-delta starter can be nicely implemented provided all the 6 terminals are available otherwise you cannot do anything. Oh, I have forgot to connect this C 2 here; A 2, B 2 and C 2 is here is not.

So, if six terminals are available; that means, so, often induction motor with six terminals are available means that it is perhaps designed for delta connected operation for normal operation and for that machine you can exploit this method of starting; that is at the time of starting and a rotor of course, I am not drawn rotor is here rotor nothing to do with rotor.

So, anyway think about this and if you have a small machine in the laboratory, you can easily implement star-delta starting to avoid large starting current although torque is reduced.

Thank you.