Electrical Machines – I
Prof. Tapas Kumar Bhattacharya
Department of Electrical Engineering
Indian Institute of Technology, Kharagpur

Lecture - 79
Starting of D.C Motor - 3- Point Starter

Welcome to lecture number 79 and we got ideas if a DC machine is connected say either in shunt or series fashion. And, if it is drawing some current running at some steady speed, then what all you have to do is you have to write down two equations; one is the back EMF equations from the circuit point of view it is V minus I R a and another is the torque equation I f into I a neglecting saturation.

And then if you change some quantities in the circuit for example, you might only change the armature voltage applied for a separately excited machine. So, machine will then operate another under another steady state conditions, then once again write down those two basic equations and take ratios and you will get a new quantities, ok. So, that was the basic thing we must know before we further proceed.

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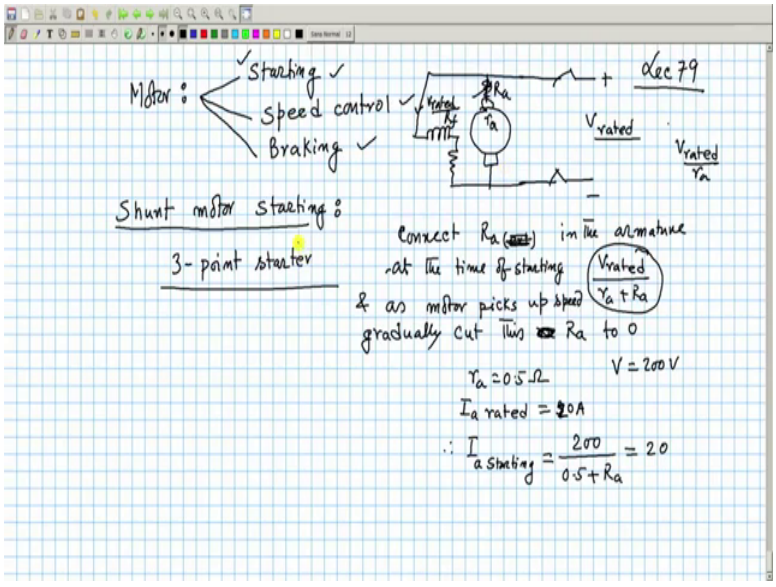

Now, for any motor operation three things are important motor, be it AC DC motor it does not matter. If it is these three things is are that its starting then its speed control, how speed can be controlled speed control and another is called breaking electrical breaking, that is if you want to bring the machine to stop very quickly electrically what

you should do these are the three things one must know about the motor. So, DC motor is also no exception to this; so, first we discuss about starting of DC motor.

And suppose a shunt motor, shunt are separately excited motor shunt motor let us take general shunt motor starting, and we know the starting phenomena that is if you have this armature and this is the field, they are connected in parallel and then here you will give supply rated voltage.

Now, we discussed about this problem starting from rest that is machine was stationary, but the order of the armature resistance is small, how small it is we also discussed about that. And if you apply full rated voltage at the time of starting, at the time of starting there is no back EMF therefore, current drawn from the armature will be very large about field circuit no problem, field circuit V by R f is the current steady state current.

Therefore, here the problem is armature current may be many times larger and if it is a large DC motor inertia may be large; therefore, back EMF we will slowly build up phi has build up, but A n will increase slowly if its inertia is high. Then, the level of that large starting current run by the armature will also persist for a longer time and your machine may be damaged particularly armature winding. And if armature winding is damaged it is very difficult once again to repair cost is affected therefore, some protection is to be taken at the time of starting.

Now, in today's con context to start such a machine you can have a variable DC supplying voltage; suppose, 220 Volt is the machine rating then you do not apply 220 Volt across the armature of the machine. You have a variable DC supply voltage with a power electronics converter slowly increase the applied voltage starting from 0, then there will be absolutely no problem.

Applied voltage is small, current drawn will be small as the machine picks up speed go on increasing the voltage and then finally, set it at the rated voltage no problem that is not a very big issue perhaps in today's cons context. But nonetheless in earlier days and it is also some places it is still used at least one starter I will tell you about that is called 3-point starter which is an electromechanical device to start a DC shunt motor, ok.

So, what is a basic idea is this that at the time of starting this voltage is rated. So, I am not talking about variable DC voltage and that would have been nice, but rated voltage

supply is available and I want to start the DC shunt motor and I know armature resistance is small. So, at the time of starting speed is 0 V by R a, which may be many times larger than the rated current that I want to avoid.

So, one solution is; obviously, connect some external resistance in the armature circuit; connect R armature external with capital letters this I will indicate R a in the armature. So, that the starting current then earlier it was V rated by R a was the starting current now it will be V rated by this small r a plus this R a external. This will be the starting current therefore, you can reduce the starting current substantially by incorporating at a distance in the armature circuit.

And, as the machine picks up speed then you gradually cut out the armature resistance to 0 external this R a back to 0. So, that machine will operate at full rated voltage within a rated armature resistance in the circuit that is the idea.

Now, therefore, I have to connect a connect R a and initially at the time of starting time of starting and and as motor picks up speed; picks up speed gradually cut this resistance this R a to 0 sort of variable resistance you connect. So, that is the idea you connect an R a initially maximum then gradually cut it back to 0.So, finally, it will be only small R a present in the armature circuit and you can reduce the armature current drawn from the supply to whatever extent you want you can do it.

Mind you, the field current is V rated by R f that is no problem total field circuit resistance, but the only problem maybe you cannot reduce it to any number you like because the starting torque is proportional to product of field current and armature current. If you reduce this armature current to a very small value then the electromagnetic torque developed by the machine will not be able to make it start.

If the motor has to start against a opposing low torque that you must see that ok, it is reduced maybe I will say that whatever is the rated current of the armature I have a knowledge; suppose, the rated current of the armature is 30 ohm 30 amperes. I at least safely it can take 30 ampere, armature resistance is suppose 0.5 ohm and I a rated is equal to 30 ampere say or 20 ampere say just for calculation sake.

Then I will say I will and suppose the supply rated voltage is 200 Volt, then I will say that I want to make the starting current I a starting is equal to this 200 Volt divided by

this 0.5 R a plus R a external and I will restrict it to 20 ampere based on that I will be able to calculate R a. So, rated current I will pass. So, that the torque developed by the machine remains high, starting torque should be high; so, from that I can calculate R a. In fact, this 0.5 is so small, so R a has to be 10 ohm approximately, you connect and get this done.

Now therefore, the solution is connect an external resistance in the armature circuit then parallelly to its field then give predicted voltage that is the idea, but the problem is not problem ok, motor is running. Now suppose, the supply goes off because of some problem on the supply side, supply becomes 0 load shedding then what happens is this machine will come to a stop; both armature current and field current will become eventually 0. If supply is switched off and machine will come to a stop and suppose supply comes back it comes to stop, but before you notice it supply comes back to this circuit with the switch on, then what will happen? Once again this R a external I have made it 0.

So, once again the current flowing through the armature will be V rated by R a and that is a dangerous thing. Therefore, if the motor is working in an industry therefore, there must be always one man present there in such a situation because you do not know anything can happen supply voltage may just go off. Then after noticing that he will once again bring this R a back to its normal value immediately, because you do not know when supply will come back. So, that once again things can go, even human intervention is necessary and human may make mistake he can forget and problems are there.

So, there must be some automatic features not just an array you connect which will not only allow you to start the motor keeping the armature current at a low value, but at the same time also protect the machine when the supply goes up. So, one starter which has been extensively used and also now it is used by some old industries you will find that. So, that thing I will discuss at least one starter you must understand how people started DC motor.

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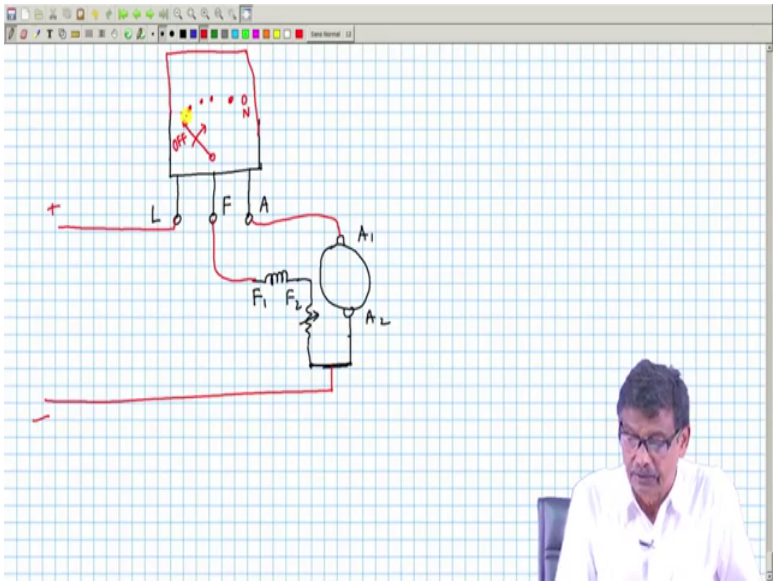

So, the circuit is like this what happens is this. These 3-points starter have in a black box if I put it, this is 3-point starter it is called, interesting its functioning 3-point starter. It will have three-terminals what is inside this we will see that, but before that I am just trying to tell. One terminal is marked as A, another terminal is marked as a L, another terminal is marked as F that is how it will be there.

Now, your DC machine will be like this, it has got armature terminals A 1 A 2 and suppose its field winding has got terminals F 1 F 2 and you would like to connect some resistance in the field circuit which you will be able to control. If you want to control speed which I have not discussed yet, but generally an external resistance is connected in the field circuit, and you have to connect it as a shunt machine so, these two can be shorted, ok.

Now, this I will parallel it here, now in this starter I will connect it like this. This A I will connected to one of the armature terminals, this F means field terminal it should be connected here and this L will go to supply line and this of course, is to be connected to negative supply like that it is to be connected L F A, understood.

Then what happens is this in this starter here physically it will be like this, it is a black box only, but here you will find there will be an handle provided where it will be written off, where it will be written on sometimes here. So, what the operator has to do is this he

has to when it is off it is disconnected he will move this point gradually like this and ultimately come to this point.

There will be several starts here, it will come to on and he releases his hand, removes his hand machine will continue to run and if supply goes off. He has to do nothing what will be automatically achieve is this, this handle it will come back to this position immediately when supply goes off that is the protective feature it takes into account. Now, the big question is, what is there inside this box? It is like this very interesting in no doubt.

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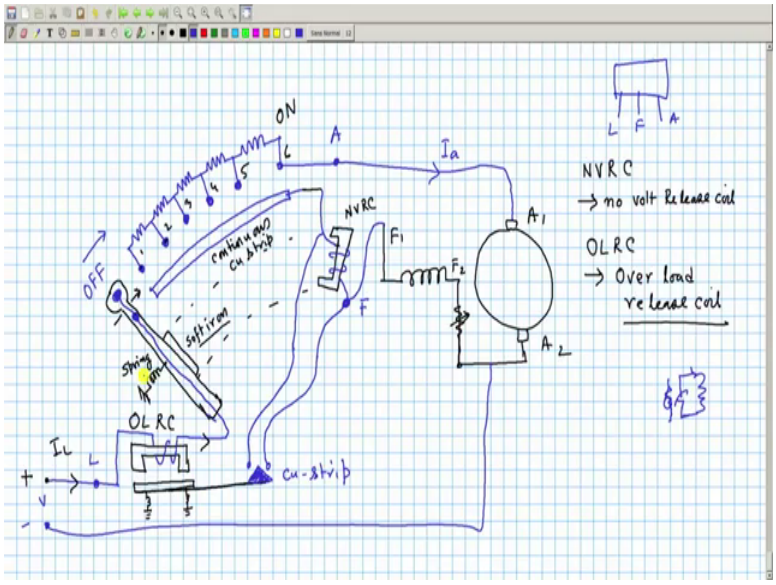

And suppose this is your armature ok and this is your field winding and these two as I told you then there may be a field resistance connected then this is on a fixed terminal; this is your F 1 this is your F 2 and this is A 1 this is A 2 and here are the supply terminals will be here suppose plus minus.

Now, what is done is this, there are several resistances like this, and from the junctions of these resistances there are some copper strips comes out; these are copper strips thick copper strips these bullets are copper strips. So, several resistances are there and it comes like that. And from this whatever comes out is your that terminal A from the starter, from the starter three-terminal will come out A, F and L as I indicated earlier. So, it is this A coming from the starter, I am drawing that box inside what is there. So, this is the armature thing, [FL].

Now, what is done is this, there is a handle here which is insulated from all the electrical connection because some operator has to move in as I indicated. Now, what is done is this, this part is very interesting here there is a small electromagnet purpose of this will be very clear like this, ok.

Now, this supply is here suppose plus and from this I will draw this with blue wire this wire and this is marked as L of the starter, it goes to supply I told you and this electromagnet a small electromagnetic is present there, it will go there and or very little turn it comes like this and then this wire is this electrical wire is taken through this handle inside got the point black one you will touch externally. So, this electrical wire is taking here and it will be terminated on a copper strip. So, bullets are all copper strips thick copper strips [FL] this is the thing you bring it here [FL].

There will be another copper strip slightly below it and you have a thick copper strip here, this is also copper strip continuous in the form of an arc. You can easily see when I put the handle move the handle maybe moved like this way, if you move it this way it can be moved. If you move it this point will touch this and this point will make this strip life and this position is the off position of the starter, it will make it life it will make it life. Now, this from this copper strip comes out your field terminals, [FL]. In fact, it is there is another electromagnet here which is I will be showing it like this, ok.

So, it will be it is inside this starter and this wire, this wire comes out like this, it comes out and this terminal is your F terminal here. So, where are the three terminals A L F; A is here, L is here and F is here. Now, so field coil is to be connected there in the field that is what I told [FL], F 1 is to be connected to F, A 1 to A and this goes to supply ok. So, this is your F and this A 1 is to be connected to A and these two points of course, you have to connect to the negative supply negative of supply voltage, this is the arrangement, [FL].

Now, the interesting part is this one; so, this is the handle blue one is the wire. Since, these are electromagnets it does something what for we have connected, there is small iron connected below it. So, that when sufficient current close it will be pulled up, it cannot remain in just like that whenever there is an electromagnet there will be spring. So that, when no current it occupies a particular position bull stone, similarly here this

electromagnet, there is a piece of soft iron attached to this soft iron piece, this is also soft iron; therefore, when this becomes electromagnet it will be pulled up ok, it is like this.

Now, let us see how the things will; forget about this electromagnet first I will tell you, but now suppose these are the position of the start 1 2 3 4 5 6. What the operator will do, he will start moving this one from left to right. The moment he comes here your armature gets supply with this external resistance connected in series with the armature; similarly, your field also will get supply this is life. So, both I a and I f is present. So, so electromagnetic torque will be developed, machine will start running.

Now, the operator what he will do he has to cut out the resistance, he will move from stud number 1 to stud number 2, then to 3 as machine picks up speed, then to 4 5 6 finally, it is here. And, when it will be here this soft iron piece we will get engaged with this therefore, this electromagnet will attract this fellow and; obviously, there will be a spring here. So, the force of this electromagnet and this spring force this spring will be stretched, they will keep it in that position it cannot be without any spring these are spring no inductor spring, understood.

So, it goes there it will get engaged your motor will run there. So, in position 6 it is on position gradually, you go all external resistance now disconnected only R a will limit the current and machine has gained enough speed. So, that you do not worry about the starting current. Now, the value some of these resistances then can be selected from as I told you the rated current I would like to pass through the armature at the time of starting and things like that.

So, when the motor will be running this handle will be in this position and this soft iron piece is here like that and everything is fine. Now, the purpose of this electromagnet will be immediately clear, suppose the supply goes off this becomes 0. If the supply goes off, this field current will also vanish and if this field current vanishes spring will bring back this handle from this position to this position immediately I mean no time lag, that is why this coiled is open called NVRC.

NVRC means no volt release coil; no volt no supply voltage no volt release coil it will release the handle to come back to off position. Therefore, there is nothing left for chances that once again it must come back to off position that is what I want because then when supply once again comes in there is a for few seconds supply goes off then it

will come back by that time. So, one knows pretty well one has to go through the same process to start this. So, this is called NVRC.

Now, what is this fellow doing, this electromagnet what is the purpose? This electromagnet is like this it its name is OLRC; OLRC called the Over Load Release Coil; Over Load Release Coil. What is it every starter for any motor induction motor or DC motor apart from limiting the starting current it will have some protective features. For example, one protective feature in case of DC motor is; obviously, must be there supply may go off anytime you do not know. So, NVRC takes care of that; it protects the motor from restarting with full voltage, ok.

Overload release coil it is also an electromagnet and this you know is essentially the sum of the armature and the field current this current in a shunt motor. This current is what? Line current. Line current is what? It is equal to I a plus this is continuous copper strip; this is continuous copper strip field current in any case much smaller than armature current. So, this is the major of armature current; armature current is decided by whom by the load present on the shaft of the motor suppose there is an overloading takes place in the motor, then also you would like to stop the machine is not you have to you would like to stop the machine.

So, what you will be doing is this, but you want to stop the machine with the help of the starter, how it can come to a stop? It can come to a stop provided the handle is released from this fellow it will come to off position that is what you need to do, how this can be done, it is done so nicely. What is done with this armature you imagine there is a handle extended handle and there is a copper strip here it is attached to this a thick copper strip.

Thick copper strip is attached to this handle, what all you have to do is these to bring back the handle from the on to the off position quickly somehow you have to de energize this coil. If you make this current in this NVRC 0 you are just assured spring this spring will bring back this handle to the off position that is what I want.

So, what is done is this a little bit of wiring is done, you from this h and from the two terminals of this NVRC you bring these two terminals here. So, that it is not touching this two when normal condition prevails up to rated current, the force is not sufficient to overcome the spring a spring tension to pull it up.

So, these two are open circuited normally open condition and therefore, everything is fine it was working. Now, suppose this current exceeds to a large value because of overloading or whatever reason then what will happen, this force of this electromagnetic we will pull up this soft iron piece up and it will go up and we will touch these two terminals.

So, how can you make current through a particular coil 0, two ways you can do; you remove the current from the coil or you put a short circuit across the coil then all the currents will be bypassed, this is precisely what is done here. Everything is working fine, started the motor on position then overload takes place what do I mean by overload, when this armature current becomes pretty large above the rated current.

In that case, this current will be also be high and it is so designed this gap, it will be pulled up before that spring was preventing that it will go up, this copper strip will go up it will short circuit these two points. Therefore, this field current will now has to flow like this, but the moment it does so, this current becomes 0 and if this current becomes 0, it cannot keep this handle in the on position spring will bring back this handled to off position.

So, you see this is a very popular starter, it was used a considerably I mean earlier days or even in some old establishments, you will find this sort of starter is connected and it gives you two protections; one is no volt protection supply may go off anytime you do not know. So that, no one can start the motor without connecting this external resistance this is R a external, R a external. It will be released that is why, it is called overload release, no volt release coil it is in series with the field current.

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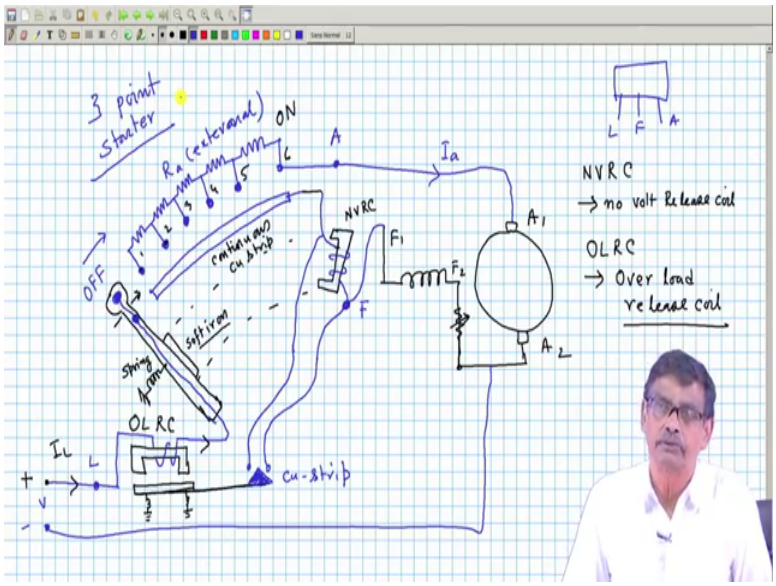

There are improved version on this there is a four point starter we will not discuss that I mean no point. In fact, what happens is these two this I will mention at later stage, at least one starter you have got some idea because this is very interesting to know how electrical electromechanical systems can be used so efficiently, it is a very robust starter do not worry about that. And so 3-points starter it is; 3-point starter for shunt motor. So, I conclude today and we will continue with then speed control of DC motors from our next lectures.

Thank you.