Electrical Machines - I
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Lecture - 80
Speed Control of Shunt Motor – I

Welcome to 80th lecture on Electrical Machines I and we were discussing about DC motors particularly, shunt and separately excited motor for the time being. And last time I told you that for any motor there are at least 3 things we should have ideas; one is about the starting of the machine, then the speed control and then electrical breaking.

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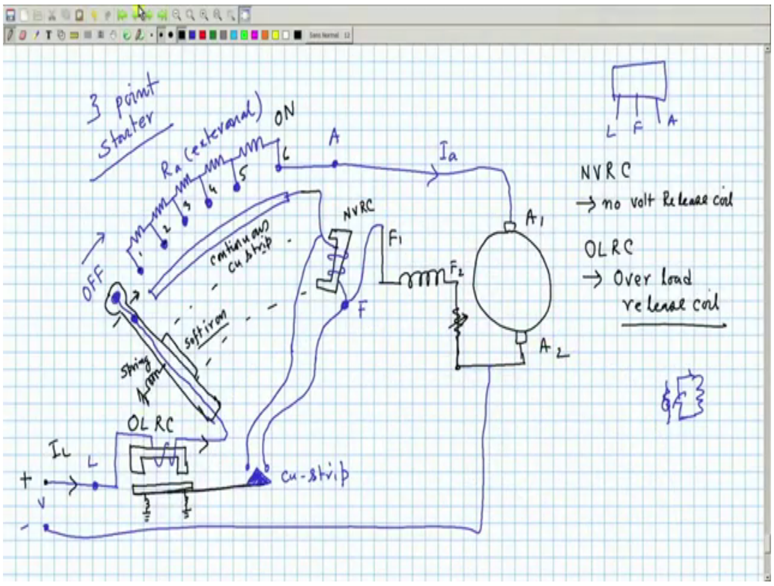

Last time I told you about a very popular; it is to be a very popular starter for shunt motor. The ideas were given starter is a device which protects the machine from very high current drawn at the time of starting, because of the absence of any back EMF. So, you insert a resistance in series with the armature, then gradually cut out and finally, it will be running with full voltage across it is armature and field supply.

In case of any overload takes place this electromagnet will take care of that and if under voltage; under voltage or no volt phenomena takes place then this electromagnet will work, I think we have discussed that.

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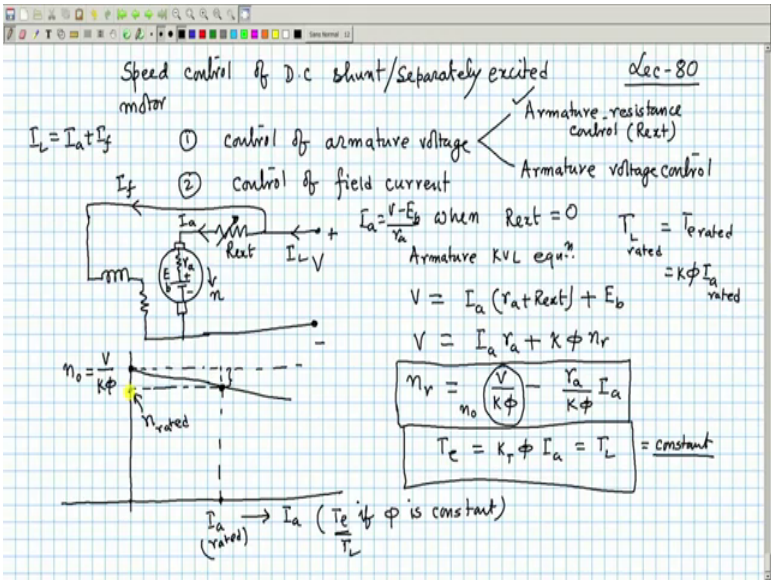

Today we will study this speed control aspects, speed control of DC shunt and separately excited motor; separately excited motor, right. In fact, DC motors were very popular in fact; so, far as speed control of the machine is concerned. Earlier it is competitor was I mean, induction motor could never compete with DC motors so far as speed control thing is concerned.

Because, of the fact in earlier days it was only 50 year supply available, speed control of induction motor was difficult either you use multiple separate stator windings to produce different number of poles and complicated; induction motor was considered to be a constant speed motor. It was DC motor where we will see right now that speed control can be achieved rather easily and smoothly without practically any complicated circuit arrangements that is the thing.

So, first to we will discuss about and basically the speed control are of 2 types. So, one is a control in the armature circuit, control of armature voltage and two, control of field current, control of field current. Now, control of armature voltage once again there were two methods; one is the armature resistance control, armature resistance control or armature voltage control.

Field current of course, you control the field current of the machine so, this armature resistance control means, you connect some R external in the armature circuit and vary it speed will change. Now, let us first try to understand this method let us see what is going to happen? Suppose you have a shunt motor like this and here is the field circuit and when I will be controlling the armature resistance I will not touch the field circuit, field current will I will keep constant it means that.

So, this is the thing. This is your field circuit and here is your external armature resistance; R external and with R external I connect these two in parallel and here is the supply given to the machine, ok. And this R external resistance I will make it variable so, that machine will operate at different speed [FL]. First of all when R external is 0 that is no external resistance is connected, but machine has it is own r a inherent armature resistance.

When it runs with some speed rps, then rps or rpm whatever it is; the basic equation how speed is related with various quantities is governed by the armature KVL equation, ok. Armature KVL equations; which is equal to the applied voltage across the armature this is I L line current drawn from the source and this is connected in parallel, this is field current and this current is the armature current Ia. And, we already know that I L is equal to I a plus I f applying KCL at that point, ok.

And, this is your back EMF. E b this battery with this polarity; therefore, KVL equation in the armature circuit we have written many a times is equal to V is equal to I a into r a plus R external plus the back EMF E b let me write it and since I am taking R external to be 0, it is equal to I a r a famous equation. K some constant into flux per pole into n r; this I could express in terms of omega r also in any unity you like you represent it.

Now, this is the applied voltage to the machine; applied voltage is the related voltage of the machine. Therefore, I will say that n r will be equal to V by K phi minus r a by K phi into I a. This is the speed, how it depends on armature current, how it depends on armature resistance and how it is depends on field current? Are all represented here in this equation that is the thing. Now, suppose what is this armature current? The value of the armature current we know is decided by whom? Decided by the mechanical load you have put on the shaft.

More the opposing torque, electromagnetic torque is to be made higher therefore, more armatures current will be drawn and in the steady state low torque is equal to electromagnetic torque. Therefore, if you increase the mechanical load torque on the shaft of the machine armature current will rise. If opposing torque is 0, then armature current ideally will be 0. Because no mechanical load is to be supplied; so, this is the equation.

The torque developed by the machine, electromagnetic torque developed by the machine; is some I will write some K T, I do not know whether these two constants are same or not we can decide into I a. And that is equal to is load torque; more the load torque is phi constant I a will be more for steady state operation. So, this is the these are the two equations we will be using to understand how speed control is achieved in a decision motor.

Now, suppose with R external 0 if I want to sketch; how speed varies with respect to armature current? If phi is constant, then this also will represent electromagnetic torque, if phi is held constant is not is constant; I will not touch the field circuit that is the thing. Therefore, the speed of the machine when I a is equal to 0 is equal to here that is V by K phi is not; that is the no load speed which is equal to suppose some n 0, no load speed with I a equal to 0 whatever is this speed.

Because I know if I a is equal to 0 E V is equal to b, then only I a will be equal to 0. I a is V minus E b by r a, whatever is r a. So, if so, V should be equal to K phi n naught at that time and note this is the no load speed. Now, if you go on increasing the shaft load torque, then what will happen? This equation tells you that speed will drop this is your n naught, this factor is your n naught.

No load from that it will drop it depends on I a and it will the slope of the line depends on r a which is small; therefore, the variation of speed may be like this as the load torque or armature current is increased, the speed will droop have a drooping characteristic. And that drooping characteristics will be like a straight line as this equation suggest, c equal to mx. What will be the slope of this line? Slope of this line is decided by r a by K phi r a is small therefore, it will be small.

Suppose the rated current of the machine is this much, I load the machine go on loading the machine, go on imposing more and more shaft load torque armature current will rise. Of course, I should not exceed its rated current suppose you reach the rated current; at that time the machine is going to run at this speed, suppose the rated speed it is, n rated nominal speed of the machine is this much.

Therefore, what we observe here that if a DC shunt motor; field current is held constant, R external is 0 then from no load to full load speed will change by this much amount and this amount is very little, because of the fact r a is small, had r a would have been 0 then it would have remain same. Therefore the change of speed from no load to the full load condition is called the speed regulation of the machine. And, in case of shunt motor the change of speed from no load to full load is only little, if you do not touch field current therefore, it is called a constant speed machine.

And, this is not the speed control it is the naturals speed change of the machine as you change the degree of loading that is all; this is not speed control it is [FL]. Now so, we have now understood that how speed drops from no load fixed value to the rated current condition which is very little and that is why some sometime shunt motors are also called constant speed motor from no load to full load variation of speed is little, ok.

Now, what is speed control means? Speed control is when the machine operates at this rated current it is supplying some mechanical load, how much is that load? T L is how much? T L rated it must be equal to T e rated, which is equal to K phi into I rated is not; this is the load torque. T e steady state operating point is nothing, but also load torque here therefore, this axis could be I a as well as representing your load torque this much is the load torque, this much is this speed.

Now, by speed control I mean, suppose opposing load torque is constant, can I run it at different speed. Got the point I will keep this load torque constant, suppose load torque constant it is now running at the speed, load torque remaining constant can I run it at different speed that is called speed control.

Of course, so, you will see that we will remove this restriction clearly is constant later, but what understanding first let us assume, the load torque on the shaft of the machine is constant and I want to run the machine at different different rpms; the answer is yes, I can do that. What I will do? I will connect an external resistance.

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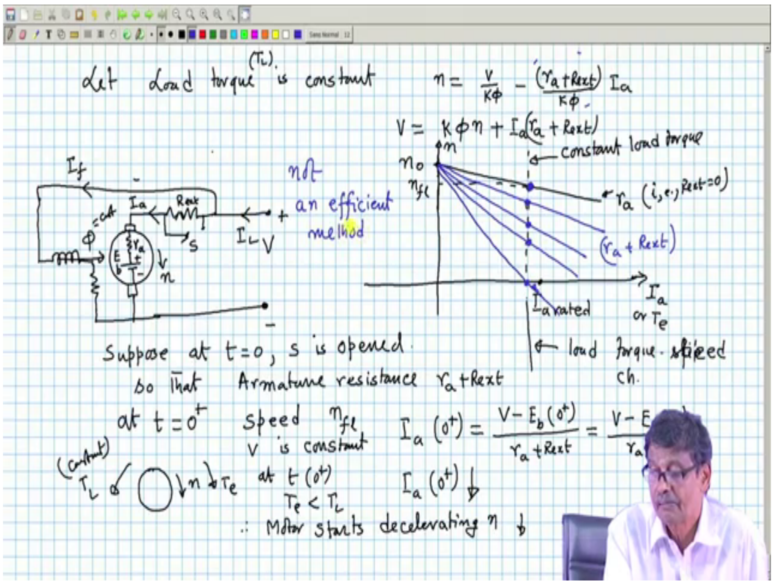

So, let load torque is constant, ok. Load torque T L and this is the circuit diagram, I will just take this circuit diagram here so, that I do not have to do. So, this is the same diagram let me put it here and armature and field. Now, I will not make R external 0, suppose machine this is the general equation of the armature voltage V is equal to K phi n plus I a r a. And, will r a plus R external. Now, let us try to understand why speed will change rather physically what is happening?

You just see that, suppose this R external I will make a circuit like this; there is a switch here like this and this switch is closed initially this is your R external, you have switched on of course, taken care so, that the starting current is limited and all this things, but finally, the machine has to run with full voltage, but this is shorted. Then what will be operating point? Operating point will be here this is the no load speed, it changes this is suppose I a rated and machine is running at this speed, is not.

This is r a with ra this is the characteristics why? Because n we have seen that is equal to V by K phi, this is the basic equation. Minus r a R external in general divided by K phi in to I a this is the thing. If and this characteristics is with R external 0 that is R external is equal to 0. Now, what I will do is this? So, machine is running at what speed now? With this switch on, with the load torque present on the shaft, this is I a or torque.

So, this is the load torque, this line is also load torque, constant load torque. And, this axis is speed axis speed this is no load speed as I told you (Refer Time: 21:59) and this is the full load speed; with no external resistance so, the intersection point of intersection of the speed torque characteristics of the motor and load they decides what will be the operating point now? It is this point this is the load torque and load torque demand is constant no matter what is this speed it has nothing to do with your motor.

It is the characteristics of the load; that means you want to run that load at 100 rpm, whatever torque will be required same torque will be required; if you want to run it at 500 rpm and so on. So, a constant load torque; so, this is the load characteristics, load torque slip characteristics. So, a constant load torque.

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Torque speed sorry torque speed no slip. So, so this point of intersection is this one that is all. Now, you imagine listen carefully, first mathematics live it a side suppose now it is running fine at this rpm I open the switch. So, that R external is suddenly inserted into the circuit the switch is opened. So, armature resistance will change instantaneously from the values small r a to the new values small a plus R external it will change, can speed change instantaneously no, it has got a inertia, supply voltage is held fixed.

Therefore, suppose I write it like this suppose; at machine is running steadily at this point at t equal to 0 that time, s is opened; s is opened, switch is opened. So, that armature resistance suddenly becomes ra plus R external. That is at t equal to 0 plus after you have executed this immediately after that what is happening?

Armature resistance becomes this. Speed will be how much at t equal to 0 plus? It will be same as a n f l, speed cannot change instantaneously so, this is speed. Supply voltage is of course, fixed. So, V is constant all along so, at t equal to 0 plus also it is V. Therefore, the armature current at time t equal to 0 plus, this will be this supply voltage minus the back EMF at 0 plus divided by r a plus R external is not this will be the thing.

Can E b changed at 0 plus. No, because at t 0 plus speed remains same and phi is constant I have not touched field circuit phi is constant. Therefore, E b 0 plus will also be same as minus E b 0 minus divided by r a plus R external. So, what thing will change? Denominator for the armature current; so, I a 0 plus must drop down armature current immediately decreases.

So, in the machine at t equal to 0 plus if armature current decreases electromagnetic torque which is product of field current and armature current flux and the armature current, electromagnet torque will decease and load torque I am telling it is constant. Therefore, at t equal to 0 plus situation is like this; this is the motor, this is suppose the direction of rotation, this is the direction of electromagnetic torque in case of motor and this is the load torque T L in opposition.

So, at t equal to 0 plus I find there will be an upside between T L and T e they will not balance at t equal to 0 plus. In fact, t e at t equal to 0 plus, T e will be less than T L. T L is held constant mechanical load, that opposing torque I will not change. Therefore, what the machine is going to do? Machine will decelerate therefore, machine will start decelerate after t equal to 0 plus.

So, motor starts decelerating that is speed starts dropping from n f l at t equal to 0 it remains n f l, but then it starts dropping it has to n f l decelerating that is speed of the machine will decrease will start decreasing. Now, if speed decreases flux constant so, this I have I am not now changing, ra plus R external I have kept it. So, back EMF must decrease, if back EMF decreases armature current which became less at t equal to 0 plus must increase or decrease must increase.

Therefore, if I a increases a time will soon come, it will draw n f armature current such that electromagnetic torque becomes once again equal to load torque therefore, at what value of armature current? Once again this two will be fixed once again the same armature current which was flowing under steady state condition before you inserted this R external.

So, finally, the armature current will not change of course, during that dynamic process if you want to analyze what is going to going what is going on when you have suddenly inserted an R external? The thing is that cannot change instantaneously, back EMF remains same, supply voltage is fix. Only thing resistance in the circuit is increased; so, V minus E b divided by R external plus ra so, current will decrease, if current decreases the electromagnetic torque decreases.

So, load torque becomes more than electromagnetic torque at t equal to 0 plus machine will decelerate it is speed will fall. And, if speed starts falling, then once again armature current starts increasing because V minus E b by ra plus R external is the current.

And, you do not told leave it to the motor; motor will see it is new operating point; it will stop further decrease in speed. Once K phi I a is equal to T L. Therefore, in case of armature control, the armature resistance control method of speed control by armature resistance we note one interesting thing; that armature current in steady state in between it might have changed as I have explained to you. In steady state once again it will draw same armature current; because phi you are not touching and load torque is remaining same.

So, it will be running at reduced speed, but supplying the same load torque. Now, what about these characteristics now? Now, let us come to this characteristics, so with external resistance incorporated in this characteristics will be like this, because slope of this line is decided that I have increased ra plus R external by r a.

So, R external here it was 0 and this is with r a plus R external. Therefore, operating point load torque will be here and a you see this is I a rated as sorry so, this point is I a rated suppose so, it will run at reduce speed. So, this is speed control, ok. You are supplying same load torque, but at reduce speed therefore, you can draw a family of curves if you have connected slightly less armature resistance operating point would have been here.

Increase the armature resistance it will be here. So, speed can be controlled very smoothly just control this R external. In fact, you can control up to the 0 speed to the rated speed supplying this same load torque, very low rpm to rated rpm for a constant load torque present on the shaft of the machine. Very smooth thing here just control this resistance only thing you have to connected external resistance there.

Only one point I would like to tell that this method is not at all efficient method, because of what? Suppose the rated current you have purchased a DC motor, rated current of the armature is suppose 20 ampere you will always love to see the armature current is maintained 20 ampere suppose it was operating here with no external resistance how much current it was drawing?

20 ampere. As you go on connecting external resistance still armature current will be 20 ampere drawn and you will love it ok, I have spent money and this motor is capable of carrying 20 ampere armature current, then let it carry 20 ampere all along that is very good, 20 ampere. But that rated current will cause extra power loss in this R external.

So, the system becomes very inefficient I square into R external, rated current square into R external is not. Therefore, this is not an efficient not efficient at all, not an efficient method. We will continue with this in the next lecture.

Thank you.