Electrical Machines - I
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Lecture – 85
Introduction to Series Motor

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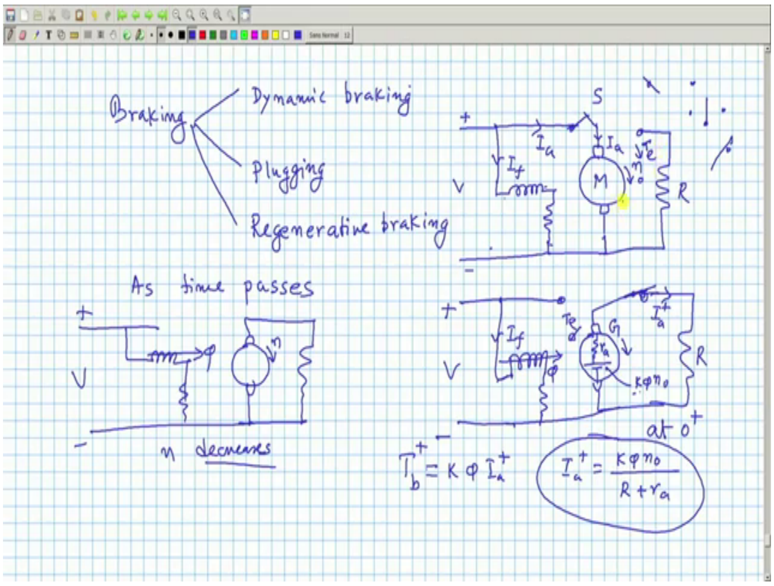

Ah. So, we have been discussing about electrical braking on DC shunt or separately excited motor. In DC dynamic braking what is done? Is armature only disconnected, it is running as a motor initially. Then only armature is disconnected from the supply.

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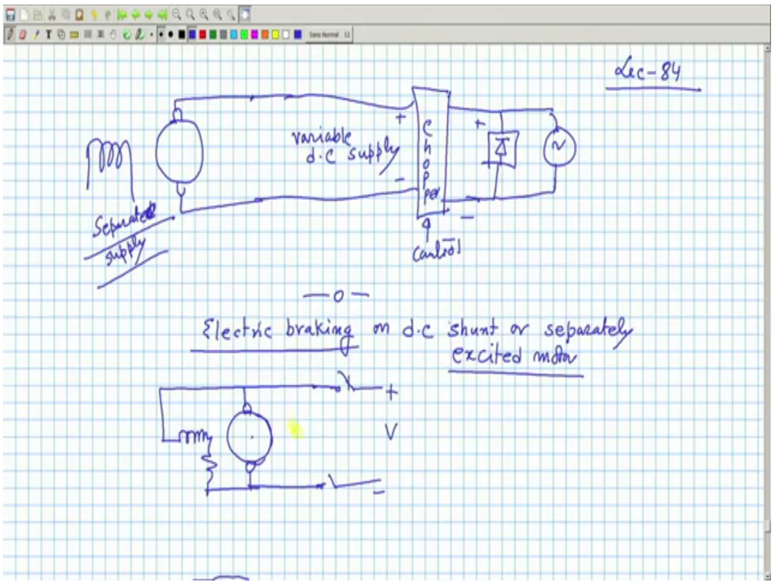

Armature is only disconnected from the supply, with this switch and connected across that resistance. Then eventually I know what would be the factor. The direction of the armature current then will reverse armature current will flow this way. Electromagnetic torque developed will be opposite to the earlier electromagnetic torque. So, it is like you are braking the motor.

You must apply an opposing torque in the direction opposite to the direction of rotation for executing braking. And I told you how to calculate the braking torque at t equal to 0 plus. In case of dynamic DC dynamic braking highest braking torque will be at t equal to 0 plus. Then speed eventually falls back emf decreases the braking torque is in itself is a function of time it gradually collapses to 0. But in this case flux is maintained ok.

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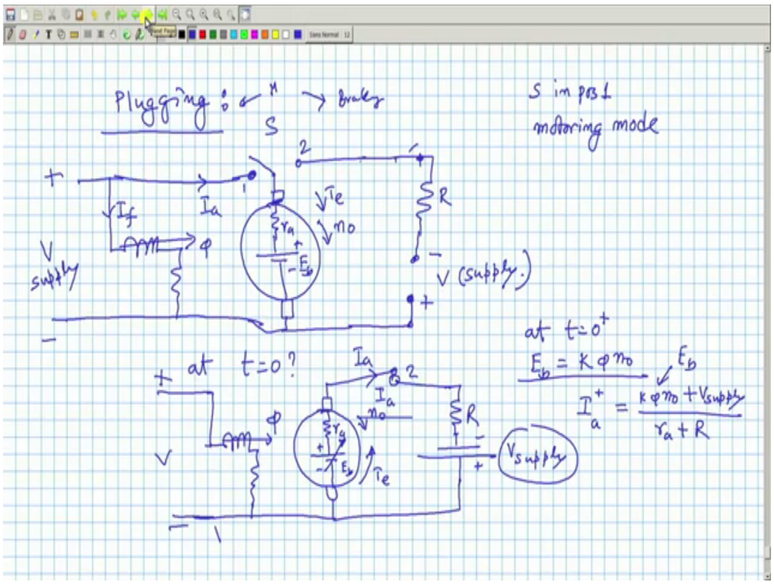

An improvement if you want to bring the machine much faster than the DC dynamic braking then what you do? You make an arrangement right hand side arrangement is almost similar to that. Except that along with this R, you connect a source say same supply voltage you bring it here. And the polarity of this source should be properly with respect to this E b it must be properly connected.

So, that E b and V together acts in the same direction so, at t equal to 0 plus. Here the current at t equal to 0 plus will be much higher than simply K phi n naught by R a plus R plus V supply be lead larger braking torque will be developed. Because there are machines with large inertia you want to bring it to stop quickly such a method should be then adopted. And in this case also field you have to maintain. If you also disconnect the field it will not work because flux will collapse E b will collapse. Of course, got the point phi into I a is the torque.

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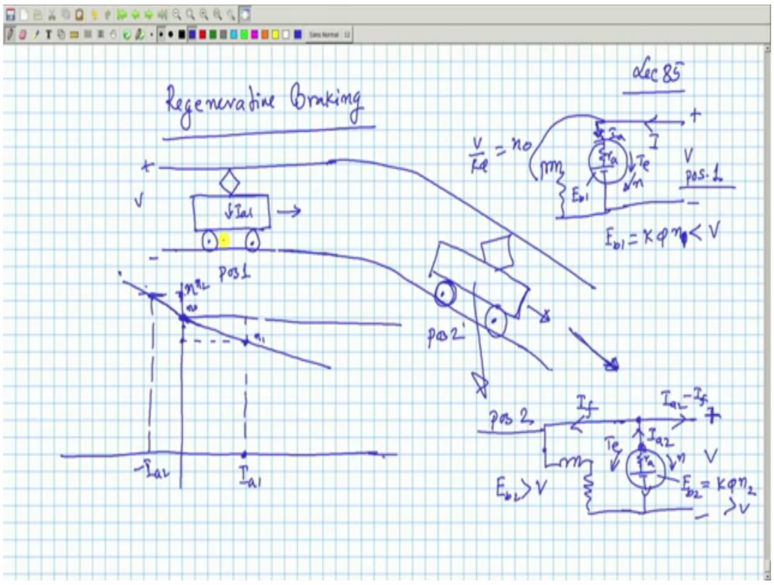

So, the another method is there that is called regenerative braking ok. Here the idea is interesting. In a previous cases, what we did that initial that kinetic energy stored is dissipated in R, is not? Ultimately eventually it is dissipated in R. So, it is like this in regenerative braking what happens is this that, braking will take place but really not for bringing the machine to come to a stop. Let me tell you one thing for example, you see that there is a track here ok. And you have a logo here and the motor drives this wheels so, that it moves in this direction. And here is the supply lines and the negative is connected to the rails and the power is collected by a say pantograph or whatever it is supply. So, here is their DC motor you imagine it is driving this and it is moving smoothly on a smooth railway track ok.

Now suppose. So, it is running as a motor, giving I mean moving this vehicle or logo from left to right a DC motor is driving the wheel. Now so, in normal case when it is on the flat track it will run as a motor fine. Now, you imagine that this track is has got a slope like this ok. This is the supply lines v and your vehicle comes here.

There is a downhill in the track and your this thing this is the wire this will be the scenario, when it negotiates. This downhill and it will still moving in this direction. Now, when it was moving on the flat track, then the electromagnetic torque developed by the motor is also equal to the opposing load torque present on the machine. And let us imagine it is a shunt motor but the moment it comes to this portion of the track which is having a ramp down here.

Then gravity m g whatever it is its weight there is a additional force will come, which will accelerate the rotor apart from the electromagnetic torque whatever is acting. But there appears an torque force or torque because of the component of the gravity present. For example, forget about any supply connected, if you just keep a vehicle like this it will just accelerate in this direction.

Forget about your supply is not there a vehicle put on wheels you put it here it will on its own come down is not mechanical thing. Now, in such a situation what happens? Suppose when it was in position 1 this is suppose position 2 vehicle has reached. Initially we know that they that the machine is having a finite no load speed is not this is speed and speed varies like this.

So, when it was here, it was drawing an armature current I a 1 shunt motor. This is the speed versus armature current characteristics, it was running at this speed and running as a motor it was drawing an armature current. I am not showing the motor armature field here just to give you the idea it was drawing an armature current here and it was running at this speed; delivering mechanical power to move this vehicle or attraction.

Now, when it comes to position two what will happen is this, the speed of the rotor of the machines which are coupled to this wheel that will go on increasing accelerating, is not? Speed will go up, that is operating point will move here got the point it will move here speed will increase. A time will come when speed this is the no load speed.

How much is its value? V by K phi is equal to n naught we have seen that ok. I will draw it straightly and nicely. So, I am now telling its speed increases beyond n naught because of some external as if sort of prime mover is present. What was the circuit here? When it was on the flat track, it was like this r a back emf and your supply V and it was drawing a current I a.

And let us imagine separately excited machine or whatever is shunt motor also no problem field is always connected like this is position 1. And not this is not I a it was drawing this current and your I a was this motoring mode. Electromagnetic torque in this direction of protection was in this direction this is position 1.

Now, in position 2; position 2 what will be the scenario? Scenario will be this is the field, this is the armature, supply voltage is still v here. And here is r a and here is your back emf in series those things remaining intact. But this back emf was proportional to k phi into whatever was the speed here n 1 like that that was the back emf. And the it was less than supply voltage that is why current was flowing in this one v minus E b by r a.

Now, I have a situation where in this zone maybe this speed has gone up to higher value, such that this back emf E b 2. This speed has become greater than n naught it is k phi n naught or n anyway n 1. So, E b 2 it has become such that speed has become k phi n 2 speed is higher at this point n 2. And which is greater than v; then what will happen field current will remain in the same direction nothing like that v by E r f, but your armature current will reverse, is not?

Because this voltage minus v divided by r a is the new armature current E b 2 is greater than supply voltage it may so, happen. Because it was accelerating like this and your I a 2 reverses. And as I told you the moment I a 2 reverses it was moving in this direction electromagnetic torque developed by the machine must reverse because I a 2 has become like this.

So, operating point has become so, it is minus I a 2. And therefore, an opposing torque comes in and your machine will then experience a opposite torque opposite with respect to n. Therefore, braking takes place ok, but it will not bring the machine to stop what it will do? It will find a another operating point doing like this, but it will do one very important thing.

It will not make this vehicle uncontrolled I mean like a free fall mg sin theta will accelerate it down. It soon will find a final velocity I have done the initial no load velocity no doubt, but the it will stabilize the thing. So, regenerative braking will put free acceleration not possible I mean will not make this free acceleration possible it will but none the less the it is braking got the point.

So, this is called regenerative braking why regenerative? Because in this case one interesting thing happens that the this current this power will be fed back to the supply I a 2 will come and I a 2 minus I f whatever it is here if we apply k c l that will flow to the positive terminal of the supply. So, power will be fed back to the supply. So, kinetic energy whatever will be lost or gained there is no loss of power no external resistance connected.

Therefore, regenerative braking means that the machines speed when it becomes greater than the no load speed of the machine. A natural reversal of current in the armature will take place. And it will produce torque in a direction opposite to the direction of rotation of the machine. And thereby some braking torque will be produced.

Now, once again I am telling it will not bring the machine to a stop. So, regenerative braking are very interesting method of temporary braking which will not allow the rotor to accelerate freely just like that. And at the same time the power will be fed back to the supplying clear. So, there are interesting problems on this you can try solving.

Therefore, these are the three methods, which I have not gone much detail into it for obvious reasons, but you get the idea what it will be. Just use very basic principles of motor generators see the direction of the torque develop and in this case also field flux is held fixed here nothing like that.

So, there are interesting problems in the book of parker smiths will point them out in our handouts you try to solve them ok. Now, today I will give you after discussing about the electrical basics of electrical breakings. I will tell you about another kind of motors which are called series motor, DC series motor ok..

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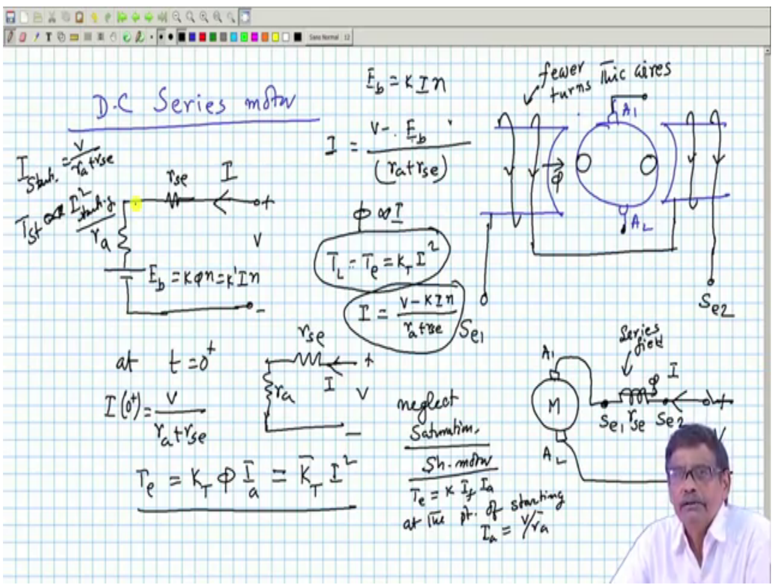

Now, there is a kind of motor, where this was the armature is not in our basic structure is same these are the poles., this is A 1, A 2 armature. Now, this field coil will be very few number of turns, but thicker wire ok. First let us see the construction this is the field coil on each pole it will be connected like this.

So, these are called and these two will be connected in series. These are connected inside the machine and these two terminals are marked as S e 1 and S e 2. So, fewer turns thick wires. In case of shunt machine there were large number of turns thin wires and these two are as usual the armature terminals.

So, this machine in the simplified diagram can be drawn like this. This is your armature two terminals; A 1, A 2 and there is the two terminals S e 1 and S e 2 and while connecting this machine this armature is connected in series with the field. And here supply will be connected to run it as a motor got the point. So, in this case there is no shunt field coil there is only one coil with very few turns because everything comes in series with the armature must have very low resistance ok. And here I will connect the supply that is the thing.

So, I can make a motor like this and I will connect it to the supply so, but because of these will the all the derivations that we have done back emf torque will change no not at all. Here what is important is this is the flux per pole, this is the armature current these two will decide everything. Flux per pole whether it is created by a series field coil or shunt filled coil armature does not care about that.

If it is running it will develop a generated voltage k phi n that remains. It will be able to produce an electromagnetic torque, that is proportional to k phi into I a that is all. So, so far as the basic equations are concerned flux per pole is now merely created by some coil which is conditioned like that there connections etcetera. And also note that, in this case the armature and field current they are same this series field.

Armature and field current are same. So, no point in distinguishing between I a and I f they almost becomes same ok. So, I will be connecting here. So, there will be a series field resistance r S e and here is the motor armature flux per pole will be created as usual flux per pole. And this armature circuit will then look like and r a with some back emf.

And here is some r S e in the electrical equivalent circuit I am telling. And there may be brass drop as usual this is the supply. And this is the current drawn by the machine and this is your back emf [FL]. Let us try to understand it from the very beginning. Suppose you have a switch here this I will tell verbally by this time I hope you understand what I am telling suppose machine was at rest.

And I have closed the switch at t equal to 0 plus how much will be the current drawn machine was at rest there was no back emf. Back emf is k phi n in this case flux per pole is also proportional to I; that I know it is equal to some k dashed into I into n; because phi is proportional to n at t equal to 0 plus. So, when you close the switch machine has not started yet rotating at t equal to 0 plus it with the equivalent circuit will be r a, r s e and your supply.

So, current drawn at I 0 plus will be equal to V; divided by r a plus r s e that is all this much will be the current, but machine has not started yet. So, no back emf is there. So, equivalent circuit at t equal to 0 plus is just like this. So, a finite current which may be very large because armature resistance are small r s e is also small will be drawn in from the supply.

And will there be electromagnetic torque developed? Yes. Because electromagnetic torque is equal to some k t into phi into I a which in this case will be some k t other constant I square that is all. So, electromagnetic torque will be developed and machine will accelerate it is there. Now, as machine accelerates that is the n increases E b increases back emf will appear.

Now after machine starts accelerating. So, this is the circuit I have to refer to get the current. So, I a will be v minus I a into r a plus r s e divided by no, v minus E b is not v minus E b let me write E b divided by r a plus r s e this will be the current as machine picks up speed. What is E b? E b is equal to sum k into phi neglecting saturation field current is same as the current drawn I so, k I n.

This will be the current this is also I a and E b depends on I this is to be noted. As machine picks up speed E b increases, but I also decreases is not. Now the question is what will be the final steady operating point? Machine speed will go on increasing and it will try to settle down steadily at some point, where the load torque will be equal to the electromagnetic torque developed by the machines.

Suppose there is opposing torque present. So, T L should be equal to T and that will be equal to k T into I square electromagnetic torque is this one suppose my machine finally, settles down to this. So, at the final steady state operating point it will draw some armature current. And what is your I? I will be at that time is equal to v minus that steady state current that is E b is equal to k phi I mean k I v minus v by r a plus r s e.

This will be these two equations, then because flux is proportional to I neglect saturation; neglect saturation. So, this is the thing now there are two three observations I must tell at this point, imagine a shunt motor. In case of shunt motor and suppose in shunt motor the torque is shunt, shunt motor these are interesting points you must note that is one is electromagnetic torque in shunt motor is k I f into I a is not electromagnetic torque development.

I f is v by r f it is no way connected to with I f. What is the value of at the point of shunt motor at the point of starting; the point of starting what is the armature current? Armature current will be v by r a only and I f is finite v by r a. So, armature current is large v by r a into I f gives you the starting torque. So, T starting torque will be this much.

Come to series motor; during series motor the starting current is K T into I square, but what is this starting current I starting in series motor is how much v by r a plus r s e, r a plus r s e is of the same order of r a. Therefore, armature current is very large in both the cases they are comparable v by r a it was there it is v by r a plus r s e. But the point I want to make it is that in case of series motor, this starting torque is proportional to I square.

Therefore, the magnitude of the starting torque is many fold highers than the starting torque of a shunt motor. Very large starting torque you can get how I am telling that because of the fact armature resistance and series field resistance are comparable. So, I starting in case of series motor back emf is not there v by r a plus r s e. And in case of shunt motor it will be v by r a starting current.

Torque is proportional to I f into I a, I f is finite which is small in case of shunt motor. So, a large quantity I a into a small number here. In case of series motor T starting is equal to k proportional to I square and this I is same as this I starting. Therefore, a series motor can produce a very large starting torque unlike a shunt motor ok, which is there are uses of this particular thing.

For example, I will today only tell this point and then next class we will continue. You suppose you imagine that, you have to crush some nuts hard nuts you have to crash with a say what it is called crusher something, at the time of starting their hard the nuts are. So, you will be requiring very large torque at that time ok. But after the nuts break becomes fine particles then you do not require large torque.

We will see that there are loads which require very large starting torque. For example, interaction a heavily loaded say wagon it is to be started. At the time when you want to start that locomotive which is fully loaded; that means, the opposite torque is very large already present on the shaft. But to make it start you must develop enough starting torque.

For shunt motor if you use it may not reached at one because I f by design is small I a may be large v by r a, but I f is small finite. But if you use a series motor, then large starting torque can be created v by r a plus r s e torque is proportional to I square. And it is indeed necessary when you want to start that locomotive which is heavily loaded fully loaded at the time of starting.

But as it accelerates and that and some finite speed do you require that much of torque? Certainly not in torque required to overcome the inertia is gone. Now, therefore, you will be requiring less amount of torque to run the locomotive at some constant speed. We will come to this point in a much more detailed way in our next lecture. But only thing I want to tell you that no matter whether it is a shunt and series motor do not forget those two basic equations.

Back emf equations v minus some I a r a drop in case of series motor which is I a into r a plus r s e minus maybe brass drop and that is equal to back emf. So, there may be different situations. So, when the applied voltage is the stork is this. So, what is the current run etcetera. So, I will write down in each cases the back emf equation and what else the torque equation t 1 equal to T L 1 for steady operations; and t 2 equal to T L 2.

And we will also see another interesting thing in the next class that a series motor should not be started with any mechanical load present on the shaft that is also another interesting thing. In case of shunt motor even if there is no opposing torque or load torque present at the time of starting you have a finite speed machine will go to that speed and will run.

But a series motor without any mechanical opposing torque load torque present. If you want to start the motor, we will say there is no finite speed machine is racing to a very large value creating problems. Those are interesting things we will discuss in my next class.

Thank you.