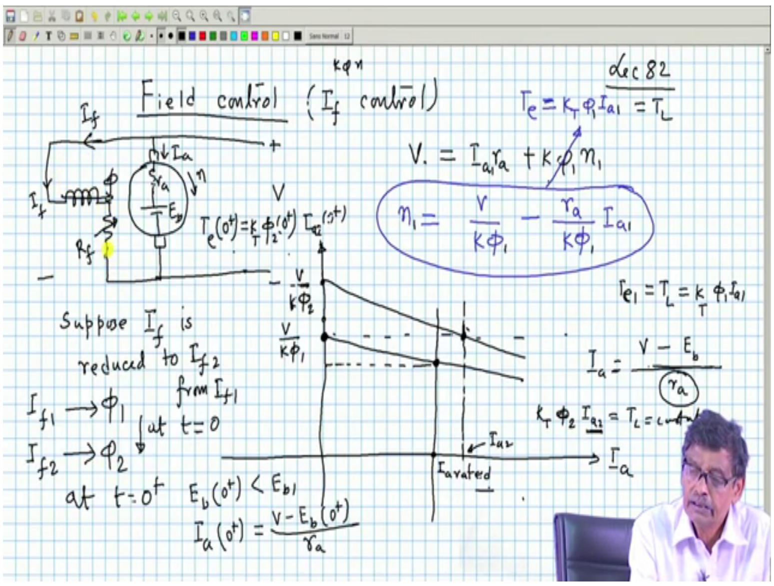
Electrical Machines- I
Prof. Tapas Kumar Bhattacharya
Department of Electrical Engineering
Indian Institute of Technology, Kharagpur

Lecture - 82
Speed Control of Shunt Motor - III

Welcome to this lecture and we have been discussing about the Speed Control of DC motor. We discussed in the earlier lectures, the speed control of the DC motor by controlling its armature voltage or by connecting some external resistances in the armature circuit. If, it is to be controlled by armature voltage method, then field circuit should be separated and, you apply a variable DC voltage. Armature registers control is inefficient, so armature voltage is a nice method and you can control this speed down to zeros very smoothly and this is done.

And, this method of speed control is most suited for the load, whose stock demands is constant at various rpm's that is what I told. Now, today I will discuss about another interesting method that is the field control.

(Refer Slide Time: 01:23)



Field control, that is also called I f field current control, I f control. And, I will also restrict our discussion till now on DC shunt motor or separately excited motor whenever it will be necessary. Since, you will be controlling the field current therefore, the circuit adopted is like this, this is your armature ok. And, this your field circuit, here I will connect supply and this is the thing these are connected parallel and here a constant voltage is applied.

This time, what I will do? I will control the field current by varying some external resistance connected in the circuit. So, that these flux per pole I will be controlling, ok. This is what I will do? [FL] In this case to understand first before I write down the equation, in the same way let us try to see physically what is going to happen. One thing is cleared here it is r a and e b, suppose the machine is running steadily at some constant rpm drawing some armature current I a.

And, field current is set to some values so, that it is drawing I f, field current. Now, in this case once again the equation remain same, you have to start with the armature KVL equation applied voltage. This time this armature voltage I am not varying so, b is equal to I a ra, ra also I will not play with no external resistance in the armature circuit, neither I am varying the voltage applied across the armature so, I a r a circuit plus K phi into speed. This time, I will be varying the flux this quantity I am varying and your n is equal to then V by K phi minus r a by K phi into I a this is the equation, is not.

And, remember the electromagnetic torque developed by the machine is equal to sum K T into phi into I a is not, no matter what you are controlling this is the rule for electromagnetic torque. Now, suppose I say that the machine is operating steadily, this axis is I a, I say and this is the speed. Suppose, field current was rated field current initially operating point, so that the no load speed was here suppose and no load speed was V by K. And, let us say that initial operating point all the quantities are like this I a 1, I a 1, phi 1 got the point, it was drawing and speed was n 1 say.

So, what I am telling machine is running steadily at some field flux say phi 1, speed is n 1, n 1, then applied voltage is V which is held fixed I a 1 r a plus back EMF from this I get these values. Therefore, at that value of field current, this characteristics if I draw, suppose this is the no load speed. So, it will be V by K phi 1.

And, then it is characteristics if you increase the current will be like this slope is r a by K phi 1. And, suppose it is the load torque; suppose, load torque is constant T L constant. Then operating point will be here and this is suppose and the speed at which the machine will be running way is this one, this is the thing, [FL] ok. Now, what we will be doing?

So, T e 1 is equal to T L and that is equal to K T phi 1 into I a 1 this is the equation it is running here.

Let us assume that this current whatever it is the rated current of the machine, ok. It is supplying intersection of the torque speed curve of the motor and the load torque gives you this 1 point of intersection. Now, suppose I suddenly increase this resistance field circuit resistance. Suppose, I f is reduced to say I f 2.

Initially it was I f 1, I f 1 produced flux phi 1. Now, I f 2 will produce flux phi 2. And, phi 2 will be less than phi 1, because I have increased this resistance r f applied voltage is fixed here because the field circuit. So, flux is reduced; reduce to field current is suppose I f is reduce to I f 2 from I f 1 got the point, this is the equation [FL].

Let us first observe or explain the sequence of events that will go on. Initially, this was the operating point phi. Now, suppose I have suddenly reduce the field current from I f 1 to I f 2 at T equal to 0. Can speed change instantaneously? No, that is the mechanical inertia decides that. So, at T equal to 0 plus which thing will change, flux has been reduced. Therefore, your back emf must have drawn back emf depends on the product of field current and speed.

So, if you suddenly say that flux has been brought down from phi 1 to phi 2 speed cannot change instantaneously that is fine, but flux you have brought down. Therefore, back emf which is K phi n speed has not changed must drop down. Therefore, armature current at T equal to 0 plus must go up is not armature current will grow up.

So, at T equal to 0 plus, what is T equal to 0? At T is equal to 0 I have this is what I have done at T equal to 0 phi 1 to phi 2. At T is equal to 0 plus I am examining E b to; E b 0 plus must be less than E b 1 that is all that is what I am telling speed cannot change flux you have reduce it will. If, that be the case then your armature current at 0 plus must go up because armature current is after all V minus E b at 0 plus divided by r a, r a I have not changed. So, the armature current will go up.

Now, the question is I had assumed load torque true demand constant ok, whatever it is constant load torque. Earlier electromagnetic torque was equal to load torque in this condition, this was equal to T L steadily running. Now, I have reduce the flux from phi 1 to phi 2, then this is at T equal to 0 plus I am examining. What has happened to my electromagnetic torque developed?

Now, electromagnetic torque develop at T equal to 0 plus is once again the same relation suppose K 2 phi 2 into I a 2 0 plus, I am sorry I will write it in a nicer way. So, T e at 0 plus will be the toque constant into phi 2 at 0 plus into I a 2 at 0 plus is not, this product will decide what is the electromagnetic torque developed.

Now, we are in a fix now a bit, because of the fact phi has reduced armature current has increased. So, whether the electromagnetic torque developed at T equal to 0 plus is greater than the electromagnetic torque which was developed by the motor at T equal to 0 minus.

That is what one should ask, then only I will say motor will start accelerating or decelerating, because load torque is constant. The fact is this, this armature current at any time armature current is applied voltage minus back emf divided by r a this is the current. Now, if you reduce the flux by say 2 percent increase in the armature current. It can be easily shown; it will be many folds then that.

Are you getting me what I am telling? Ok. This flux is reduce armature current has increased whether the product will be greater than the previous electromagnetic torque. I am telling it will be greater, because of the fact the increment in the armature current will be many fold than the reduction in the flux, because you are dividing it by a very small quantity r a got the point, this is at the most crucial point.

We will solve problem you can easily see that. Therefore, what is going to happen then the electromagnetic torque developed by the motor at T equal to 0 plus will be more than the electromagnetic torque, the motor developed at T equal to 0 minus. And, I am telling load torque is constant therefore, motor will start accelerating from T equal to 0 plus onwards, if it accelerates, it is armature current will then start falling.

And, finally, once again it will draw final steady state armature current, which will make K T phi 2 into the final armature current to be equal to same load torque, load torque I have assumed constant. So, what do I say about the armature current drawn from the supply, when we have reduce the flux with constant load torque present on the shaft.

So, new armature current will be this is constant I have assumed. Therefore, new armature current is T L by K T phi 2 and phi 2 I have I know I have deliberately reduced it.

So, the armature the new armature current drawn will be more than what was I a 1 earlier got the point. Therefore, we reduce the field current load torque constant, final armature current drawn by the machine will go up and up. Unlike the D.C armature control method; armature control method, there armature current was always constant and that is why we told it is better suited for constant load torque.

But, in case of field control I immediately discovered that if the load torque is constant as I told you I would always like to see the motor is drawing armature is carrying always constant current rated current. But, if it was earlier at this point carrying rated current and if I have reduced the flux, the current drawn new armature current drawn at steady state will be more than these if load torque is constant got the point.

Here of course, phi is not constant therefore, it is difficult to say that this is load torque are you getting ok, load torque is load torque constant. But, see so now, let us see in the characteristics terms what is going to happen? If, you have reduce the field current, new torque slip characteristics look at this phi I have reduced. So, new no load speed will be V by K phi 2, it will be here.

And, then it will fall, but the slope will not be parallel. Because, phi has this is the slope of the line phi I have reduced. So, slope decrement in speed will be in at a much faster rate, this will no longer be parallel as we have seen it was parallel in case of armature voltage control, but it will be like this. So, it was drawing this much current. Here, I cannot show the load characteristics, if this is I a, because load torque is I a into phi, ok.

So, it is I a only I a armature current. Now, what I am telling, if, the load torque is constant it will run at higher speed, but with increased armature current. May be here, it was running here. Now, we have reduce the field current it will run there, if the load torque is constant. Mind you load torque is what product of armature current and the flux per pole, here it was I a rated; here it will be how much is the load torque at this point.

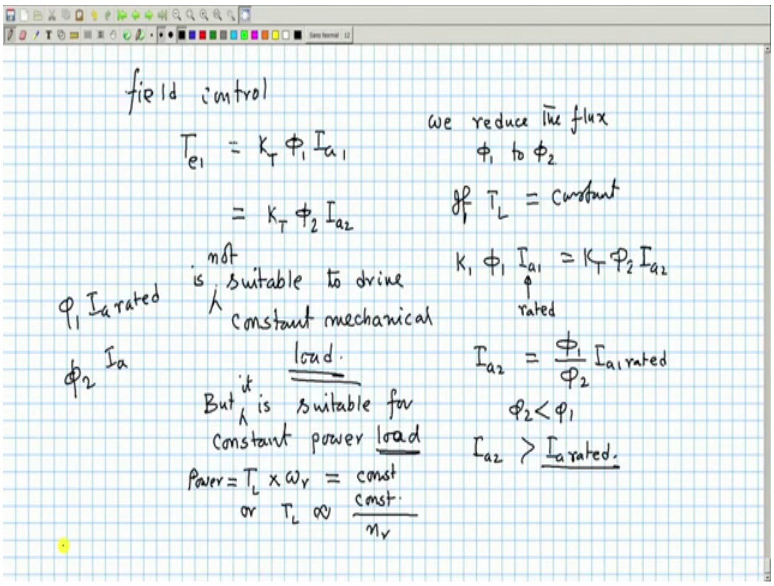
This new I a 2 into phi 2; I a 2 phi 2 is more than this. Therefore, load torque is increased like that load torque is will remain constant and it will run at the speed. Therefore, it looks like the field control method better do not use it for constant load torque. If, the mechanical load is constant then better do not adopt to run the motor at higher and higher speed for constant load torque.

If, load torque is constant we have reduced phi, simply look at the statistic equation phi into I a. If, your initial current was I a rated, if you have reduce the flux, what will be the new armature current it must go up. So, that the product remains constant and if your initial current was I rated your new I a will be more than the rated values, that I do not like is not. Therefore, and; obviously, what happen if I go on increasing field current see at based this resistance.

If, you decrease this resistance, then only field current will be increased. So, at best you make this R f external 0 you cannot make r f negative is not. Therefore, variation of field current method means, flux control. You only increase the resistance, you cannot increase the field current beyond this value V by resistance of this coil at base you can make R f equal to 0, no.

So, this speed control above the rated speed is adopted by flux control, go on reducing the field current speed will raise. Now, the question is see I think you have got me I will try to summarize the result.

(Refer Slide Time: 24:12)



Suppose, field control I am talking about field control. Electromagnetic torque developed by the machine is K T into phi into I a that is known. In field control what I will be doing, I we will reduce the flux; we reduce the flux. So, suppose initially electromagnetic torque was this steady operating point I am telling. If, you reduce the flux from phi 1 to phi 2, then how much is the electromagnetic torque developed by the machine, it will be K T new field current. And, this armature current I a 2, what I am telling is if you insist that T L equal to constant; T L equal to constant, I will say then K T phi 1 I a 1 is equal to K T phi 2 I a 2, that is what it will be steady operating point.

But, I know and suppose if I a 1 is rated, then what will be I a 2? I a 2 will be phi 1 by phi 2 into I a 1 rated, but phi 2 is less than phi 1 therefore, I a 2 will become greater then I a rated that is what I wanted to tell. So, if somebody connects a constant mechanical load and initially it is drawing rated armature current, then he reduces the flux, then immediately current armature current will become more than that.

Therefore, this drive these method of control of speed is not suitable to drive constant mechanical load.

Student: (Refer Time: 27:13).

It is not suitable very important to drive the constant mechanical load. See, your ultimate thing is you would always like to see your armature is carrying rated current that is the crucial thing. But, it is suitable for; constant power load.

What is constant power load? It is also the load characteristics, constant mechanical power load. Suppose, you have a load whose T L into omega r is equal to constant, what is omega r load speed, then or T L is proportional to constant by n r, n is the load torque speed omega r is 2 phi n r etcetera. So, it will be proportional to these this is what power that is mechanical load whatever you have connected, it tells that it always requires constant power, that is now it is running at 100 rpm torque is so much.

So, torque into speed this product remains constant, that is if you want to run it at higher speed, it requires lesser torque. What is the constant power load? Higher the speed is that load requires lesser torque to be applied it is the characteristics of the load. Such a load is caused should be then called constant power load, higher speed torque requirement is lesser. And, for such load this field control is absolutely failed? why, I will tell just verbally today, then I will explain next day with the help of some example.

That, if you higher speed you want to you want to run it D.C motor at higher speed, higher than the rated speed you reduce the field current. But, your load torque is such that when it runs at higher speed, it required lesser torque to be produced by the machine, then what will happen, phi you have increased. So, armature current will decrease then, initially if it was carrying rated current making phi 1 into I a rated is the torque. Next time, it is phi 2, but the armature current new armature current drawn will be such that this product remains same as these, I mean into speed.

Therefore, you see this type of a control of speed will be most suitable for loads which requires constant power mechanical load, torque into speed is constant. Speed make high then T L required by the load is less therefore, T required developed by the motor will be less and T is phi into I a 2 therefore, phi 2 into I a 2 will be less. So, I a 2 will be less I mean may be of the same rated current, you think about it and next time we will continue with our discussion with some numerical example.

So, remember that this field current method is suitable for constant power drive and armature voltage method is suitable for constant torque drive. And, armature voltage method is adopted whenever you want to control the speed below the rated speed and field control method is to be adopted when you want to control the speed above the rated speed. We will continue our discussion next time.

Thank you.