Electrical Machines - I
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Lecture – 81
Speed Control of Shunt Motor – II

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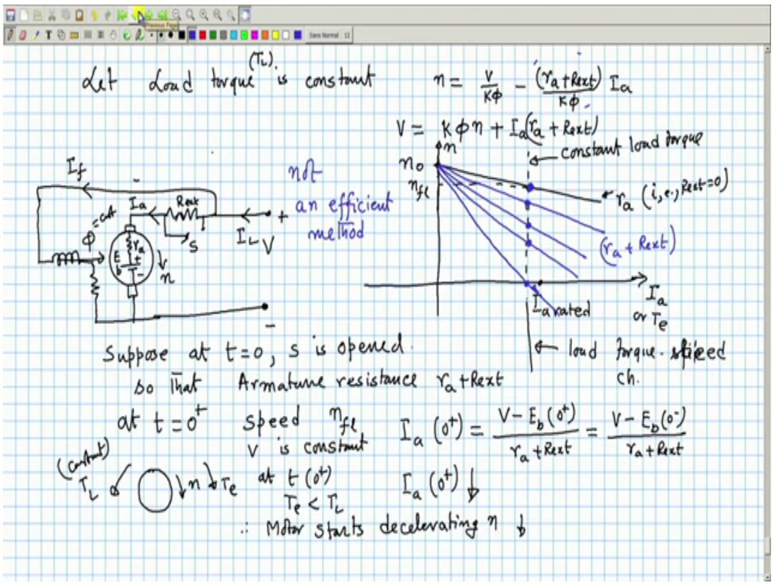

Welcome to the next lecture and we have been discussing very important and interesting topics on DC motor speed control, and how we have taken up first shunts separately excited machine. So, if you want to control the speed of the machine, by connecting an external resistance in the armature circuit here that is R external. Then the operating point, steady operating point will be the point of intersection of the electromagnetic torque.

Torque versus speed characteristics of the machine, speed we plot on the y axis and torque or armature current on the x axis. And I am not touching the field current rated flux it is operating then, the operating point with no external resistance will be here. There will be a small drop in speed that is why shunt motor from no load to full load variation of speed is very little, that is called speed regulation.

But, if you want to control the speed down to 0 by connecting an external resistance in the armature circuit that you can do. Because, the torques speed characteristic, speed torque characteristics of the DC motor can be modified. And if it is constant a load torque, you can run it at different different speed at the speed, at the speed, at the speed and so on. Down to 0 speed even, it is moved to control very nice method apparently but it is not at all efficient. Because the armature will always draw rated current and I square into r external will be the huge power loss in the armature circuit.

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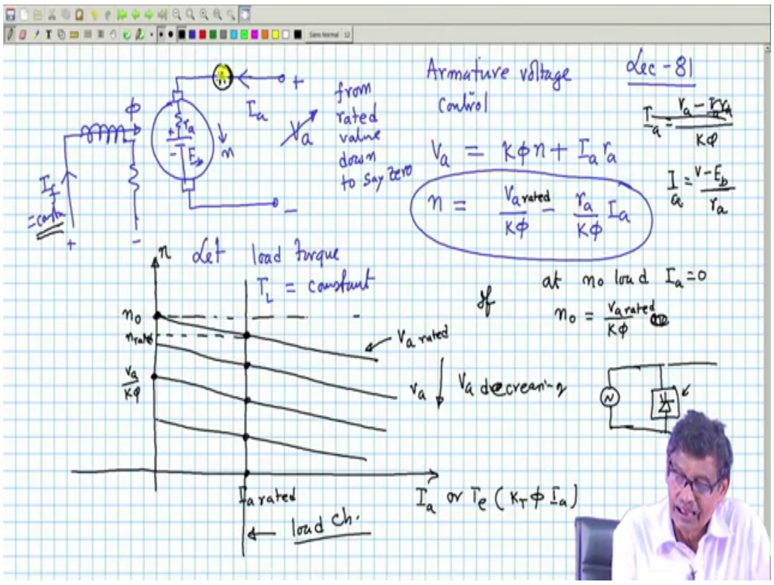

So, what is the next good method? Next good method will be to armature control only I will do armature sight control, but armature voltage I will change. The moment I say I will change the armature voltage applied, then it must be a separately exited motor. That is same shunt machine what I will do is this is your armature fine armature circuit and this is your field circuit. And the field circuit, I will pass constant current whatever it is I f. So, this method is armature voltage control.

Mind you, you should not be this earlier method should not be told armature voltage control. Armature voltage is fixed external; sometimes students get confused armature control ok, but here I am connecting external resistance; somebody may say ok, you are applying lesser voltage in the armature circuit because of this drop but that is not the good way of telling. Because, I am my armature circuit voltage applied is fixed, I have changing external value of the resistance connected in the armature.

If you say it is armature voltage control it should be like this that is, I will not connect any external resistance. This is your back EMF E v, this is your plus minus, this voltage I now call because it is separately excited it has to be if you want to control the armature voltage field I will not touch constant field current at rated current. So, that it produces flux phi volt and it is drawing a current of I a.

So, once again then they K V a equation in the armature circuit in the same way it is K phi n; speed of the machine is suppose n. It is running at steady state suppose and it is equal to this plus I a r a, no R external I am connecting. Then your speed will be equal to V a by K phi; V a by K phi minus r a by K phi into I a, this will be the basic equation. Now, this armature voltage I will control, this I will control. Now, what will be the range of the control of the voltage?

Suppose it is a 220 Volt DC motor, then the maximum voltage you will apply is 220 Volt. Definitely not a voltage you will apply across the armature greater than 220 volt then the rating of the machine will be exceeded so far as voltage is concerned. So, its highest limit variation of V a I am telling rated voltage from I will control this voltage V a from rated value down to say 0, like that very small voltage, that is that will be the range of variation of v a straight. I should not apply a voltage greater than rated value; because its rating will be exceeded, there will be insulation problem things like that. If it is a 220 Volt machine range of variation of V a will be between say 0 to 220 volt any way that is fine.

Now and also let load torque T L is constant therefore, if you find the machine is running steadily with some applied voltage. You are sure that electromagnetic torque produced by the machine is also this much, that you know by this time always think in that way. Now, let us try to see the characteristics of the machine. Speed I will sketch on the y axis speed and here on the x axis I will sketch I a or electromagnetic torque developed by the machine, which is equal to sum K T into phi into I a. Phi I will keep constant, this is constant phi is not changing.

Now, therefore, at no load suppose at no load same thing at no load I a is equal to 0 therefore, no load speed is equal to V a by K phi or that is the thing. So, this speed is n 0 no load speed which is equal to V a by K phi what is V a? Applied voltage, divided by K phi, it is fine. Now, this is the thing, suppose this is the rated current of the armature I a rated. Corresponding to this rated torque will be phi into I a in (Refer Time: 09:05) meter. So, this is the, this vertical line is the load characteristics mechanical load characteristics mind you speed versus torque. How much torque your load demands so, that it can run at a given speed. It has nothing to do with your electrical motor; it is its own separate characteristics.

Now for the motor you know this is n 0; suppose you have applied rated voltage, if V a rated suppose this is V a rated corresponding to that this is n naught. Then as we have seen, if you increase the load torque, this speed will fall and it will operate at this r p m which is n rated suppose, got the point. That is this characteristics is drawn with V a rated applied voltage is o n rated voltage. So, there is a speed regulation this is not speed control and this is load torque. So, operating point will be here very close to the no load speed slightly less than that. May be speed regulation is within 5 percent or so with respect to this no load voltage.

Now, what I will do is this; I will reduce this armature voltage to a lesser value; because there is no scope for increasing the voltage beyond rated value. So, only thing I can do is I go on applying if it is a 220 Volt machine 220 Volt, then I will reduce the voltage is to 200 Volt may be then 180 Volt like that this armature voltage because of this. So, you reduce the voltage first let us try to understand what is happening in the machine. Initially this is the operating point with rated voltage, suppose suddenly you reduce the voltage to a lesser value. If you reduce this armature voltage, you see armature current is equal to V a minus I a r a by K phi, is not? No, armature current I am sorry, I will write it like this I a is equal to V minus back EMF by K phi minus.

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r a, is not; this is the expression for the amateur current. Now, what I am telling it is initially running steadily everything T is equal to T L, drawing this much armature current running at this RPM phi. You know imagine voltage is slightly reduced. If you reduce the voltage and that time you call T equal to 0. At T equal to 0 plus immediately after you have reduced this voltage, what is going to happen?

Armature current will decrease because E b cannot change instantaneously phi is at fixed phi and speed cannot changes instantaneously. Therefore, back EMF at T equal to 0 plus remains what it was at T equal to 0 minus and therefore, armature current will decrease, if armature current decreases electromagnetic torque developed by the machine will decrease that T equal to 0 plus.

If electromagnetic torque decreases but I have assumed load torque is constant. Therefore, load torque will exceed the electromagnetic torque and this to act in opposition so speed will fall. If speed falls; will speed falls indefinitely no, as speed falls then armature current starts building up V minus E b by r a; E b falls armature current once again increases.

Finally, motor will seek a find a steady operating point such that, once again same armature current is drawn; so, as to match the electromagnetic torque but it will run at a reduced speed. Now the question is, this is the characteristic with V a rated what this characteristics will look like if V a is reduced.

In case of r a it was like this from the same point, but you see the no load speed depend upon V a by K phi applied voltage by K phi. Therefore, this characteristics will shift parallel to this, is not. And this slop of this variation almost it will remain parallel remains same r a by K phi; K phi is constant r a is constant it will be like this.

So, V a decreasing this way, V a decreasing and operating point will be at reduced speed here. Further reduce this voltage it will be like this, further reduce the voltage it will be like this got the point. Similarly, you can run the same motor supplying a constant load torque at various speeds and machine will continue to draw rated current and it will run at different different speed.

What is this no load speed, this no load speed is whatever is the V a applied, that V a divided by K phi, is not that will be the thing. Therefore, no load speed itself changes and you can once again it is a smooth control of speed of the motor only thing you require a variable DC supply voltage. Now, in earlier days to have a variable DC supply voltage itself was a problem. You know, because transformer using transformer auto transformer for a from a fixed AC voltage you can get variable magnitude AC output voltage, how simple it is, but in case of DC supply it is not so ok. Of course, nowadays it is also not a problem, because what you do is this, you have AC supply that is why DC motors are still in use.

This armature control what you do, your AC supply is there, because I told you, DC generation is also not there. So, what you will be doing? AC supply is there, use a rectifier block controlled rectifier block and get variable DC here. It is s c r based say converter AC to DC converter. And then that voltage you applied to the armature very nice or may be AC first make it DC then you some chopper circuit buck converter to vary the voltage at is.

Nowadays, it is so simple. What is the advantage of this method? With respect to the previous one, no external resistance I am carrying. And when you do this armature voltage control for a constant load torque, what is this ammeter reading? Ammeter reading will remain same at its rated value; of course, during the transient period when the machine is looking for the new operating point I m a change.

But finally, at the steady state point armature current will remain constant at rated values. And that is what we always try to see DC motor 20 ampere is the rated current, let it carry always rated current. No point in running the machine to carry 10 ampere current all along, what is the point? So, rated current machine is fully loaded, but still you are supplying a constant load torque at various RPM.

Down to zero speed even is not, you can select characteristics like that. Therefore, armature voltage control method is very efficient method and smooth variation of speed you can get. Earlier days before this rectifiers were used, what people oh that I will tell later, Ward Leonard method was very popular that I will tell you. To get a variable DC voltage you purchase another DC generator and connect it here.

Dedicated DC generator to supply this motor vary the field current of that generator to get variable voltage. This I will just give you a block diagram at later stage. But now, it is un thing couple I mean to control the speed of a DC motor by armature voltage variation what I am telling that purchase another DC generator and connect it here separately excited DC generator vary the field current of that so, that this armature voltage could be controlled. That is not a good proposition cost of the thing will just go many times higher another.

And DC generator if it is you require a prime mover may be a induction motor. So, you require not only a DC generator, butalso a another AC motors. Assuming AC supply is only available that was the case in earlier days only supply available is this AC. So, this I will just draw in a block diagram.

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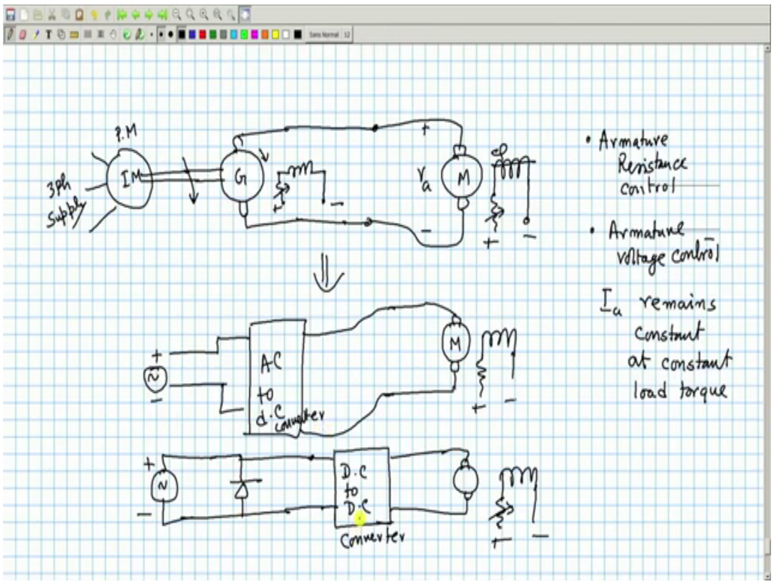

So, as to so, what you do? You connected induction motor, three-phase induction motor couple it to a DC generator and make itself excited. Its filled current you will be able to vary, got the point but idea is very simple, these the generator general. Therefore, prime mover is you are this induction motor, prime mover three phase supply AC supply earlier days this was the situation three phase supply, prime mover connected to the shaft of the generator, separately excited generator what is this voltage? This voltage is K phi into n at whatever speed it is running.

And then this voltage you apply to your motor whose speed you want to control. And this motor is also made separately excited, it has got its own field plus minus, it will produce flux. And, this voltage what I am telling in the previous diagram V a; I will be able to control by varying the field current.

Induction motor also it is almost a constant speed machine; therefore, where is this field current, get various values of armature voltage and do it. Therefore, to control this speed of this DC motor by armature applied voltage control method, what you need? This scheme tells you that you require another DC generator, and not only that and other DC AC motors to drive the generator, a very involved arrangement. Simply you wanted to control the speed of this DC motors.

Now, what I am telling those days are gone, no nobody is going to invest so much money what you doing is this now motor, because otherwise it is a very nice method, what you do? This whole thing will be replaced by AC supply may be single phase supply, then a block AC to dc converter and then apply it to this, this AC to dc converter could be a rectifier bridge controlled rectifier bridge with thyristor or it could be some DC to DC chopper circuit.

In case of DC to DC chopper circuit what you do, this is the thing supply plus minus have a rectifier bridge; diode bridge rectifier fix DC voltage. You will get from the output and then DC to DC chopper, DC to DC converter and motor field is separately excited of course, that is all. It do not require bulky machines, it will occupy space, cost this that a small converter it will do. That is why DC motors are still in use and this is how armature voltage control method can be used.

Now, I will make one comment here that armature resistance in both this method armature resistance; armature resistance control which of course we will not be using. We know it is inefficient armature resistance control and armature voltage control. In both this method I a remains constant I am sorry, I a remains constant at constant load torque. So, if your load torque is full load torque then I a will be, I a rated and that is very good one good thing about that, ok.

So, I will come to this point a little later that is suppose the load torque is not constant, ok. Let me make that comment also. So, that you understand what it is. Suppose your load torque is constant at rated value and it is I a rated, ok. And I put a condition load torque is constant these are the operating point. Suppose I say that these an interesting point so, that you can analyze on your own what is going on.

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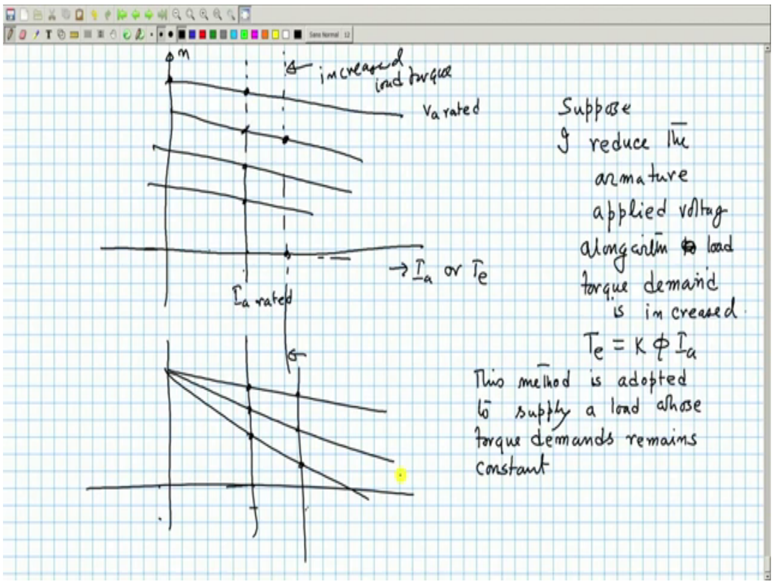

Suppose they what I am trying to tell, this is this speed this is I a or torque that is fine. This the no load speed V a rated and this is suppose I a rated, machine is operating here. Now, suppose I say that I will reduce the voltage and also increases the load torque; I mean I should be why I putted restriction on that that is what I am telling.

Suppose I reduce the voltage, armature applied voltage reduce the armature applied voltage, but also along with load torque demand is increase load torque demand and also load torque is a. Mind you in case of electro magnitude torque developed by the machine is K phi I a. If you increase the load torque on the shaft of the machine, phi is constant I a must be more than what it was at this point.

Therefore if you increase the load torque, the motor is going to draw a current which will be greater than the rated current machine will be overloaded, is not. And if you reduce the voltage, your new operating point it will run at a lesser speed no doubt, but it will draw higher current. And if you are earlier steady state operating point was drawing rated current it is bound to draw a current which is greater than rated current.

See, in between what is happening, I am not interested in steady state I know this much, electromagnetic torque and load torque has to be same. Therefore, this armature voltage control method is most suited for constant load torque demand. If the load torque is constant, corresponding to that rated current its current will not increase, armature current will be detected. That is what this point, this point it will go like this.

But if you say, it will run at reduced speed but torque demand is more then operating point will shift here. This is the new increase load torque got the point. Therefore, armature voltage control method or armature resistance control method. Both this method will be most suited for constant load torque, because then everything is so nice, at rated current always I will pass and I will be running the load at different different speed I am controlling the speed.

In case of armature resistance control this was the situation, rated current it will run this speed. If somebody says no I have increased this was the rated torque load torque suddenly increases to this value. Then the this x is being current or torque it will run here, but machine will be over loaded. If this is rated current, this current run will be much higher; because you are not touching flux got the point. Therefore, armature voltage control is most suited for constant load torque.

So, this method is adopted to supply a load whose torque demands remains constant nothing is better than that. Armature current rated value, rated torque and let that torque remains constant, you will be able to run at different-different rpm and so on.

Therefore, you see this armature voltage method of control is can be done either by connecting external armature resistance like this, but this is not good inefficient. So, armature voltage control which is a very nice methods smooth control. And compared to other days nowadays the variation of armature applied voltage can be achieved not by big-big machines external (Refer Time: 34:47) to be connected to your motor.

This is the motor I want to control the speed. Now, connect a converter have some control so that these applied voltage can be varied and wherever constant load torque is to be supplied at of this method, that is what the ultimate conclusion of this method, [FL]. So, we will continue with this.

Thank you.