Electrical Machines - I
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Lecture - 87
Series Motor Speed Control

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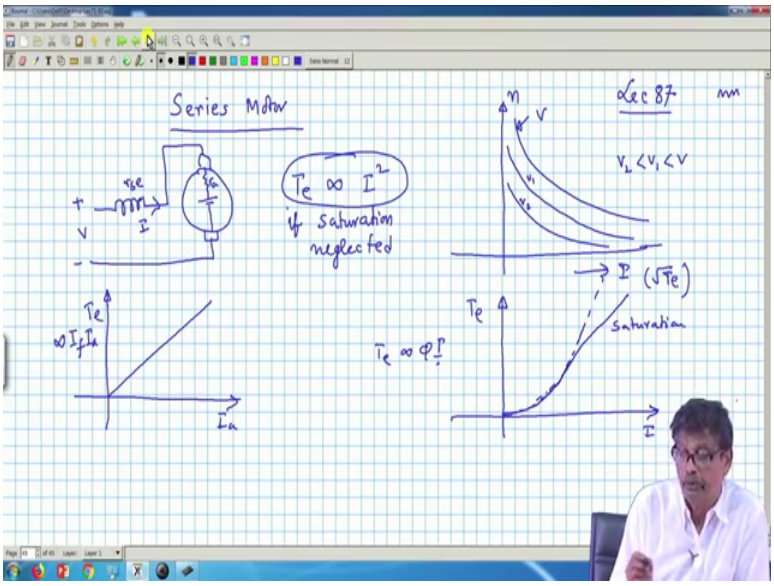

Welcome to lecture number 87, we were discussing about Series Motor. So, the basic characteristics of series motor, we have seen one of the characteristics is speed versus current and this current is proportional to root over Te. So, series motor the connection is one of the simplest connection. So, this is the motor and this is the series field few turns ok.

After (Refer Time: 01:03) any way this is the thing and here is the applied voltage V and the field current and armature current are same because, of the series connection and speed torque characteristics is like this. Which is inverse in nature, we have seen that ok. And therefore, with low torque vanishingly small speed will go up. And torque is proportional to I square that is what we have seen.

If saturation is neglected saturation neglected. So, if you simply sketch torque developed by the machine against current I. So, I 0 torque 0. So, it will be some parabolic way it will go on increasing I and torque parabolic way it will go on raising, but what happens is this if you go on increasing the current a time will come when flux per pole will not be proportional to I at large value of current it will reach saturation.

So, what people say that at large value of I a it will be almost like a straight line after that. So, this is saturation as takes place and if you say no saturation it will go on increasing parallelly. So, torque versus I characteristics. In case of shunt motor you remember, the torque versus armature current characteristics Te versus armature current for shunt motor was linear in nature because, torque is proportional to I f into I a is not I f is constant.

So, and there was armature current and field current at different. So, it was a straight line, but it was in case of series motor it will be parabolic in nature. And if you neglect saturation it will go on increasing like this. With saturation of course, it will become once again proportional to I mean I then that I is the armature current is not torque is proportional to this is the true thing I.

So, initially phi is proportional to I, it is this portion after that phi is arrested to a fixed value because, of saturation, but it is proportional to then I that is what we get it. Therefore, to control the speed of series motor we have seen, we can vary the armature voltage. I should not say armature voltage terminal voltage of the machine. Of course, this terminal voltage will be very close to that of back EMF.

Because after all r a and r s c both are small it has to be. So, it is with respect to some parameter voltage V it is like this and if you want to control the speed, you can get a family of carts with V 1 V 2. So, that V 2 is less then V 1 less than, where V is the rated voltage. Now can I control the in case of shunt motor what did we do? To control the speed below the base value, we control the armature voltage.

I connected the motor as a separately excited motor and varied the armature voltage to control the speed below the base speed. Above the base speed if you want to control the speed, one could increase the armature voltage no doubt, but armature voltage has got a rated value upto that only I will be able to control the voltage. So, if I want to have this speed above the base speed or rated speed of the machine, field control was adopted weakening the field current means your raising the speed higher and higher. In case of series motor, can I also control the field current?.

Apparently if you look at this circuit diagram separate field control is not possible how? Because, armature and field current theirs one and the same because, of this series connection ok.

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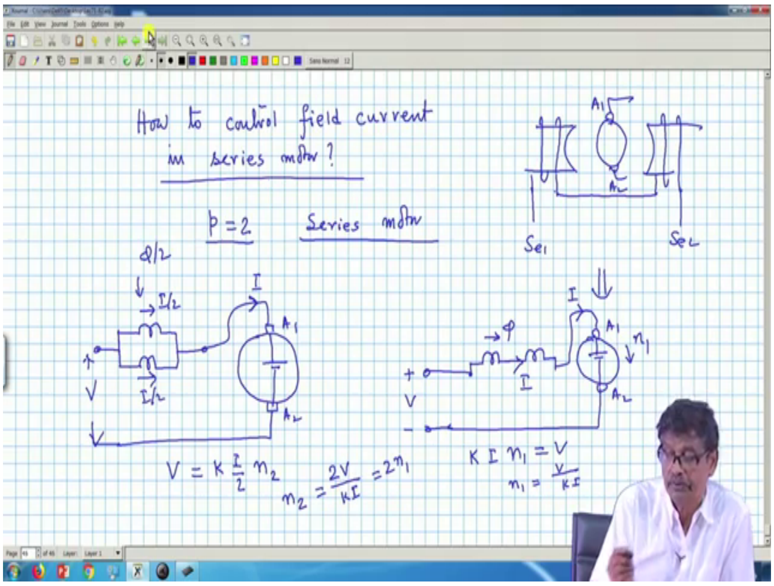

So, in case of shunt series motor how to control; how to control field current in series motor? There are very interesting ways of controlling the field current. So, in other words, what I am telling is that; that is it possible to connect the motors in a slightly different way. So, that I will be having some say separately on the field current. Let us see one of the things. For example, if I say that I have a 2 pole machine p is equal to 2; 2 pole series motor.

Means, what on each pole phase there are this is one pole phase this is the other pole phase identical number of turns are there and these two are I have told you are connected in series and this is your Se 1and S e 2 that is what I introduce to you the field coils. So, I see there are two separate field coils. Now, this two field coils, I can slightly play with in this fashion. So, in normal series motor they are connected in series these toward the terminals and then there is armature terminals.

This is what we have done so far A 1 A 2 and this A 1 is connected with S e 1 this two are in series supply with the voltage like that. So far what we have done? I can do this way, this is my armature terminals A 1 A 2. There are two coils I will now show them two coil like this. This is coil 1 coil 2 and this two I will connect in series and this is what I am telling Se 1 Se 2 and then you connect this two in series. This is the normal way of connecting series motor and you see your I is same as the field current flux per pole will be there.

But another innovation can be done. It is like this is the armature fine this two coils I will connect them in parallel. This coil and this coil I will connect them in parallel and this I will treat as my field coil terminals and connect this two in series I can do that. In that case the armature current and the current which is producing flux per pole, they will different. In fact, if it is I and if this two coils are identical this will be I by 2 and this will be I by 2 This is your supply voltage, V got the idea?

So, at two pole machine having two coils I can connect either in this way or I can connect this two coils in parallel and then this parallel combination in series with the armature and get it like this. Then I will say that for the same current here I here the coil currents are I, but for the same current I here. The current in this two coils are I by 2 I by 2. Therefore, if flux per pole phi which is important K phi I a is the torque back EMF is K phi n what is phi; phi is flux per pole. So, flux per pole in this case, if it is phi in this case it will be phi by 2 is not? Because, your passing through the same number of turns up the current.

Therefore, your have able to weekend the flux by two times. And in effect we have weekend the flux got the point? Let me tell you in a I mean something mathematically ok. This is the applied voltage V I think your following me, the way I want to train you is that in DC machine to get the quick results I am always emphasising this point armature resistance whichever things are connected in series with the armature for example, field coils their having very low value of resistance.

So, to understand what is happening very quickly? You neglect those resistances and you can reach the correct conclusion very quickly. For example, let us assumes r a is vanishingly small r ac is vanishingly small in this case you find the machine is running at a speed n. What I am telling ok? This motor in this fashion is observe to run at a steady state speed n. What is this speed? I will straight way write if this resistances are neglected, then it is only the back EMF which will be present. And back EMF is K into phi that is proportional to I into n that is equal V in this case.

So, this will be the situation. In this case once again back EMF is same with no resistance present here back EMF will be same as the supply voltage because, no drops. So, V is equal to same K into instead of I it will be I by 2. And the new speed I want to find out n2 let us call this is n 1. So, what will be n 2? N 2 will be 2 V by K I is not? Here n 1 is V by K I.

So, now, the speed will be twice that approximately twice of the speed. Provided it is loaded to same current same armature current got the point? Therefore, you see I have weekend the flux in a indirect way speed is more now. So, I can connect the field coils in a way I have connected and of course, with a two polar machine you can we can the flux for the same armature current in both the cases. Only two things you can do, that is connect them in series or in parallel. If it is a four pole machine of course, you can do more things p equal to suppose 4.

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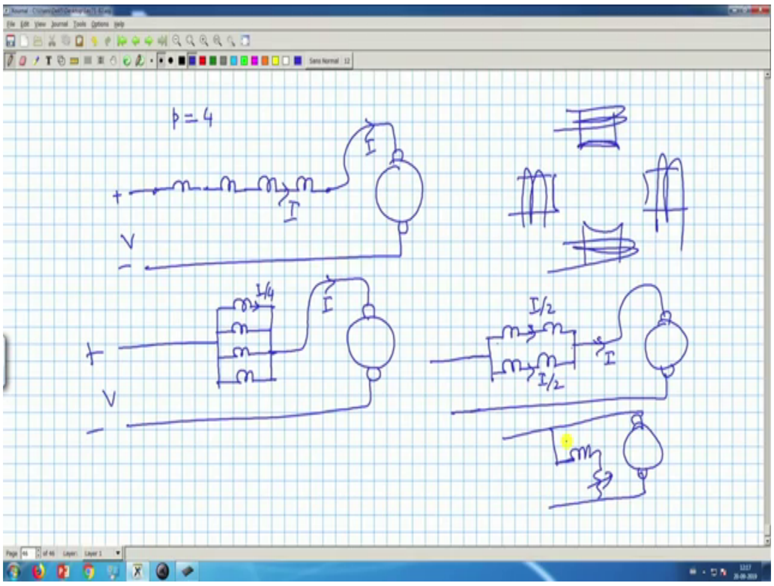

That means, physically there a 4 coils present this is one pole this is another pole sorry this is another pole, this is another pole and each one of them is having coils identical coils 4 pole machine. Therefore, I can do several things now connect all the field coils in series 4 coils 2 3 4. And consider this to be your series field terminals connect them in series with the motor.

This is the applied voltage, let it carry current. You could connect all the coils in parallel. And if the machine is loaded to carry its rated current armature current, in this case current flowing through each coil is I itself, but here it will be if there identical coil, it will be I by 4 current will be divided there is no back EMF here only resistances.

So, flux per pole compare to this is reduced by factor of 4. You could also connect two in series another two in series and connect it like this. So, in this case flux per pole will be reduced by factor of 2 and so on; therefore, field control can be done one of the way nice way of doing it is this way, but not like a smooth field current control as we did in case of a shunt motor.

In shunt motor the connection was like this and this is the resistance we controlled to decrease the flux per pole that is all, but here in discreet steps some 4 speeds may be possible 1, 2, 3 level of speed control can be possible you must keep this in wind. Any way if you do not like to neglect the resistance all the resistances are there ra rac then I will write very faithfully, the back EMFs and the torque equation and also let us not assume low torque remains constant or not.

And I will write down the torque equation balancing the low torque that is and the back EMF equations, take their ratios and you will be able to solve the problem understood this point. Another way of controlling the speed is called use field control in series motor.

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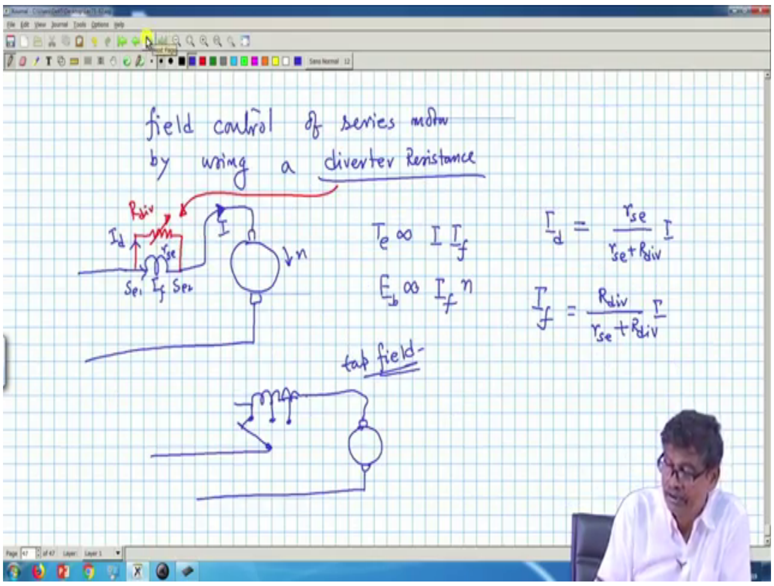

Field control of series motor by using a diverter resistance. What it is? It is telling that this is the motor and this is the our original field where I have not separated two coils at least two coils we at their connected in series as I told you. This way you connect it and then your I a and I a for same your answer tied you cannot control the field current separately.

But what you do know? You connect a resistance in parallel with the field circuit and this resistance is the diverter resistance called the diverter resistance. Where is this diverter resistance R diverter, then what happens is this when the machine is running is steadily at certain rpm n and drawing some current I. Then the field current we have been able to make it different from I because this current is suppose I d this current is I f I can say.

In this case I must write the electromagnetic torque developed by the machine is not proportional to I square it will be proportional to the armature current here is now, a clear distinction between field current and armature current I a armature current I into I f. And back EMF is also should be carefully written is at proportional to field current I f and n. And how I f and I r related? It will be related if this total current is I. Then I d this current will be the total current I I d this diverter resistance current will be total current into this resistance is suppose r s e into r se divided by r s e plus R diverter that is also a small resistance with high current rating. And your I f will be equal to R diverter divided by some of this resistances additional equations comes.

What is I? I is the armature current. So, this way also you can control the field circuit in the machine. There is another called tap field, we are not going into that there is a in that case what happen series field has got several taps 1 2 3 step. And you can this is not a very popular method.

Because you have to make and break the circuit in order to your supply comes here, field winding then armature. You can vary the number of turns of the field circuit tap field just I am mentioning. I have mentioned it in my notes also, you see those notes have been uploaded go through it and try to find out several aspects of speed control of series motor by controlling the armature not armature separately supply voltage, terminal voltage by controlling the field current these are very nice thing.

So, I mean field can be connected in series parallel and several flux weakening scheme can be incorporated. Whatever little time is left, I will now just tell you to just solving one numerical problem.

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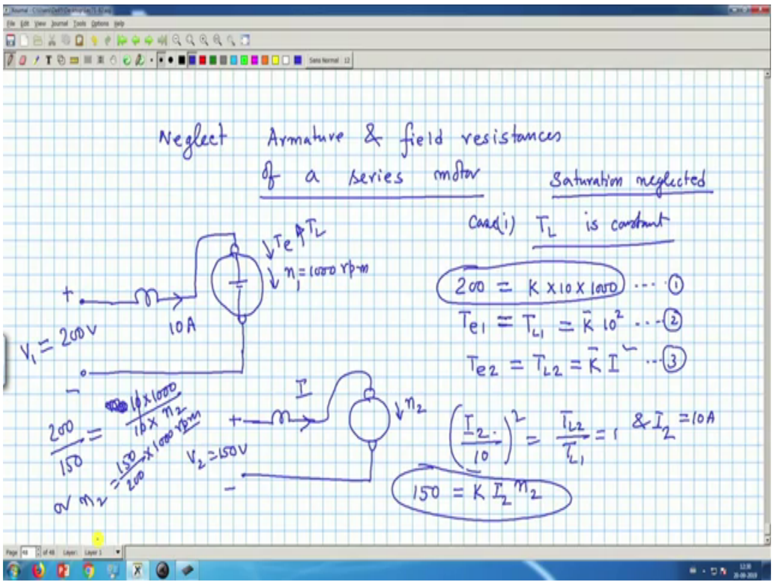

For example, if I say that neglect armature and field resistances of a series motor. Suppose you neglect those resistances I say that a series motor is connected like this and I say that you have applied 200 volt plus minus and it was seen drawing a current of 10 ampere and running it at a steady speed of say1000 rpm. So, this is n 1 and this is V 1 applied voltage 10 ampere like that it is doing like this ok.

And suppose I say case 1 T L is constant no matter at what speed the low torque rotates low torque opposite torque is constant. So, we know this is T e and this is T L. So, from the initial steady state conditions, I can say that 200 volt applied voltage is equal to this resistance and this resistances are neglected. So, supply voltage will be balanced by the back EMF. And what is the back EMF? Back EMF is proportional to flux per pole.

That is proportional to K into 10 into 1000 this is one equation. And also I will write that electromagnetic torque now, produced neglect saturation suppose I say saturation neglected. Electromagnetic torque developed is equal to the low torque T L 1 and which must be equal to some other constant K into 10 square; this is these corresponding to this steady state operation.

Suppose I say now, what I have done is this supply voltage has been changed to 150 volt. I want to know, what is the speed and what is the current drawn by the machine. Case 1 low torque is constant. So, how much current it is now going to draw from the supply, if you have reduce the supply voltage to 150 volt and what will be the new speed? Low torque T L 2 is same as the previous low torque.

So, first thing I will say that T e 2 is equal to T L 2 and it must be equal to K bar into I a 2 square is not? If low torque is constant this is the thing. Therefore, if you take the ratio between 2 and 3 I a 2 by 10 whole square is equal to T L 2 by T L 1. And if T L 2 and T L 1 are same as per this statement, this is equal to 1 and I will say I a 2 will remain unchanged. Final steady state current when you have applied 150 volt is going to be this.

What will be the new speed? New speed will be equal to 150 volt back EMF equation is equal to K into phi I into n 2. I mean I should not write I a 2 square because, if they are same got the point? I a. So, supply voltage is K I n 2 therefore, what will be n 2 now? So, this one this and this you take the ratio that is 200 by 150 is equal to n 2 no 10 into 1000 by I; I have got 10 ampere once again in the second case.

Making a mess of it then let this be called I 2. So, I 2 is also 10 ampere. Therefore, 10 into n 2 or you can then calculate n 2 will be equal to 150 by 200 into 1000 so much rpm. So, speed will be reduced by the same factor as you have reduce the supply voltage ok.

Thank you, we will continue with this in this.