Electrical Machines -1

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Lecture – 86
Series Motor Characteristics

Welcome to the lecture on Series Motor, DC series motor.

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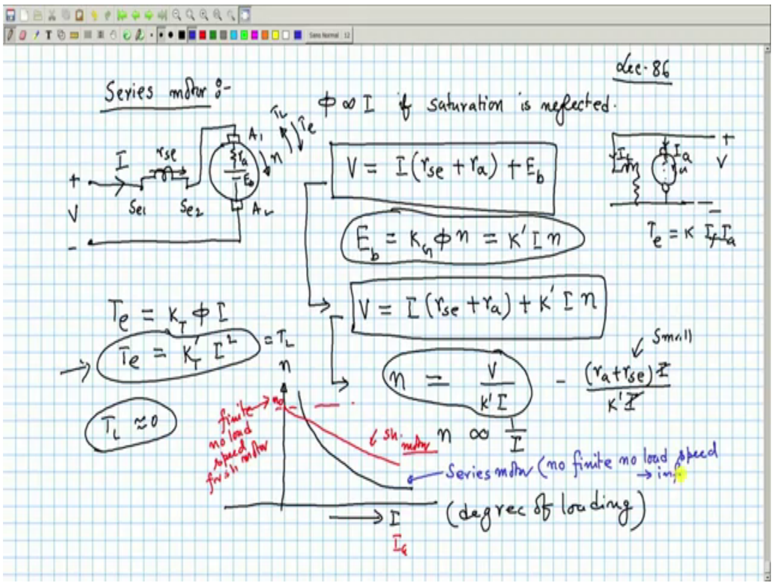

And, we have seen that in case of DC series motor the armature is as usual, but there is the field winding which are having fewer number of turns that is why I am just drawing like this only few turns and field terminals are marked as S e 1 and S e 2 and these two are as usual armature terminals and what happens is this, the field winding is connected in series with the armature.

Unlike shunt machine where the field winding is connected across, and which means, that the armature and field current are same for this machine and here you supply the machine with some DC voltage V. And, this current is I and at some steady operating point, the machine will be running at some RPSA NRPS and growing some current.

Now, the point to be noted here is that armature and field current are same. Therefore, there is no distinction between if and I a as it is, right now. Now, what will be the basic equations? The field coil although it is number of turns are less, but it will carry now, large current same as that of armature current. So, the field coil thickness will be large, unlike shunt field coils. Fewer turns no doubt, but large current so, it will produce substantial flux. So, flux per pole will be proportional to I, if saturation is neglected; if saturation is neglected. Then of course, the rest of the things will remain same that is the back emf here what will be the thing r a and there is some back emf E b, ok.

And, your KVL equation in the simple series circuit will be V into I into resistance of the series field winding plus resistance of the armature winding plus browse drop; if any you can add and plus the back emf, this will be the basic equation. Now, what is E b? E b the back emf generated, it is proportional to K phi n. So, it will be some K G into phi flux per pole into NRPS, etcetera, but phi is proportional to I.

Therefore, it is also same as with some other constant; I into n that is the thing it will happen, ok. Now, if you look at this equation carefully, then I will write it as V is equal to I into r S e plus r a plus for E b, I write it as K dashed I into n. This will be the equation, KVL equation of the machine.

Suppose the machine is operating steadily at some RPMN drawing some finite current I, this will be the basic equation, ok. And, what about the torque equation; these are the only 2 equations we can important; one is the back emf equation for any dc machine analysis these two equations matter therefore, Te will be some constant K T into phi into I armature current, although it is I, but this is armature current that is why I.

And, this is equal to some K T dashed into I square these are the 2 equations, ok. Now, one can see that the torque produced is directly proportional to I square, in case of series motor and if you consider the motor to be this point I told in my last class, but once again I am repeating, if I am starting the motor when it was stationary switched on the supply then the current drawn in by the machine will be simply V by r a plus r S e.

E b is absent at that time n equal to 0 and torque is proportional to I square, in case of shunt motor it is the armature and this is the field. If you applied the full voltage E b absent only r a is there so, armature current will be similarly, large I a. I a is of course, small rated value will flow V by r f whatever is there, but the torque is proportional to I a into I f torque, starting torque is proportional to some K dashed into I f into I a. Therefore, the starting torque will be quite large in case of a series motor of similar ratings that we must specify same rating, same kind of armature coil then the starting torque will be very large, and, this is the thing.

Now, what are the speed depends on what? If you look at this equation this is the relationship of speed; speed will be equal to from this equation, how speed is related? Is equal to V if I make a mistake pointed out so, V minus this minus r a plus r S e into I and this divided by K dashed into I this divided by K dashed into I this will be the equation.

Now, this I goes and r a plus r S e is small. So, this small negative term you forget about so, what happens is, this speed is practical this term will be quite small, small negative. So, essentially speed is proportional to 1 by I for a fixed applied voltage. Therefore, the if we if you sketch, speed versus the current this current happens, to be same as armature and the armature current is decided by load and this will have an inverse relationship like this.

So, in case of series motor, who decides the value of I? The load present on the shaft of the machine. How much torque it has to developed? It has to be same as the low torque if it is running steadily this we have learned therefore, the magnitude of the current drawn from the supply is decided by the opposing low torque present on the shaft of the machine, this is T L and this is T. In steady state these two are same therefore, I am telling that the current drawn from the source is decided by T L is not, low torque present on the shaft of the machine.

And, I find that as low torque decreases, if you decrease low torque; that means, the I value will decrease from this equation, because K T dash I squared is equal to T L. It is now, drawing some current I for some T L; make T L half, current will decrease further reduce T L current will further decreased these are the steady state current I am not telling the dynamics, how the things changes?

Therefore, it looks like if I so, this is also degree of loading it represents; degree of loading, mechanical loading T L so, if you decrease T L, the value of I you will decrease not linearly, but anyway it will decrease. If we assume that there is no opposing torque at all on the shaft of the machine that is T L is close to 0 suppose.

Then I find that ok, the motor to operate at steady state it must draw vanishingly small current I, if T L value is decrease the current run this apply in the steady state has to be very small and, if I is very small you see speed will go up tremendously, because there is no finite no load speed I equal to 0 speed is going to be in finite. This equation tells me as I appropriate 0 speed appropriates infinitely, large value that is why people say never ever tried to start a DC series motor. We do not ensuring that there is some mechanical load torque present; otherwise machine will raise to a very high value of speed and thereby damaging the motor.

Therefore a series motor should never be started with no load on the shaft of the machine even if the practical machine, even there is no load there will be some frictional load present which is very small then also it will be dangerous, but that is not the case in case of shunt motor why? Because shunt motor if I draw it here, I versus speed if you recall there is a finite speed no low speed you recall, shunt motor.

There is absolutely no problem, because with I this I means, I a then armature current that decides the load torque K I f I a field current, I am not touching therefore, there is a finite no load speed for a shunt motor, finite no load speed for shunt motor. But for series motor no this is not the case this is the characteristics series motor. No, no finite, no low speed in fact, it is infinite going to infinity, no load speed which is certainly not allowed.

Because, motor will be damaged and all these things therefore, keeping this in mind we should operate a series motor although series motor has got a very large starting torque; it will produce a large starting torque, it will accelerate fast, it can overcome if already opposing load torque is present very fast, that is why it is very useful for traction purposes. And, series motor will be like this, torque is proportional to like that.

We will come at this a come to this point several times as we go on discussing about it further. For example, in case of a so, this is one characteristics of series motor that is speed versus I and we have seen torque is proportional to I square is not that I have seen therefore, these axis also represent torque, because although it is not linearly proportional. But, you can always write I is proportional to root over T is not from this therefore, if this is I it some way represent to root t or the electromagnetic torque present on this shaft of the machine and this axis is what speed ? So, at no load I is the degree of loading decides by armature current and this is origin therefore, it will be like that, ok.

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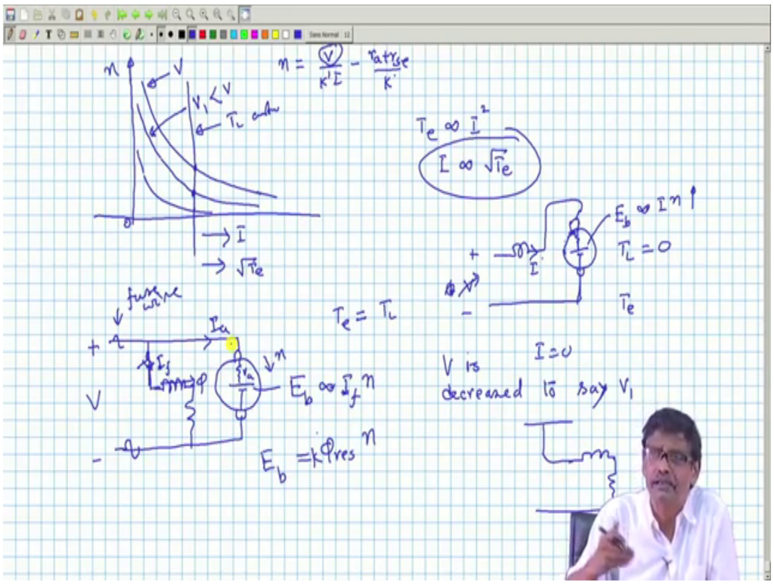

Therefore, machine will run at this speed. When speed is very small that is supposed at the time of starting the machine, toque developed by the machine will be very high this is root T, but anyway T when you are going to start the motors with these small 0 therefore, torque will be very high, but as machine picks up speed, back emf comes, I decreases and electromagnetic torque decreases and leave it to the motor. Motor will always try to seek a steady operating point where T will be equal to T L and then it will run at steady speed.

But in absence of any opposing load torque present on the shaft, machine will go on trying to make the current 0, how the machine can makes a current 0? Suppose there is no just physically let us try to understand, what is going to happen? This is your circuit you have applied voltage, suppose I say machine is started from the what go when speed was 0 I have switched on the supply and let us assume there is no load torque T L is 0 absolutely no load torque at that time what will happen?

You have energized the circuit at the time T equal to 0 plus it will draw very large current, large starting torque will be there, electromagnetic torque will be present and machine will accelerate fast, speed will go up; at as speed goes up this back emf appears which is proportional to I into n so, speed goes up this goes up, but I decreases is not.

Mission is not knowing all these things, it only sees I have to increase this speed further, because I is decreasing so, that it draws enough current to balance T L, but T L is 0 so, it will try to make this I 0 trying very hard to rise it is speed as much as it can; that means, it will go on increasing the speed, with T L equal to 0 what it is seeking? It is seeking that I must make I equal to 0, because there is no low torque present.

So, how load torque, load torque will be balanced by T; T is proportional to I square therefore, how it can make I equal to 0 it can make I equal to 0 provided this back emf and supply voltages are equal then only current drawn by the machine will be 0, but how it can make, how E b can match supply voltage? Only by raising speed higher and higher, it goes on trying to do that.

In the process be the approaches infinitely large such that finally, current drawn has to be made 0, because you are telling your load torque is absent, but in presence of load torque, it will it is speed will rise soon it will find a steady operating point where the load torque and electromagnetic torque will match and it will draw a finite current and machine will run steadily at that speed that is the whole idea. See in series motor that is the interesting part of it therefore, in series motor never operated or tried to start a DC series motor we do not ensuring that there is no ensured that there is load torque present, then attempt to start then it will really reach a final steady operating point and your machine will operate fine, .

So, this is the thing, but whenever you draw this speed versus current or speed versus torque characteristics I must, because you see this equation is what? n is equals to V by K dashed I, n equal to V by some K dashed I is not and minus some negative number some r a plus r S e by what by K dashed something will come, but this number I do not bother, because that is the small negative number it is telling to be subtracted why it is a small number? Because r a plus r S e is small quite small so, the moment I draw these characteristics I must also right at what? That is V you may now think that I will control V perhaps, to control the speed of the machine got the point.

See one obvious thing is from these I now, learned that this big torque characteristics I can change it to another characteristics, I can draw if the applied voltage I change for example, if I decrease this supply voltage V, V is decreased to say V 1 it is decreased, if it is decreased these characteristics will remain same, but it will now come below is not a family of curves can be drawn V 1 less than V.

Therefore, if you are supplying a constant load torque machine will run at different different speed decrease it further is not, I can then control the speed by controlling the applied voltage across the machine terminal, this voltage you vary assumed some load torque constant this is the T L suppose and therefore, you will be I think it is not T L, but T equal to T L it has to be load torque a constant load torque means, a constant current I draw a vertical line and therefore, you will get operating different operating points.

So, this is one way of controlling speed of a series motor. In this context I would like to tell you another important thing see ultimately, what is happening here as you switched on this apply as I told you initially current is I large electromagnetic torque, in absence of any load torque present, it will accelerate fast so, that I value decreases it will try to make it 0; so, that these back emf matches V which it can do with smaller value of I with large n that is what I told you and it is avoided that is finally, it is looking for a final steady state operating point where I drawn has to be 0, how it can do it ?

In this context one point so, that it has got similar argument that is why I am telling for example, consider a shunt motor; this is an interesting part a DC shunt motor is like this, suppose here you are applying voltage is not and making is running steadily in this case what happens? Switch on the supply field current is finite n equal to 0 initially, armature current is V by r a torque is developed not as a larger torque as in a DC motor, but anyway it will develop a starting torque and if it can overcome load torque let us assume load torque is absent; in this case what is happening?.

This is r a back emf will appear, E b will rise if load torque is absent final I a has to be 0, because T equal to T L so, final I a how it can be 0 it can be 0 provided your back emf matches V then this current will be these voltage minus back emf divided by r a and in this case since, this flux was independent of this armature current flux remain constant therefore, it is there is a finite speed then, because machine can nicely speed up it is proportional to I f into in.

It will it speed will go up to a fine their exist a finite value of speed which will make I f into n that is V c b is equal to V I a will get 0, that that is how you get finite speed this is known, but the point I want to tell in this machine also shunt motor; only one precaution one should take for example, you at least must ensure what you know some students were when working with a DC shunt motor in the laboratory while connecting the field winding, armature winding they have correctly connected.

But suppose the field connection is a not formally made some loose thing is there that is a this field coil these are the field terminals, while you connected there is some loose connection here. Are you getting me? This connections are not formed you should then you just ask yourself ok, motor is working nice learning at certain speed n rpm then what happens is this field circuit becomes opened, because of that loose connection.

What will be the consequence of that? So, what is this statement of the problem? A shunt motor operating steadily ok, at n supplying some load torque drawing some finite armature current running at finite speed then let us also put it like this I suppose I have connected a shorting switch I will open this; when the shunt motor was operating steadily I will open this that is I will make field collapse, but still the armature is connected across the supply then what is going to happen? That means, what will be the flux per pole now?

I should not say 0 the flux per pole will become equal to the residual flux whatever very little flux no doubt I f a has vanished, but there is opposing load torque present and suddenly the field circuit become open circuited; if such a thing happens, this is weakening of the field current what happens to this speed? Speed will go up you have as if reducing the field current is not, we have seen to increase this speed above base speed we control the field current reduce the field current increase this resistance speed will go up.

But, in this case an extreme situation open this field has become so, much we cannot that it approach almost 0 phi residual, but making a will pretreated as if you have a changed the field current to a very extremely low value. So, that the flux per pole is phi residual. So, what the make motor will try to do? It will try to with this small residual field; phi residual into n is now back emf is not when you open the switch this is the scenario and load torque is constant so, with less value of phi r s how load torque electromagnetic torque can match the load torque? It will require some current which will make final steady state armature current into phi residual same as load current. So, machine speed will raise so, that armature current decreases and it will speed up to also very large value in order to match that.

So, a shunt motor now, nicely operating. If by chance it is field circuit becomes open a dangerous situation speed will once again raised to a very high value that is why while connecting a shunt motor make sure that field circuit connections are very tightly done. No question of these that loosely do not connect any terminal here, otherwise you will run the risk motor is running fine, but because of something this where comes out flux collapses almost to 0. Then machine does not know machine will try to make its back emf as high as possible.

So, that it will draw enough current which will make I a into phi residual is equal to your load torque and in order to do that n will be very large. So, this point I just want to make in series motor of course, there is nothing like if it is a open circuit here ok, machine is disconnected nothing suppose the these field circuit open circuit means, what? Armature is also disconnected from the supply such a, but here the problem is different you must ensure there is load torque present.

That is why there is no separate protection taken for the field circuit in a shunt motor; if you want to take a protection connect fuse wires in the lines for the motor has such fuse wires some bodies may say oh I will connect also fuse wire for protection of field circuit and protection for armature circuit separately no, no never do that. Because who knows this field if you connect a fuse wires here if it just goes off then you will be in a terrible situation speed will rest to a high value, commutation failure that will be sparks this, that current will shoot up. So, these are interesting practical phenomena which may occur if you are a little bit careless in handling DC motor.

So, remember that in case of DC series motor, always ensure opposing load torque is present you cannot afford to start a DC series motor, we do not any load torque. Then machine speed will rest to high value mechanical failure, there may be damaging the commutated segment brasses, this, that several problems we will take place so, we will continue with this in the next class.

Thank you.