Electrical Machines - I
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Lecture – 83
Field Control (Contd.)

Welcome to lecture 83. We have been discussing about the Field Controller for DC motors.

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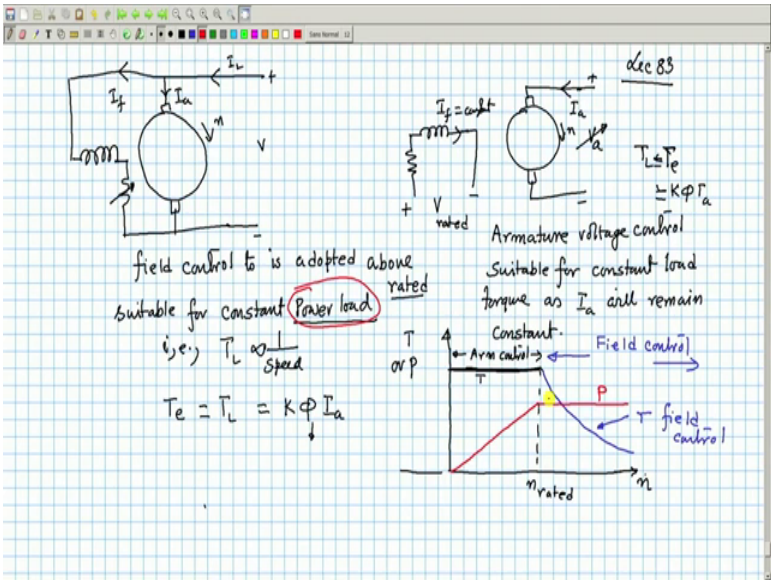

And, there are two very important methods. In which one method where armature voltage is varied keeping field current constant, I will not touch field current, it will constant remain constant and I will vary armature voltage from a variable dc supply voltage. And, then I found that if the load torque is constant. Then armature current will remain constant no matter what armature voltage you have applied. And, therefore, it will be suitable for constant load torque drive.

In the sense that I would always like to say that armature carries close to it is rated current, it will carry rated current at various speed of rotation when the load torque is constant. It does not mean that if the load torque is not constant you cannot still vary armature voltage and gate current. But, if suppose load torque is proportional to the speed, then what will happen at lower speed when the armature voltage is less, it will carry lesser armature current that is there.

Because, load torque is equal to electromagnetic torque is equal to your K phi I a is not. Therefore, if phi is constant if a load torque demand is less then I a will be less that is all. And, of course, you cannot apply a voltage across the armature which is greater than it is rated value. So, it is variation of V a will be from 0 to the rated value of the armature that was there. In the field control what you do you apply rated voltage.

And this machine in this case armature voltage control you must connect it as a separately excited machine. Here rated voltage you applied of the field coil, that is equal to we know from the nameplate rating. In this case you can connect it as a shunt motor no problem and this voltage is rated value V. And, you vary this field current and at steady state operation, once again T L will be equal to T electromagnetic torque will be equal to T L and, the electromagnetic torque is now proportional to K phi into I a.

Since, I am playing with the field current I f hence I am also changing phi. So, if I reduce flux, then electromagnetic torque at T equal to 0 plus will be more than the load torque if it is a constant load torque drive. And, it will finally, draw an armature current which was greater than the previous armature current. Therefore, it was initially carrying rated armature current and you have reduced the flux load torque is constant. Then machine is going to draw an armature current which will be higher than the rated. So, therefore, it will not be suitable for a constant load torque trial.

Rather it will be suitable if at higher speed load torque demand is lesser. So, load torque should be inversely proportional to load torque should be inversely proportional to the speed or load torque into speed should be constant, that is the mechanical load which is connected on the shaft of the machine at higher speed it requires lesser torque.

So, that flux has increased, flux has decreased then I a will be adjusted. So, that this product is equal to present load torque. And, if resent load torque is less at higher speed therefore; it will be most suitable for that. So, this and this field control that is to run the machine at higher speed; generally, above base speed ok. Field control to controls field control is adopted is adopted above rated speed, below rated speed control the armature and so on; so, that is the idea.

And, these things are expressed in this way that suppose, I say that this side is the torque ok. Then, if load torque is constant this side is torque. Suppose, I will change this this side and this side is suppose speed, then I will I can show it like this that up to the and this is suppose n rated.

So, here is the, this axis I will plot two things either torque or power delivered. So, this is torque; constant torque up to rated speed you vary the armature voltage ok. So, this is between 0 speed to rated speed control armature control in this zone, armature control, this is torque constant. And, if you control the field this I will draw with a different colour, it will be at higher the rated speed torque requires will be less, it will be like this. So, this is, this will be the torque characteristics.

So, field control. So, torque demand when it is becoming lesser and lesser with increased speed, it is most suitable. Then perhaps you will be able to pass always rated current in the armature that is what we want and you vary the speed above the rated value. So, this way this is the torque. In in case of so, this side is then the field controller, weakening the field you are reducing the field current field control above this in this zone.

So, speed will increase as you decrease and it will be like this. The same thing which essentially means that, if torque remain in constant speed is changing in some other scale. So, this is torque and you can also show this power curve, it will be like this. This red one is the power curve torque is constant speed is increasing torque into speed is power.

So, it will be linearly increasing, then constant power load that is what I wrote here field control and so on. So, you know a shunt motor these are the two very popular method of controlling speed ok, but only thing is you if you want to run the machine at higher and higher speed, you will be weakening the field current. So, what happens is this main flux is very much reduced. Although, armature current under this condition will be about rated current and therefore effect of armature reaction will be much more pronounced, because many field flux is less.

So, these are the disadvantages, you should not run it at any high speed you like of course, so mechanical restrictions will be there. So, this is the point I wanted to make about the field control of shunt motor. In this regard I would like to point out another interesting thing that because I am telling about weakening of field current means, you will be increasing the flux. Before, I discussed that point, let us see what will you how to find out suppose a DC motor is there ok.

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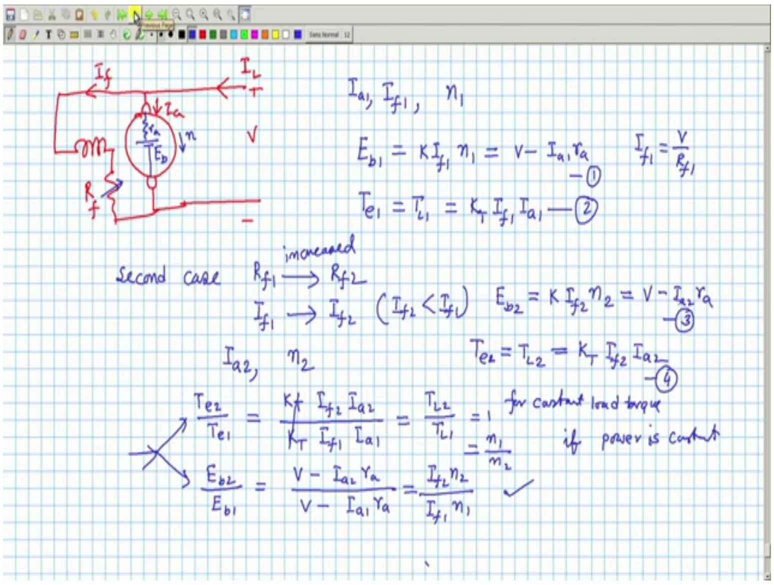

This is the DC motor armature and this is your field circuit, ok. This is the field circuit optimum motto, this is the armature current it is drawing, this is no, this is line current always show correctly and this is the armature current I a and this is field current at some value of field current and this is the field resistance generally. Now, suppose this is the voltage, initially steady state operating point only I will tell.

Though in the first steady state operating point suppose the armature current is I a 1 ok, field current is I f 1 ok, and so, basic equation will be as you know R a and there is some E b this is the circuit. So, it is running at some rpm say n 1. Steps a calculations in DC machines are pretty simple two equations you have to write. What is that, one is the K V L equation in the armature circuit, that is back E m f equation. So, suppose E b 1 is equal to K and let us neglect saturation.

So, far I f I can write I f 1 E b 1 is equal to K phi 1 into n 1. And, this is equal to b minus I a 1 into r a, this is 1 equation. Now, what I will do is this, I will change the, and what is I f 1? I f 1 is equal to V by R f 1, I will be changing this R f field control.

So, this is the initial operating point and what is the torque developed by the machine T e 1 is equal to load torque 1 T L 1. And, this is equal to some torque constant this constant may be equal if the speeds are in radian per second, otherwise torque constant p z by 2 pi a torque constant into field current into I 1 product of this 2. So, this is the two sets of equations 1, 2, that is what I will be doing. Now, suppose in the second case field resistance R f 1 is increased to R f 2 suppose.

So, that field current becomes I f 1 to I f 2 and; obviously, I f 2 will be less than I f 1, because I have increased the field current. Now, in this case the armature current in the steady state becomes suppose I a to speed becomes n 2 and so on. So, these two equations will be E b 2 is equal to K I f' 2 into n 2 and this will be equal to terminal voltage fixed V minus I a 2 r a, armature resistance I have also not changed.

So, equation 3 it will be and the torque equation will be T e 2 is equal to T L 2 is equal to K T into I f 2 into I a 2, this will be the thing. Now, I want to know I will not put that restriction general case load torque constant or it load torque is inversely proportional to the speed that can easily be seen.

So, these are the general 4 equations. So, I would like to know if I want to run the machine at suppose now it is running at n 1 R P S initially I want to increase the speed by 10 percent. So, that n 2 becomes equal to 1.1 into n 1, then what should be my new R f 2 that is type of questions I am trying to solve here.

So, first thing is you play with T e 2 by T e 1 as equal to K T I f 2 I a 2 divided by K T I f 1 by I a 1 this is the thing, ok. So, this is one equation and this should be equal to T L 2 by T L 1. If, torque remains toque demand remains same this will become 1 is not for constant load torque, load torque. This ratio will be 1 or if it is T L is inversely proportional to speed it will be n 2 by n 1 or n 1 by n 2 right or equal to n 1 by n 2 if power is constant. Depending upon that this ratio will be fixed up.

So, this is the K T goes and I a 2 by I a 1. And, another set of equation is there which is E b 1, this is what exactly you have to do all the time, take the ratio of the back E m f s and take the ratio of the electromagnetic toques no matter, whether it is a shunt series motor, we will see it later.

So, this will be equal to b minus I a 2 r a divided by V minus I a 1 r a E b 2 by E b 1. And, this will be equal to E b 2 is a f 2 n 2 by I f 1 n 1. Now, what happens is this, if I say I want to run it at a speed n 2 10 percent higher than n 1, then this is one equation, which will relate I f to I f' 1 etcetera and this is the other equation I f 2 I a 1.

So, what all you have to do is from these two sets of equation, you have to make an equation involving only I f 2. And, that equation will become in general a quadratic equation. And, from this I will be able to then estimate what should be my R f 2, that is the if you solve it with some numerical example, if time permits I will do it. Although in my note I have included one such problems to do either you have increase the reduce the flux by a certain amount, then what should be the new speed that is one kind of problem or if I want to run the machine at 10 15 percent higher than the rated speed, what should be the value of R f 2?

But all what you have to do is to concentrate on these two equations. These two equations depending upon, it maybe see ultimately load torque may change with speed as desired it is desired, but it you may put any load torque for general analysis. Then, see yourself whether it will be good or not, initially if it was carrying rated current and if you have reduced flux, you are sure the armature current drawn has to be higher, is not for constant load torque.

So, this is how the calculations are to be made? But, one thing I cannot resist from commenting here is that, see it will be a quadratic equation in suppose I tell you change the variables. So, that it becomes an equation involving I f 2 only solve for I f 2, I then get R f 2 that is fine, but for very quick estimation you can do another interesting thing, that is that will not be the exact correct answer, but it is worth noting. Because, armature here I have not connected any external armature resistance I am after all controlling the field resistance. So, the armature resistance rob is very armature resistance being small can be neglected here.

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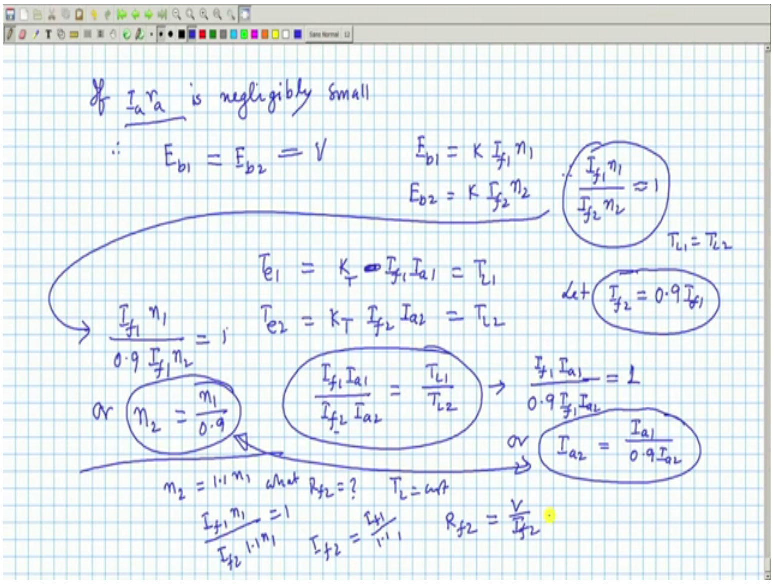

If it is neglected so approximately you can say that, if r a is; I r a is negligibly small, which will be small only negligibly small, then a your E b 1 and is equal to E b 2 is equal to V, there ends the matter is not. And, E b 1 was equal to K I f 1 into n 1 E b 2 was equal to K I f 2 into it was there. And, therefore, I get I f 1 n 1 is equal to I f 2 n 2 and that will be closely 1 that which has to be.

So, back EMF is fixed supply voltage is I a r drop if you neglect. So, this will be the 1 equation and then the torque equations are there T 1 is equal to K T phi sorry I f 1 I a 1 and T E 2 is equal to K T I f' 2 into I a 2, and this is equal to T L 1 steady state operation T L 2 and take this ratio. So, I f 1 I a 1 is equal to I f 2 I a 2 is equal to T L 1 by T L 2 is not. These two simple equations and that the quadratic equation you can avoid.

And, express I f' 1 in terms of I f 2 here is not. And, therefore, you will get a linear equations from which n 2 can be estimated n 2 can be estimated very easily quickly. And, what I am telling is this estimation of n 2 neglecting a I r a drop will be very close to the exact value. Estimation quickly is very important from engineer's point of view that is ok. If, I reduce the flux by this amount I f 2 is.

So, what I will do? Suppose, I say let I f 2 is made reduced by 10 percent. So, it becomes 0.9 I f 1. Then from this equation tells me that I f 1 into I a 1 is equal to 0.9, I f 1 into I a 2. And, suppose the load torque is constant, it is given that T L 1 is equal to T L 2, then this must be equal to 1, then T L 1 by T L 2.

Therefore, I f 1 goes I will be first getting I a 2; I a 2 will be I a 1 by 0.9 I a 2; I now know I a 2. So, armature current is known and it will be higher than the previous armature current. If, I a 1 was rated it will cross this rated current limit I a 2 ok that will be the thing.

And, from this what you get? See I have assumed this to be this one. So, I f 1 from this equation I will say, that field current you have reduced, so I f 1 n 1 by I f 2 which is equal to 0.9 I f 1 and this is equal to 1 into n 2 you know. So, how this problem statement of the problem is field current I have reduced to by 10 percent I f 2 has become this one, what is the new speed I the machine will be running?

So, I f 1 by this and this is equal to 1. Therefore, you will be getting that n 2 will be n 1 by 0.9 and new armature current will be this much these are the two answers I am looking for. So, no quadratic equation nothing, in my earlier case what I was telling that ok, because of this presence of this term, if you eliminate bring all the variables in terms of a I f 2 and I f 1 are related.

Now, 0.9 into I f 1 is equal to I f 2 it will be a quadratic equation, but quickly it can be estimated, more problems you solve better it will be. And, this ratio need not be also equal to 1. In fact, it should not be if initially, it was running at rated current you should not put a constant mechanical load, rated current will be higher if I a 1 was rated. So, that is why that restriction was put to that ok, rather load torque demand will become lesser at higher speed, T L is inversely proportional to 1 n.

So, very interesting problems can be set from this, ok. So, always try to see quickly estimate and, if you have not playing with armature resistance like resistance control, that is now a days it is not at all done armature resistance control. So, these r a small, i r a is also small. So, then say V is equal to E b no matter what is this R f, this must go into your head. And, you can always approximate that for if you are not so, sceptic about correct results ok, but how much will be the speed very quickly you can estimate, ok.

So, always keep your mind open, if exact things are necessary you will be able to handle no doubt by playing with these equations, but very quickly also you can estimate the new speed of the motor, when you either say that field current I have changed to this value or conversely if I say I want to run at 10 percent higher speed then what should I do?

Then in this equation I f 2 will be unknown are you getting suppose I say, that I want to run n 2 this is another problem, that is n 2 is equal to 1.1, is not 10 percent into n 1, what R f? R f 2 is how much, this is the problem. In that case, what I and load torque constant suppose T l constant, then what I will do? I f 1 n 1 divided by here, I f 2 I want to calculate I f 2 into n 2 and n 2 is 1.1 into n 1 and that is equal to 1.

So, from this I will be getting the values of I f 2 as 1.1 by I f 1.

Student: That is right, (Refer Time: 30:51).

Um?

Student: I f 2.

I f 2 sorry, I f 2 will become I f 1 divided by 1.1 let us fill current; I f 1 known I will get I f 2. Hence, I will say R f 2 you better say T 2 this V by I f 2 problem is over; no quadratic equation nothing in both the cases.

So, always try to use this concepts at least to verify your results, you have taken everything is into account, solve this circuit got this speed new armature current, but you should not shut your eyes to say that ok. I R a drop is a small drop and quickly you will be getting the results and better compare the results, ok. So, we will continue with the discussions in our next class.

Thank you.