Electrical Machines
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Lecture 23: DC Motors: Basics and Speed-Torque Relationships

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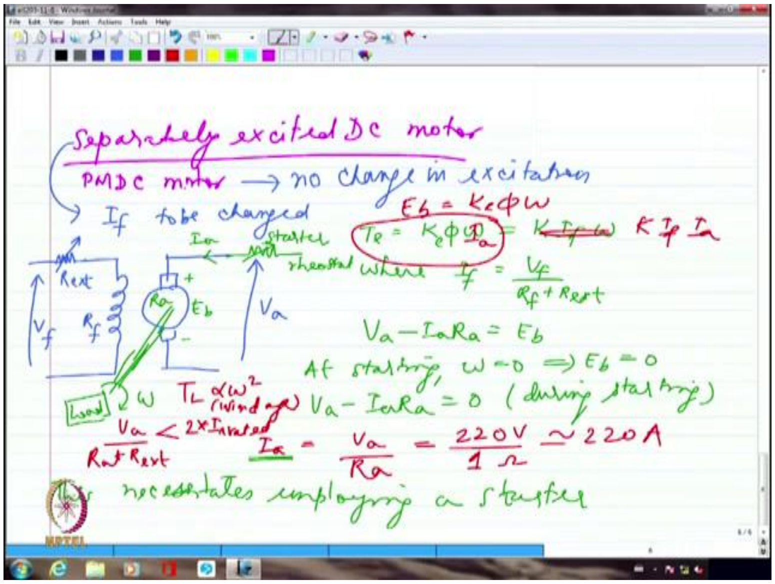

We started off with separately excited DC Motors; so we looked at actually separately excited DC motors which we said is similar to a PMDC motor that is a Permanent Magnet DC Motor. Only thing is there is no scope for change in excitation whereas this will allow I_f to be changed as per whatever the voltage that I am apply but normally the voltage I apply will be the same as that of the armature voltage because most of the times only one single DC voltage may be available as the supply voltage.

So I may have this as the armature and I am going to have this as the field and I may have a resistance in series. For some reason if I want to reduce the field excitation to the motor so this is going to be a variable resistance, let me call this as R_{ext} , the resistance of this is R_f, this is V_f which should be hopefully same as V_a. So this is the armature voltage and we are going to have a shaft which is connected to this to which the load is here is the load, so I am going to have a mechanical load which is actually rotating at a speed of ω because of the motion that was or the torque that was imported by the motor to the shaft and hence to the load system as well.

So I am going to have $T_e = K\phi I_a = KI_f I_a$ where I_f is going to be $I_f = V_f / (R_f + R_{ext})$. if I am having an external resistance also connected in the field circuit. And I should also be able to write that there should be a back EMF of induce here with plus here and minus here and the current that is flowing is I_a and armature resistance here is R_a because of which I am going to have $E_b = V_a - I_a R_a$, which is the back EMF which incidentally tells me when I start the machine at that point I am going to have the speed is zero, $\omega = 0$.

Therefore, $E_b = V_a - I_a R_a = 0$ and $I_a = \frac{V_a}{R_a}$. Torque is not the function of ω, torque, $T_e = K\phi I_a = KI_f I_a$.

Back EMF is $E_b = K\phi\omega$.

No relationship is directly between the speed and torque. So this is going to be if I just take for a normal 2.2 kW motor or something this maybe of the order of 1 ohm maybe this is 220 volts so this is going to be 220 ampere whereas the rated current may be of the order of 10 or 12 amperes nothing more than that.

So I am going to see that very huge current flows through the armature circuit, if I do not include any external resistance during the starting condition of a DC motor. So it is very essential to have a starter so this necessitates employing a starter. So unless I employ a starter a starter in most of the cases will only have a large resistance nothing else. A starter will generally consist of a very large value of resistance so if I have a large resistance included in series here so I may call this as the starter resistance or starter rheostat because it will be a variable resistance.

So this starter rheostat will be included in such a way that the maximum resistance is included which would be actually limiting the armature current well within the limit that can be tolerated by the commutator and the armature conductors most of the times when we design machines we will give a factor of safety of 2 or 1.5 or 1.75 depending upon what type of requirement I have.

For example if I am talking about an elevator, elevator will definitely have a requirement for a very high starting torque because many of us would get in and then after that only the motor is going to start. You have to have a large starting torque requirement in certain applications like for example an elevator, a train; a train will have multiple number of the cars attached right, bogeys attached to the engine. So all of them have to be essentially pulled, if all of them need to be pulled you require a huge amount of starting torque.

So if I require a larger starting torque very clearly as the torque equation indicates I will require a larger armature current as well. So I may put the limit on the armature current as twice the rated current or something like that the peak current that can be carried by the armature not on a continuous basis, for a short while. For a short while I may allow my machine to carry twice the rated armature current. So if I actually put a limit like that then I am going to include an external resistance so I would say $V_a / (R_a + R_{ext}) < 2I_{arated}$. I may put a limit like this.

So I would chose my external resistance value or the starter resistance value in such a way that the current is limited to two times the rated current, I am just giving an example it can be 1.75 it can be 1.5 depending upon what kind of requirement I have with respect to my motor. For example with the fan which is being driven by a DC motor and which is very similar to a windage loss. For a windage generally $T \propto \omega^2$. This is for windage which is actually showing how much is the resistance offered by the surrounding air, so if I have a load which is like an elevator if I have a load like a train or if I have a load like a fan the characteristics would be very different in terms of load speed torque characteristics.

So I am going to have the requirement of different values of torque for different situations according to which I will say my machine can carry a maximum of so much of torque or so much of current and so on.

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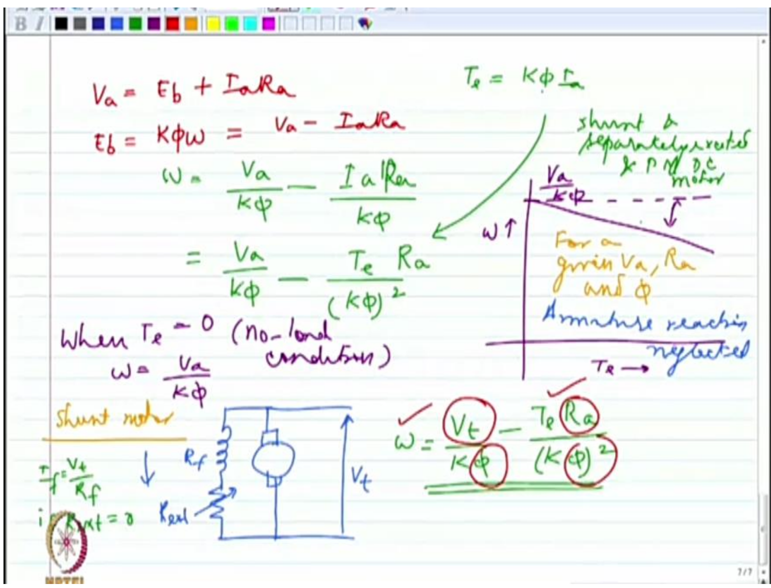

So coming back to what we said actually are the EMF equations which is $V_a = E_b + I_a R_a$, we can write $E_b = K\phi\omega = V_a - I_a R_a$, because of which I can write $\omega = \frac{V_a}{K\phi} - \frac{I_a R_a}{K\phi} = \frac{V_a}{K\phi} - \frac{T_e R_a}{(K\phi)^2}$.

So replacing $I_a = \frac{T_e}{K\phi}$, this clearly gives me a straight line torque speed relationship provided I do not consider armature reaction. I have not looked at armature reaction in this particular case. So If I do not consider armature reaction I am going to have basically if $T_e = 0$, $\omega = \frac{V_a}{K\phi}$, very clearly the armature apply voltage plays a very vital role in deciding what is the speed at zero torque or no load condition.

So if I assume that I do not have any drop in the speed at all. If it is an ideal motor, whatever be the load that I am putting I should not get any drop in the speed. But it had been the ideal motor I would have gotten the speed somewhat like this. But it is not an ideal motor clearly there is an armature resistance which is going to take a toll on the overall speed because of which I am going to have a drop in the speed.

So as I load it more and more I am going to have a drop in the speed and this actually is in one sense similar to I_aR_a, only thing is I can write this as a function of T_e because I_a and T_e are directly related. This is very clearly for a given so this relationship I should say is for a given V_aR_a and flux (ϕ). I do not want to change the flux it is a separately excited machine, I am going to keep the flux as a constant. I do not want to change the armature resistance it is inherently whatever is available, I am not really changing that and I am giving rated voltage.

So this is going to be the characteristics, as far as the speed torque characteristics are concerned for a separately excited machines. So also will be the case for a permanent magnet DC machine because permanent magnet DC machine again flux will be a constant I will not be able to change the flux. So it is exactly behaving in the same manner as that of a separately excited DC machine, right?

On the other hand if I look at a shunt motor. Yes?

Student: (())(13:27)

Professor: That I_aR_a loss but I am rather depicted this as $\frac{T_e}{(K\phi)^2}$. So it is actually $\frac{I_a}{K\phi}$ further.

Student: (())(13:42)

Professor: Which armature loss?

Student: (())(13:47)

Professor: I_aR_a is the armature loss. Armature voltage drop, so we are essentially considering the same thing. Armature reaction I am neglecting. If we are considering armature reaction clearly the reaction will be non-linear, it cannot be linear because the saturation will get into picture, non-linearity will definitely creep in.

So we have not considered armature reaction so I should say very clearly one more thing is armature reaction is neglected. So if I am considering a shunt motor because separately excited motor and shunt motor are almost similar in terms of their behavior, unlike the generator because in the case of generator I am not giving any supply to normally my generator at all if it is a self-excited generator. It is going to generate everything from scratch.

Whereas here what I am going to do is here is my armature and here is the field and probably I will include a resistance in series if I want to adjust the field. So let me call this as R_{ext} and this is R_f and this $R_{ext} = 0$ if I want to include minimum amount of resistance. So along with this I am going to now apply a voltage which I may call that as V because I cannot call it as V_f or V_a, I am calling that as V. Sometimes some of the books give this as V_t.

If I assume that again I have set this at minimum resistance value, with this as minimum resistance value I am going to get the field current which is actually going to be $\frac{V_t}{R_f}$ if R_{ext} is set at its minimum value or R_{ext}, this is what is going to be my filed current.

So as long as I do not change the R_{ext} value from zero and as long as I am keeping $V_t = V_a$, I am not really allowing that to be changed because it is a shunt machine I am just connecting a common supply I would say it behaves like a separately excited machine. So this is essentially going to have the same characteristics as $\frac{V_t}{K\phi} - \frac{T_e R_a}{(K\phi)^2}$. This is going to give me the same characteristics as long as I can keep the $R_{ext} = 0$ and I keep the power supply V_t as the constant for the armature as well as field.

So this is essentially the characteristic for shunt as well as separately excited and also for PMDC motor. So this gives me basically the characteristics for all three types of motors that is separately excited motors, PM motors as well as shunt motor. All of them are going to have almost similar characteristic because I am assuming that I am not including any extra resistance in the field circuit that is what I am assuming.

Now because I have this I should be able to say at the given torque if I want to get different values of speed I should be able to get different values of speed either by adjusting the voltage or by adjusting the armature resistance or by adjusting the flux value. So three of these different methods will be employed normally for speed control of DC motors.

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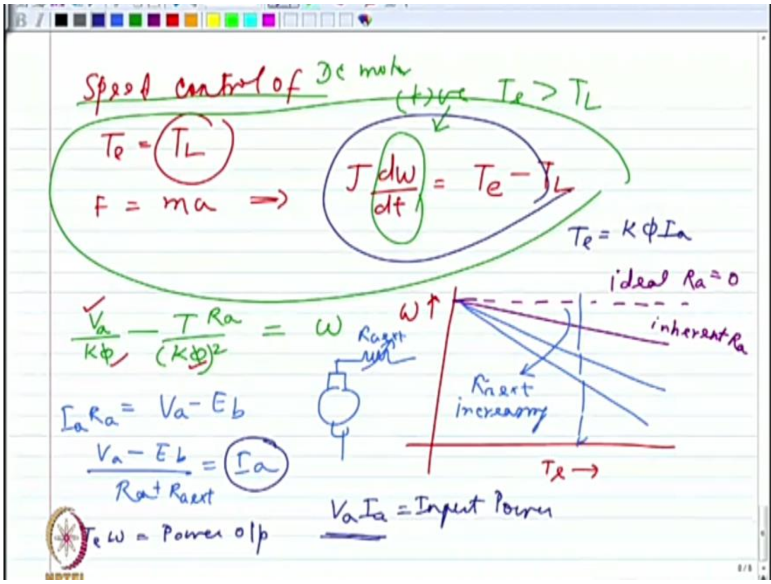

Student: (())(18:32)

Professor: No, back emf is basically whatever is the reaction that you are getting as the counter emf due to the conductors moving in a magnetic field, the conductors are moving in a magnetic field so it is getting an induced emf. But if you look at the armature reaction, the armature reaction is what is actually distorted on the whole in the original flux that you had looked at the machine.

So when you consider armature reaction it is not correct to assume that the flux is a constant. The flux of the machine which is actually produced by the field current that will not be a constant anymore, if I consider armature reactions then the armature conductors are carrying current. And in the case of motor the armature conductors will any way carry some current. As you load the motor more and more I will require more electromagnetic torque which means I will require more armature current.

If there is more armature current there will be more armature flux, there will be more amount of armature reactions so you might see more of the demagnetizing more of the cross-magnetizing and more magnetizing flux. So overall flux will distorted due to the cross-magnetization and overall flux will get depleted because of demagnetization, because the magnetization will not be able to increase it that much due to saturation. This is the major difference between armature reaction and the back emf.

The back emf is always considered, you can never ever consider the operation of a motor without a back emf but you can very well neglect armature reaction.

Student: (())(20:33)

Professor: That is what we said basically as the series field, the series field can be made into made in such a way that the series field can add or subtract. But if the armature flux itself is only adds all the time you would see ultimately completely Lenz's law being defined. Lenz's law has to exist, it has it cannot be defined so otherwise the flux will literally go to infinity.

Student: (())(21:10)

Professor: It is existing in the form of back emf but apart from that if you really make everywhere magnetizing. It is not possible you have to have dots somewhere cross somewhere.

And for the current to return you definitely have to have dots somewhere cross somewhere. So naturally if you have demagnetizing somewhere you will have magnetizing somewhere and vice versa. You cannot have everything to be magnetized it is not possible. So you are not going to be possibly looking at increasing flux in most of the cases in a DC machine due to armature reaction that is generally not possible.

Student: (())(22:00)

Professor: Windage laws if we want to neglect we can neglect I have not even included the mechanical equation as yet. I have to include the mechanical equation, if you look at the mechanical equation you have to say $T_e = T_l$. What you consider as the low torque is a matter of detail, if it is a fan type load I will write $T_l = C_1\omega^2$. If it is a constant torque load like an elevator I will write that as simply a constant C_1 or C_2.

If I am looking at it as a friction viscous friction, for example there may be a viscous liquid is being pumped, depending upon the velocities with which the liquid is moving you are going to have a corresponding value of load torque demand increasing proportionately. So you have load torque $T_l = K\omega$.

So we are essentially looking at the low torque as some value which depends upon whatever is your load mechanism, so I can have different types of load mechanism. What you have to understand is just like how you write $F = ma$ in the linear system I should be able to write $J\frac{d\omega}{dt} = T_e - T_L$

When I start the motor that is why I said if it is an elevator and let us say five of us get in the electromagnetic torque demand the low torque demand is fixed depending upon how many of us have got in. But the electromagnetic torque has to be slightly higher than that otherwise I am not going to be able to get an acceleration. I want this to be positive if this has to be positive then necessarily $T_e > T_L$.

For example five of us get in, the demand is 10 Nm then you have to generate in the motor at least 11 Nm, 12 Nm. Only then it is going to give an acceleration otherwise no way the motor will accelerate, right.

So we are looking at first of all only the electrical phenomena, all these are already involved mechanical phenomena what we are looking at. So mechanical equations govern the acceleration rate and the acceleration rate also depends upon T_e and T_e is governed by armature current. So we have a link between the electrical quantity and the mechanical quantity in the form of the electromechanical energy conversion.

So the current is being converted into torque in a motor, in the same way in a generator you see the same way from the mechanical power you are converting into electrical power, Right? So if you are actually looking at the speed control, let me write this equation once again. I am having $\omega = V/K\phi - T_e R_a/(K\phi)^2$, it maybe V_a or V_t does not matter. This is what we wrote as the speed torque equation.

Now if I am keeping V_a as a constant, I am keeping flux as a constant. I am only modifying R_a, if I am increasing the armature resistance by including some external resistance I am going to have more and more drop in the form of I_aR_a drop. Because of which if I actually look at the speed torque characteristic. If this is my speed this is the torque I am going to have probably under normal conditions without any external resistance being included it is falling maybe slightly. So maybe it was at 1500 rpm or something from that it may fall to 1400 or 1300 rpm so that is it.

So this ideal when $R_a = 0$, this is with inherent R_a, if I include more resistance if I am going to include more and more armature resistance. In that case I am going to have very clearly these characteristics will steeply fall because I am trying to actually drop a huge amount of voltage in the armature resistance itself. If you may recall we wrote $V_a - E_b = I_a R_a$, this is how we started the equation. So I should be able to say $\frac{V_a - E_b}{R_a} = I_a$, if we do not include any external resistance.

Student: (())(27:49)

Professor: I have not allowed the field current to increase I am keeping the field current fixed. I have applied a particular value of voltage to the field system so the field resistance is fixed 150 ohms to 200 ohms, the filed current is a constant. I am not allowing the field current to increase because I am keeping basically my voltage applied as a constant so it is not going to change. So field current is not changing I am including the increase in the armature resistance, what is going to happen to the speed provided I am looking at basically the torque demand?

This is the torque so maybe I am going to keep the torque demand at the same value. I can keep if I was also gotten into the elevator it is not going to change the torque demand whatever I do, maybe I would like to make the mechanism move at 20 m/s I may like to make it move at you know 1 m/s depending upon my whims and fancies I can always adjust the speed for a given torque. So this torque demand is a constant.

Let us say what I have demanded from the load side is a constant, under that condition I want to see whether I will be able to achieve different values of speed. That can be done by including an external resistance in the armature circuit. So if is say this is R_{aext} I can always modify the armature current by having R_{aext} value. If armature current is modified I am going to get immediately right away I am going to definitely get more amount of drop basically in the speed. So that essentially tells me that by adjusting the armature resistance I would be able to definitely get as speed control at a constant torque demand.

But this actually is going to be extremely lossy, if I look at the whole thing I am going to have extremely large amounts of losses. Please imagine the armature current is basically tenths of amperes of current and what I am including as an external resistance is going to have again probably some amount of large value. It may not be as small as armature resistance but still I will have maybe $1\Omega,\ 2\Omega$ whatever. So I am going to have a huge amount of power dissipation taking place in this particular you know method of speed control.

If I increase R_{aext} I am going to get more and more drop in the speed for a given torque value. If I am looking at a given torque I will have you know drop in the speed. Please realize also that $P_{out} = T_e\omega = V_a I_a$, I should not just say I_a it should be $I_a + I_f$, if it is a shunt machine. So this is going to be my input power so obviously I am going to have reduction in the input power also probably because of which I will have reduction in the output power not reduction in the torque but reduction in the speed.

Reduction in the torque is not visible but reduction in the speed.

Student: (())(32:03)

Professor: I am not keeping the torque as the constant if my mechanism asks for a constant torque value I cannot do anything right. If I am looking at basically that is why I gave you repeatedly elevator examples. Let us say we have gotten into the elevator and all of us are just staying there the torque demand is a constant because it has to go against the gravity. I can make it go against the gravity at 2 m/s 5 m/s. I want to change the speed, how do I change the speed at a constant torque demand. This is what we are looking at.

Please understand that the torque is set in stone, it is actually demanded by the load mechanism. I do not have a control over it. What I have a control over is the speed. See we are looking at $K\phi I_a$, so if I am looking at basically I_a decreasing in all probability in all probability right then I actually look at increase in the armature current rather increase in the current. My armature current should have dropped it will drop transiently. When it is dropping immediately what is going to happen is I_aR_a into R_{ext}, if I assume that it is going to be somewhat larger because R_{ext} has increased quite a bit.

I am definitely going to have a reduction in the back EMF as well so this actually will cause not reduction it will have an increase in the back EMF. So I am going to have actually immediately the speed will actually start dropping to bring down basically the back EMF. So what is going to happen is if I am looking at a small reduction in the armature current that happens transiently. The moment armature current drops I am going to see that the back EMF might increase slightly and the back EMF increases slightly then you are going to see that the speed will drop to bring down the back emf to the original value itself so that the entire balance is maintained.

If you have really a drop in the torque then the mechanism will lose its speed because of this particular balance this balance is lost, the load torque demand is the same whereas the torque what I have got is smaller. So the speed has to drop there is no other way. So it is actually a continuously self-correcting mechanism. The moment you reduce the armature resistance you may feel some oscillations in the armature current, you may some oscillations in the back emf. Finally it will settle down at a value where the original torque demanded remains the same, you come back to the original torque value but you are going to see that the speed has dropped.

This is what you would see because more amount has been dropped off in the form of I_a square R_a plus R_{ext} drop. So more power has been lost $P_{loss} = I_a^2\left(R_a + R_{ext}\right)$.

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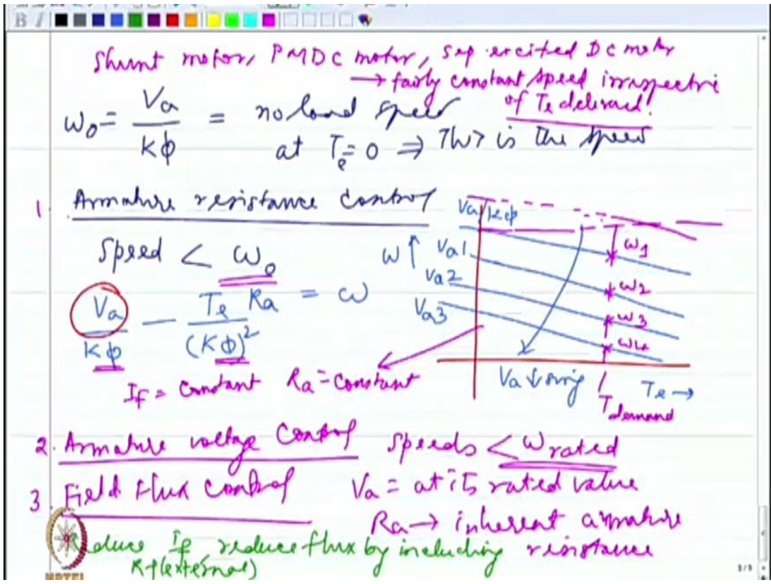

So this armature resistance control clearly if I am looking at $\omega_0 = {V_a}/{K\phi}$ as the no load speed or at torque equal to zero I am going to have this as the speed. I will have clearly armature resistance control giving me the range where the speed will be less than the no load speed, speed cannot be no more than the no load speed because I am subtracting it always from the no load speed. I have set V_a at a constant value so ${V_a}/{K\phi}$ is set in stone. Then I will be only able to reduce the speed further and further. I cannot go beyond rated speed, please remember what we have drawn as the characteristics, it is only coming below it cannot go above that is what I am trying to say. It cannot go above it has to always lie below ${V_a}/{K\phi}$, it cannot go above.

I am looking at only one variable at a time. I am not changing everything; everything if I change it will be more confusing. So I am looking at only one variable at a time so if I am looking at armature voltage changed please note that the slope of the torque speed characteristic is decided by what is the R_a drop, if R_a drop is more it was becoming more steep it was becoming steeper otherwise it is kind of the slope is very small.

So this is the normal characteristics for ${V_a}/{K\phi}$. If I am not changing the armature systems and if I am not changing the flux the flow should essentially remain the same, it cannot modify itself. So If I reduce the armature voltage I will have basically parallel characteristics. So this maybe for V_{a1} this maybe for V_{a2}, this maybe for V_{a3} and this is essentially V_a decreasing.

So this is T_e and this is ω then I reduce the voltage, maybe it is meant for 220 V. I can operate it at 180 V, I have a rectifier maybe I can put a autotransformer, autotransformer a rectifier I can always vary the voltage output of the autotransformer, the rectifier voltage will also change correspondingly, if the rectifier voltage changes I should be able to get different values of speed at a given torque.

So if I am talking about a given torque, this is the torque value demand, demanded. So if this is the torque demanded is should be able to get different values of speed maybe this is ω_1 this ω_2, this is ω_3, this is ω_4. All of them are changing drastically because of different values of armature reading.

Student: (())(39:56)

Professor: If it is a shunt motor, yes! It will affect flux also so this is much more valid for a separately excited DC motor or a permanent magnet DC motor, clearly. If it is a shunt motor and if I am using a common supply for both then I am definitely going to have a problem with the field current as well, that will also decrease. So I should assume that maybe it is a PM motor or at least in this particular case shunt winding I have to connect it to a separate power supply.

So I am assuming clearly here I_f is a constant and R_a is a constant. I am not changing them so I am assuming for these characteristics, these two hold good that is what I am assuming.

Student: (())(40:59)

Professor: You can vary R_f but you cannot you can only come down. R_f is the inherent field resistance you have R_{fext}. You can only reduce I_f you cannot definitely go for higher values of I_f because you are already operating close to saturation. And inherent resistance you cannot make a resistance possible that is the problem right you cannot really add a negative resistance that is not possible.

So this essentially tells me actually that we are having you know the armature voltage control method possible again for speed less than the rated speed preferably because if I am talking about a motor rotating at 300 rpm with a 220 V supply normally, under normal operating conditions with rated excitations and so on and so forth. If I say that if I want to achieve a speed greater than 1500 rpm that means I have to go for a voltage also which will be higher than this normal rated voltage. Only then I will be able to achieve a speed which is greater than the nominal rated speed.

So I have to constantly or permanently apply or continuously apply maybe 300 V, 280 V, only then I am going to get a speed which is higher than the normal values of speed that I operate upon with constant excitation and constant R_a, but this is definitely not good for the insulation especially if I do it on a continuous basis I would have basically designed my motor with the view point that I do not want it to generate more than this particular value, if it is a motor I do not want to apply more than this particular value.

So the insulations of armature windings would have been designed with the rated voltage in mind. So if I try to apply a larger voltage it is definitely not good for the machine especially if I do it for prolong periods of time. So generally armature voltage control is also used only for $\omega < \omega_{rated}$.

So whenever I am having a machine rated for say 1500 rpm means it will work as a motor with rated voltage, drawing rated current, delivering rated torque at rated speed. So if I say 2.2 kW motor, if the rated speed is given as 1500 rpm I should be able to calculate what is the rated torque, $T_e = \frac{2200}{\frac{2\pi}{60} \times 1500}$. I should be able to calculate the rated torque.

So when we talk about rated speed, rated speed corresponds to basically whatever is the motor delivering, the speed while it is delivering the rated torque drawing rated current from a rated supply with rated excitation all of them under rated conditions. That is what is known as rated speed. So this is the second method of speed control so we have seen armature resistance control and armature voltage control. Both of them are only meant for speeds which are less than either no load speed or rated speed and you also see that the shunt motor does not have much drop in the speed because R_a is generally small unless I include a very large external resistance I am not going to have much of drop in the speed.

So most of the time we can say shunt motor, separately excited motor or permanent magnet motor, all of them will be fairly constant speed drives or constant speed characteristics. They have fairly not exactly accurately but fairly constant speed because you would see that series motor is just the other way round. We will talk about series motor eventually. But what we see in the shunt motor or PM motor or separately excited motor. All of them have fairly constant speed irrespective of T_e delivered.

So we are essentially looking at the shunt motor or the PMDC motor as having fairly a constant value of speed provided of course V_a is a constant, flux is a constant and so on and so forth and R_a is also a constant.

Then last type of control is known as field flux control, the third type of control is filed flux control. It can be filed flux control or field current control because flux is controlled by having the current of the field circuit controlled. So again looking at this equation we can say we can modify the flux but keep V_a and R_a

as constants. I am not going to change both of them. So I would say V_a is at its rated value and R_a is inherent armature resistance.

So if I have no modification in the armature resistance and no modification in applied voltage very clearly this tells me that when I increase the flux which I cannot do much because I have already been close to saturation point. The only thing what probably I can do is to reduce the flux because I can include additional resistance in the field circuit and I would be able to deplete the flux if I want.

So originally maybe I had you know a flux of 0.1, 0.2 Wb now maybe I would try to bring it down to 0.05, 0.06 Wb. So I will be able to reduce the flux by reducing the field current, by including additional value of field circuit resistance. So I would be able to reduce I_f, reduce flux by including R_{fext}. I am going to include a field circuit resistance externally.

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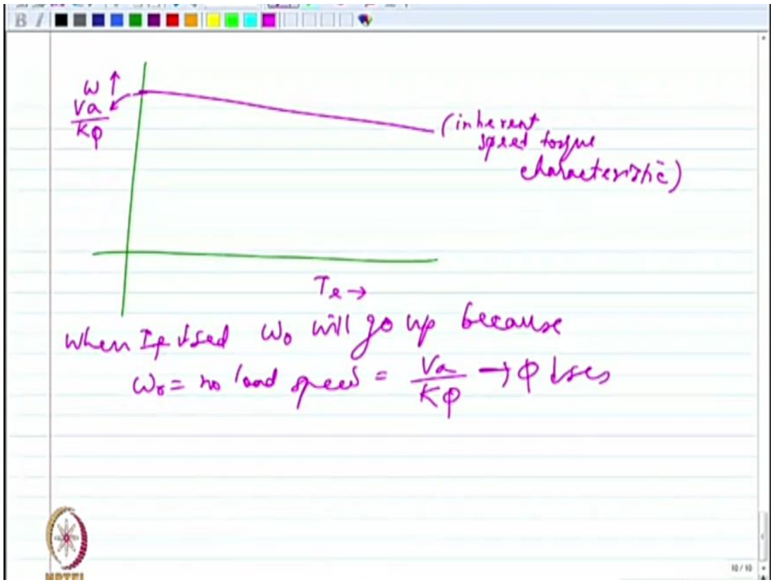

So what is going to happen in this particular case is let us say I have the original speed torque characteristics somewhat like this. This is my speed, this is my torque, and this is the inherent speed torque characteristic. What I mean by inherent is I am not intervened with any of the parameters, R_a is original value, R_f is whatever is the original value I am not including anything extra, what I am including as the armature voltage is rated value, I have not increased or decreased any of them. All of them are at nominal values.

So this is originally what I got as $\frac{V_a}{K\phi}$, speed is zero I mean torque is zero. So this is the no load speed of the machine $\frac{V_a}{K\phi}$. Now I am trying to reduce actually the excitation, very clearly when I_f is decreased ω_0 will go up. Because ω_0 or the no load speed is going to be $V_a/K\phi$ and ϕ decreases, because of which I am going to have definitely reduction in the flux will cause an increase in the speed.

If you actually look at the motor mechanism you can say if I reduce the flux at the given speed and my V_a is also constant, the back EMF will drop because the back EMF is proportional to flux multiplied by speed. The speed had been the same value; it is governed by the mechanical time constant or inertia so it will take a while before it changes. The speed will remain the same, I have reduced the flux. When I reduce the flux the back EMF is going to drop. When the back EMF drops immediately I would see the armature current rises transient in a transient manner.

Once the armature current rises I will probably generate a larger torque, if I generate a larger torque there will be an acceleration so the speed automatically increases. If the speed increases originally I had $K\phi\omega$, ϕ has decreased now the speed will hit that value such that $K\phi\omega$ comes back to its original condition. So invariably when you reduce the flux you will see a transient increase in the current which will eventually settles down at the original value itself but in the process if I_a settles down to the original value the torque has to drop because torque is $K\phi I_a$.