# Electrical Machines

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**Lecture - 22**

## DC Generator Characteristics and Introduction to DC Motors

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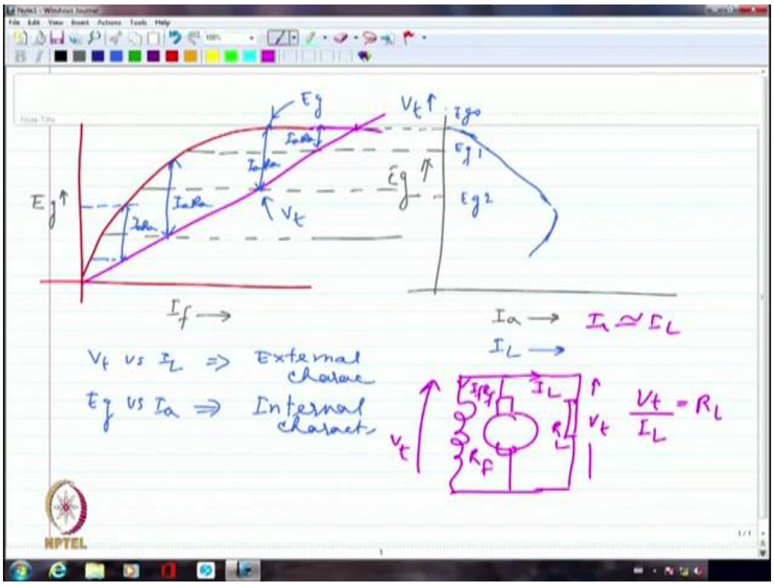


So, we had looked at the external characteristics of the shunt excited DC Machine then we had looked the compound machines how they will give the characteristics one small correction I would like to put up if you may recall we had actually drawn the magnetization characteristic somewhat like this and we had also drawn the field characteristic somewhat like this.

So, both of them wherever they interested we called this as the operating point under normal condition and we said this is $E_g$, and this is $I_f$, this is what we had said and then when I plotted external characteristic I should have taken the $V_t$ which is actually not $E_g$ it is the voltage across the field winding, so what we plotted yesterday was internal characteristics, that is known as internal characteristics.

Internal characteristics actually talks about, what is $E_g$ versus $I_a$, $I_a$ is the armature current which is internal current and $E_g$ is the internally generated voltage, so what we had actually looked at was each of these voltages, so we looked at probably some voltage like this, another voltage like this, the third voltage like this, the fourth voltage like this and so on, this is what we looked at continuously.

And then we had plotted basically whatever was the value available, probably if I just look at this point, this is what is $I_aR_a$ drop that is available and similarly, if I look at another point like this, this is what is the $I_aR_a$ drop available, so if I look at this as $E_g$ naught, $E_{g1}$, $E_{g2}$ and so on, correspondingly I would be able to get here $I_a$ is 0, here $I_a$ will be small value probably, so I should plot it somewhat like this, then probably here $I_a$ is larger, so I have to take it like this and so on and so forth.

So, I am going to have continuously you know increasing current and after sometimes, after sometime I am probably going to see that even in this case $I_a$ is pretty large whereas if I probably look at another voltage like this, Right? I am going to have something like this, so here probably $I_aR_a$ drop at this point is really not as large as what I am getting here, here it is larger whereas here this is going to be slightly smaller, so it comes in the decreasing direction.

So, when I plot $E_g$ versus $I_a$ I called that as the internal characteristics whereas if I plot $I_L$ versus $V_t$, so $V_t$ versus $I_L$ is known as external characteristics, Right? whereas $E_g$ versus $I_a$, is known as internal characteristics, please note that for this particular operating point this is $E_g$ versus this is $V_t$, there is a difference, huge amount of difference in terms of voltage, so I am definitely going to have less amount of $V_t$ available as compared to $E_g$, because $I_aR_a$ is the drop that is taking place internally, so we have shown a huge drop clearly that is what is going to word really giving me the armature current. Right?

So, this is actually the value which is corresponding to the terminal voltage, so the terminal voltage in this particular case if I look at $E_g$ it is here were as $V_t$ is here, so $V_t$ is going to be definitely smaller, because I am going to have basically $V_t$ is coming as the output which is also coming across the field, so this is $R_F$, so I am going to have $I_fR_F$ here and I am going have the load here and I would have $V_t$ is here and $V_t$ divided by whatever is $I_L$ is going to be $R_L$, so this is $R_L$, so this is $I_L$.

And $I_L$ is approximately equal to $I_a$ we can still assume because $I_f$ is very-very small fraction of the overall current that is been supplied by the armature, because of the fact that $R_F$ is going to be quite large, so I can still assume at least $I_a$ is approximately equal to $I_L$ but I cannot definitely assume $E_g$ equal to $V_t$, so that is the reason why just wanted to make this small correction. Any questions because I hear a lot of crosstalk if you have any questions please address it here, please, thank you.

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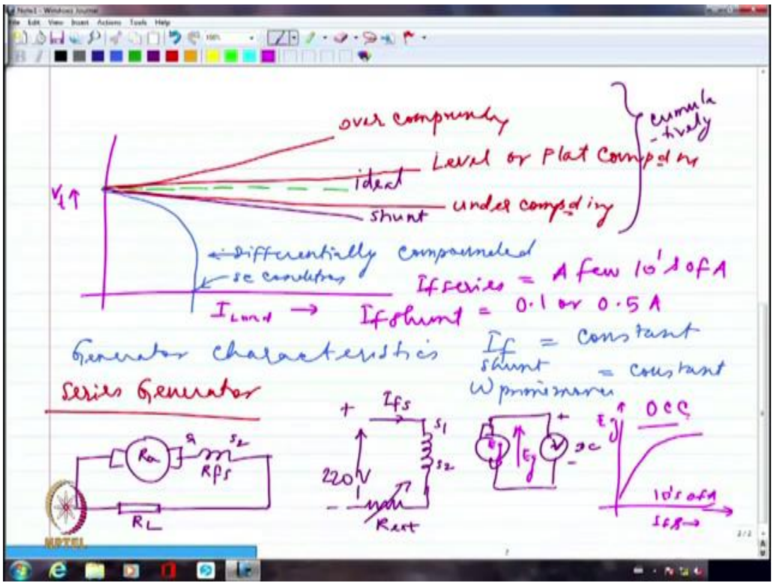


So, so much so for shunt excited generator I will again recall the characteristics what we draw for the compound generator, so we said basically again we are looking at the load current or armature current either way is fine and I am looking at what is $V_t$ the terminal voltage. So, if I am talking about ideal characteristics I should have had the characteristics somewhat like this, but if I am looking at the shunt generator characteristics or separately excited generator for that matter I will have a drop like this.

So, this is essentially let us say shunt no series at all, no series winding at all, so this must having the ideal characteristics but if I am providing compensation with the help of having a series winding which will actually increase the overall flux because the overall flux is going to be phi shunt plus phi series, I can provide excessive amount of compensation in which case probably the voltage will rise quite a bit.

So, I would call this as over compounding, whereas I may have somewhere in between the shunt configuration and the actual ideal configuration or level compounded configuration, we will call this as under compounding whereas if I am having the compensation in such a way that it is almost closed to the ideal characteristics, Right? very close to the ideal characteristics which will actually have the terminal voltage fairly constant, irrespective of the load the time putting on the machine, then I may call this as level or flat compounding.

So, these 3 actually are coming under the category of cumulatively compounded generator. So, cumulatively compounded generator indicates that the series and shunt are always in the aiding configuration, they are going to aid each other were as the last one what we just said was differential compounded, so in which case it is going to fall dawn to 0 voltage condition because I am going to have at some point the series field completely killing may be the shunt flux, because of which the overall voltage that is generated itself is going to be come eventually 0.

So, this we call as the differential compounding, so this is essentially the characteristics of a differentially compounded generator, differentially compounded generator has only one single application, only one application that is generally in welding. In welding in invariably when the work piece is getting stuck to you know the electrode, then we are going to have a dead short circuit, it is a dead short circuit, so if I am having dead short circuit still I do not want the current to go to extremely large values.

So, this essentially tells you the short circuit condition, this is the short circuit condition literally, so in the case of short circuit condition where I want to limit the current still and short circuit means voltage is 0 obviously, so this really comes in handy because I do not have to put any special control for making sure that the current you know does not excide a particular set limit I do not have to do anything.

So, in the case of welding generator I can use a differentially compounded DC Generator which is work perfectly fine especially when the work piece and the electrode are getting stuck to each other, you will still have a short circuit condition with limited current because the voltage itself is getting really limited in the case of differentially compounded generator whereas all the other applications would require generally cumulatively compounded generator, if I am talking about holding the voltage almost as a constant, or if I want slight increase in a voltage during the machine being loaded further and further and so on.

So, generator characteristics are generally drawn with the field excitation most of the times that is the main field excitation generally is kept as a constant, we tend not to vary the $I_F$ shunt, generally we try to keep this as a constant also omega of the prime mover we try to keep it as a constant. We tend to keep this 2 as a constant because we are looking at the capability of the generator to generate a given voltage and a given amount of power or current when I am holding these 2 as a constant, that is when I keep the excitation as a constant and when I keep actually the speed also as a constant, please understand the speed is the characteristic of a prime mover and I am not testing the prime mover.

What I am testing is a generator, so I would not like to really take the prime mover characteristic inter count, I would like to keep the speed as a constant, at a given speed how my generator responds that is what is my concern. So, generally when I draw the generator characteristics I would like to keep this 2 as a constant, the field excitation I would keep as a constant at rated excitation. I have defined already what is rated excitation; rated excitation is that particular value of field current at which my machine will be generating rated voltage, Right? with the speed being at rated speed or given speed, whatever is the given speed that will be at rated value.

So, only that is known as the rated excitation, so I am going to keep the field current, shunt field current especially at rated value. Right? Last what we are going to discuss is the series generator which is hardly ever used, it is hardly ever used but just for the sake of continuity we are going to discuss about it and this is used as a motor quite often series motors employed ever where, but series generator is hardly ever employed, think about it as far as the series generator is concerned I am going to have the field here and I have to connect the load here. Right?

So, if I do not have any load there is no field current as well, if there is no field current there is not going to be much of generation except for the residual magnetism, so it does not make really any sense to draw the open circuit characteristics of a series generator because if I keep it as an open circuit, there is a question of field current if the field current is not there I am not going to really draw any characteristic at all, so there is no point, so that is the reason why normally if I call the series field as S1 S2, I am going to actually separately excite this S1 S2 to draw the open circuit characteristics that is the only way out to draw the open circuit characteristics of a series generator.

For that I have to first of all separately excite S1 S2 give different value of field current and see what kind of voltage is generated across this armature, so I am going to put a voltmeter here, so I am going to connect a voltmeter with, you know, plus minus DC voltmeter of course I will put a DC voltmeter with plus minus like this that is essentially going to give me 4 different value of the field current.

What I am to get as basically the voltage generated across the armature but one thing we have to be careful is because the series field is always connected in series with the armature I will have $R_a$ and $R_f$ series comparable with each other, what I mean is if I say it is 0.2 ohms or 0.3 ohms that is what is the armature resistance the series field resistance is also going to be only 0.2 or 0.3 ohms nothing more than that because it will be require carrying the same current as that of the armature current, Right? but what I am applying is maybe 220 volts, I may not have any other supply in my laboratory or in my you know industrial environment.

So, when I want to conduct a open circuit characteristic test, I have to necessarily apply 220 volts and if I am applying 220 volts to a 0.2 of resistance huge amount of current will flow, so I cannot afford to do that and also please realise that this is going to have a back EMF in all probability or generated EMF even if I am looking at it as a motor.

So, if I look at the series field winding, the series field winding and the armature current, armature resistance along with the load resistance are limiting the current all of them put together, so $E_g$ divided by R series plus whatever is $R_a$ plus $R_L$ all of them are coming in series that is what is limiting the current, so if I just applied 220 volts to the series field winding there is nothing to limit the current properly.

So, I have to include necessarily and external resistance, unless I include and external resistance, I am going to see that the series field is going to draw enormously large current, very-very large current, so it is definitely not a viable option to connect 220 volts supply directly across the series field, so I necessarily need to connect an external resistance.

So, I am going to have the current that is flowing through the series field circuit, let me call that as $I_{fs}$ series field current, so I can adjust this current by adjusting the external resistance and I would be able to get an open circuit characteristic even for this, so the OCC will have $I_{fs}$ on one side and $E_g$ on the other side, so this is $E_g$ what I am getting here is $E_g$.

So, I am going to have essentially the open circuit characteristics if plotted and that will be probably somewhat like this. Right? Now, with this as the characteristic I should be able to definitely say that this $I_{fs}$ compare to $I_{f\ shunt}$, $I_{f\ shunt}$ might have been 0.1, 0.2, 0.3 amperes whereas $I_{fseries}$ will be 1 ampere 2 ampere 3 ampere and so on, please understand this because the series field will always carry armature current which is of the order of a few amperes because the armature resistance itself is only 0.1, 0.21 that is what it generating the power ultimately, whereas shunt field has 150 ohms or 200 ohms as it resistance.

So, if I apply 220 volts divided by 200 ohms I am going to get very-very small current. So generally if I look at $I_{f\ shunt}$ it will be of the order of only 0.1 or 0.5 ampere, whereas $I_{fseries}$ will be of the order of a few 10s of ampere if it is a larger machine even larger then that it will few 100s of ampere, in fact, it depend upon the rating of the machine, so it is not going to be a small current, so this will be very clearly 10s of ampere in all probability, Right? whereas in the shunt field when we draw the open circuit characteristics you will always look at the current value to be about 0.1, 0.2 that is it.

So, the low ranger meter will be used in shunt generator field coil high ranger meters will be used in you know the series field coil always, so this is the OCC of the series generator.

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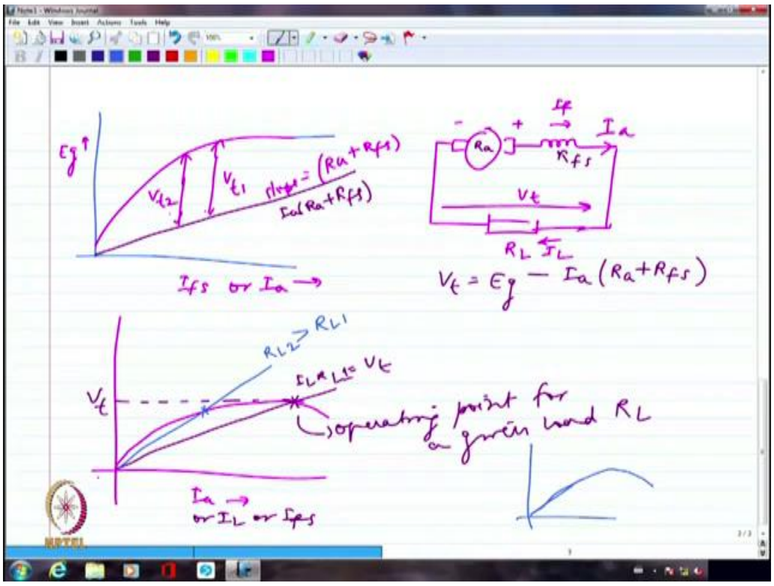


So, now let us try to look at again the external characteristics briefly, so if I am going to have actually this as the OCC, Right? this is $E_g$ and this is going to be my $I_{fs}$ or I would say this is also incidentally $I_a$ later on when I am going to connect it really as a series generator, so when I connect it as a series generator I am going to have this along with this field and then I am going to have the load here, Right? so this is $R_L$, this is if I say this is plus and this is minus I am going to have this as $V_t$, the terminal voltage Right? and I am going to have $R_a$ here and $R_{fs}$ here.

So, if I look at what is the drop and what is terminal voltage, the terminal voltage is going to be $E_g$ minus $I_a$ multiplied by $R_a$ plus $R_{fs}$, Right? that is how it going to be, so I should probably have that line drawn like this, I am just are arbitrarily drawing a line which is actually $I_a$ multiplied by $R_a$ plus $R_{fs}$, so the slope of this line is clearly will be $R_a$ plus $R_{fs}$ what is the series field resistance plus armature resistance together.

Now, whatever is leftover will be only this much will be the terminal voltage, this is what is available as the terminal voltage, so this is what is $V_t$ at every point whatever is the difference between the open circuit characteristics and whatever is the field resistance plus armature resistance line, the difference between this two come up as the terminal voltage, so I am going to get terminal voltage at every point, this is $V_{t1}$ may be this is $V_{t2}$ and so on and so forth, this is what I am going to get as the terminal voltage.

So, if I want to really plot the external characteristic I have to say it is $I_a$ after all $I_a$ equal to IL equal to $I_f$, there is no difference at all, please note that this current is the same if I make all this as $I_a$ or this is $I_f$ or if I call this as $I_L$ all of them are the same, all of them are in series, so all the 3 are essentially the same in a series machine.

So, now if I actually plot how this value would be, it will be definitely less than $E_g$, terminal voltage will be less than $E_g$, so it may start like this and them I should draw, definitely the amplitude what I am getting will be smaller and smaller probably I am going to have more and more drop so because of which it might actually fall, eventually the voltage will definitely fall because $I_a$ is increasing $I_a$ multiplied by $R_a$ plus $R_{fs}$ will definitely increase.

So what is available at the load terminal will fall eventually, so this is how it going to be and if I have actually the load characteristics which is $I_L$ multiplied by $R_L$, maybe if I have $I_L$ multiplied by $R_L$ at this particular line, load line this is the load line. So, in which case this is equal to $V_t$ that's what we are drawing, so this is $I_a$ or $I_L$ or $I_{fs}$, all of them are the same, so it does not matter I can write anything as my you know x axis.

So, this will be the operating point for a given load where the load line is intersecting with this characteristics, so this is going to be actually the $V_t$ value, Right? if I have a different value of load resistance, may be the load resistance is larger, so let me call this one as $R_{L1}$, if I have a different value of load resistance may be somewhat like this where $R_{L2}$ is the load resistance which is greater than $R_{L1}$. In that case the voltage happens to be much smaller, so as I increase the load resistance further and further or as I draw smaller and smaller current I am going to have less and less voltage as the operating voltage for my series generator. Right?

Conversation between professor and student starts.

Student: (())(25:43)

Professor: It will decrease after some point because if I look at the drop $I_aR_a$ drop, $I_a$ multiplied by $R_a$ plus $R_{fs}$ drop will be quite sumptuous as compare to what I am having as the saturated value of voltage, please remember that the voltage is going to saturated, this voltage is saturating it is not going to increase much, so that is like a constant out of which I am cutting of $I_a$ time $R_a$ plus $R_{fs}$.

Student: (())(26:21)

Professor: No, see until here it is increasing, until here it is increasing, so I am showing the increase probably until sometime after that itself it should start dropping, yes, you are right the flat portion will not be their much, it should start dropping.

Conversation between professor and student ends.

You got his question what he is asking is if the voltage is shown to be flat the saturation has been you know attained then after that itself it should start dropping right away because the voltage is a constant $I_aR_a$ drop is continuously increasing as my $I_a$ is increasing, so you should not have any flat portion at all, it should start dropping right away.

What he means is I should have probably drawn the characteristic, it is increasing alright and after that it should start dropping hardly ever there should be a flat portion, in the series generator that's right. So, this essentially completes our discussion on the generator operation and the generator characteristic as far as the DC machine is concerned.

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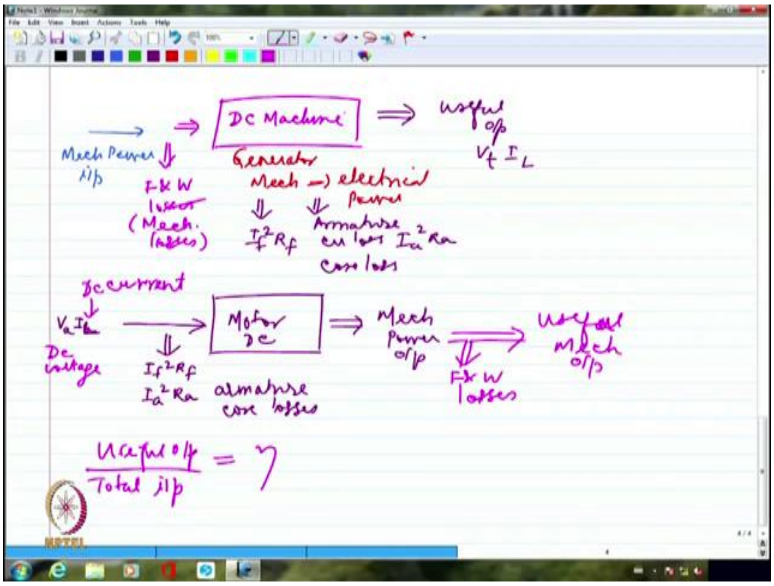


Now, we are going to migrate to motors. What we looked at so far is I am giving a mechanical power input some portion goes away as friction and windage losses which are actually corresponding to the rotational losses or mechanical losses, friction and windage losses as I told you friction all of you know windage is due to the wind which is surrounding it which is going to actually impede the motion because you are not really looking at the machine running in vacuum it is surrounded the air, so it is known as the windage loss.

So, friction and windage losses are mechanical loss. What is available after this is actually being said to the DC machine? This DC machine which is working as a generator is actually converting the mechanical power into electrical power that is what it is doing and through the electromagnetic you know via media in between you are having the via media that is what is allowing the conversion to take place.

Now, very clearly even this will have some losses, one of the losses that we normally see is $I_f$ square $R_f$ in the field circuit I am going to have definitely some losses I would not really called them as exactly core losses because it is actually the copper loss, the resistance of the copper winding which is existing in the field, after all I am sending a DC, so there is no question of hysteresis loss and eddy current loss in the field circuit, so I will not called them as core losses it is $I_f$ square $R_f$ which is the copper loss inside the system.

Then I am going to have armature copper loss and armature might also have some core loss, so armature will have some core loss, please understand armature is carrying you 1know a current which is alternating, which is not a DC current that is why armature core has to be laminated so I will have to definitely account for the armature core losses and the armature copper losses which are actually $I_a$ square $R_a$ apart from that I will have core loss also in the armature.

Now, what is available after this is going to come out as the useful output which will be $V_t$ multiplied by $I_L$ this is what is the useful output that is available in the form of the load current multiplied by the terminal voltage that is the useful output power. So, this is essentially my generator power flow how exactly the power flow takes place in the generator, whereas if I look at the motor, I am going to have the motor here, where I have to give actually the input at may be $V_a$ and $I_a$, so I have to give armature voltage and armature current totally.

Rather than saying $I_a$, maybe I might like to say it is $I_L$ because it is the total line current that I am passing into the machine, may be if it is a shunt machine I am going to have some amount of current being carried by the field circuit, some of the current being carried by the armature circuit, so it is better to write this as $V_t$ multiplied by I=, out of which again I will have some portion actually lost probably as $I_f$ square $R_f$ some portion probably last as $I_a$ square $R_a$ and also armature core losses.

So, this will be lost definitely as some of the losses after I give certain amount of power to my machine in the form of electrical power, Right? now what is coming out ultimately is actually the mechanical power output, now what is actually lost from here is friction and windage losses, now what is left over finally is the useful mechanical output, so this is going to be the useful mechanical output that comes out.

Conversation between professor and students starts.

Student: (())(33:04)

Professor: Generally in DC machine we are not going to laminate the field and we are going to always give a DC current, DC current to excite the field, so what I am giving here is also a DC voltage, this is a DC voltage and this is a DC current. Because it is all DC completely there is no hysteresis, there is no eddy current, eddy current and hysteresis will show up only if I am going back and forth in terms of the flux or if I am traversing hysteresis loop which never happens in a DC machines field system. Armature you are having AC right commutator and brushes we put only because what we are having inside is AC what comes out is DC by the split ring.

So, what is inside is AC, so it will have hysteresis losses, eddy current losses that is why we wrote armature core losses, so armature will have core losses whereas field will not have core losses, Right? so this is going to be the basic power flow diagram as far as the DC motor and the DC generator both are concerned, so when you calculate the efficiency finally we will say useful output whether it is mechanical or electrical is a matter of detail depending upon whether I am talking about the generator or motor divided by total input this is what is the efficiency.

So, the efficiency will be calculated based upon the total input time giving and what is the useful output I am having ultimately and the ratings are generally given in the form of whatever is the useful output, so if am given for a DC machine it is a 2.2 kilo watt machine 2.2 kilo watt indicates the useful output that will come out but when I am giving the voltage and the current the rated current and rated voltage if it is a DC motor that indicates the input obviously, if it is a generator that indicates the output. Right? So, voltage and current when I specify very clearly in a motor it is going to indirectly talk about the input.

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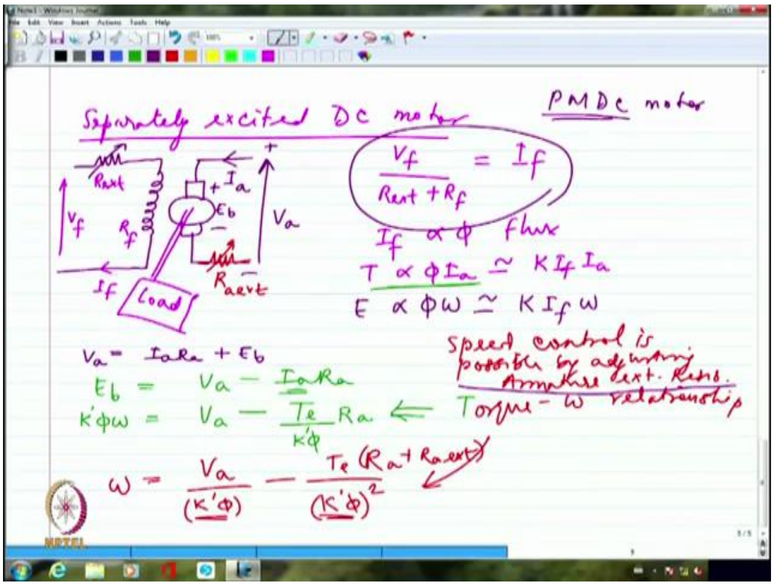


So, let us now try to with this background let us try to look at the DC motor configuration, so let me start out with separately excited DC motor, so I have a separate excitation for the DC field winding, so this is going to be my armature I am actually connecting a voltage supply which is $V_a$ let me probably say this as positive this as negative, so I am inputting a current in this direction let me call this as $I_a$ the field is separately excited, so I am going to have the field connected to a separate source probably with a field resistance as well which is a variable resistance.

So, this is $R_{external}$ and this is going to be $I_F$ and what I am actually connecting here is $V_f$, in all probability in the laboratory an all I am going to have $V_f$ and $V_a$ to be almost of the same value 220 volts or whatever, so I will as a rule have $R_f$ to be pretty large because of which $I_F$ will be only order of one ampere or less, it going really really small. So, $R_f$ basically will be very large so I am going to have $V_f$ divided by $R_{external}$ plus $R_f$ is equal to you know $I_F$ whatever is the field current. Right? Now I am going to have this $I_a$ passing through this and of course the load is now coupled to the shaft of the DC motor, so I am going to have a mechanical load coupled here.

Conversation between professor and student starts.

Student: (())(38:06)

Professor: In case I want to reduce it further for some reason, if I want to reduce let us say the current further for some reason we will look at speed control there we will see that we might play around with the field current a little bit in a DC motor, Right? please understand that $I_F$

is going to be somewhat proportional to the flux, so if this is proportional to the flux, the torque is proportional to phi multiplied by $I_a$ this is what we said, so I can say indirectly this is approximately equal to some constant multiplied by $I_F$ multiplied by $I_a$.

Conversation between professor and student ends.

So, if I want to adjust the torque I might like to adjust my field current or armature current as the case may be, so whenever I want a torque control I might adjust my armature current or field current, so this essentially tells me there is some kind of control operations I can incorporate in to the DC motor to arrive at the required value of torque required value of current and so on required value of speed and so on.

One more equation we wrote for the DC machine in general is E is proportional to phi multiplied by omega, so I can write this to be approximately equal to K times may $I_F$ multiplied by omega which indirectly tells me maybe I can I have a control over the speed by adjusting probably the voltage which is actually the back EMF in this case it is not really applied voltage.

Let me now try to write the electrical equation, these are some of the equations which we already knew, let me try to write the electrical equations, we wrote one of the electrical equation already. Right? Now, I should be able to say $V_a$ equal to clearly $I_a$ time $R_a$ but I will definitely have a back EMF induced whether I like it or not and back EMF by which you are following Lenz's  law it has to definitely oppose whatever is the original voltage.

So, I should have the back EMF actually having the positive here and negative here so that they are not in series addition they are in series opposition, so $E_b$ and $V_a$ are going to be in series opposition, you think about it you have basically a conductor sitting inside the armature I have applied a voltage, Right? then I have applied a voltage it is going to carry a current in all probability and enormously large current unless I limit it so it is going to carry a large current and it is going to generate a torque because of the torque it is going to start moving.

When it is moving, the same conductor which is actually sitting in the magnetic field and it is moving will have an induced EMF and that induced EMF we called as the back EMF or counter EMF, that counter EMF cannot be dominating over the applied voltage, if it is dominating over the applied voltage the entire action of the machine is killed that is it, it is not going to have any current, so necessarily that voltage is slightly subdued or less then whatever is the applied voltage.

So, that is less by what amount that will be less by $I_a$ $R_a$, so I am going to have $V_a$ equal to $E_b$ which is actually working like a voltage source which is opposing the applied voltage, so I am going to have $V_a$ equal to $I_aR_a$ plus $E_b$ or on the other hand I can write $E_b$ equal to $V_a$ minus $I_aR_a$ which I can again write this is some K $I_f$ omega or k dash phi omega, Right? which will be equal to $V_a$ minus I can write $I_a$ as torque divided by k phi, Right? so let me write this as torque electrode magnetic torque divided by k phi multiplied by $R_a$.

This gives me the torque speed relationship of a separately excited DC motor, so this is the governing equation for the torque speed relationship of a separately excited DC motor, so this is essentially the important relationship for a machine which is working as motor, ok k dash I can write this as a k dash thank you.

So, this is the back EMF constant or toque constant that is k dash, so I should be able to write now the equation as omega equal to $V_a$ divided by k dash phi minus $T_e$ divided by k dash phi the whole square multiplied by $R_a$, so this gives me the torque speed relationship for a separately excited DC motor and if I want to keep the flux as a constant because it separately excited motor I have a complete control over the field current that I am passing it is an independent supply, if I assume that I am keeping it at rated value the flux or the field current at rated value, at rated value this is going to be a constant this is going to be a constant. Right?

So, I can directly say by adjusting the armature resistance I should be able to get a speed whatever I want probably given the voltage, given the torque and so on and so forth, I am just giving you an example, let us say a DC motor is driving our elevator, Right? maybe if I was have got and in which means the torque is a constant the torque to be developed by the machine is fairly a constant, so I can try to run the machine at whatever rpm or whatever speed I want provided, I actually adjust my armature resistance or externally I can include a resistance in the armature circuit.

So, along with this if I want I can always include a resistance in the armature circuit, if I include a resistance in the armature circuit that will actually modify this equation to $R_a$ plus $R_{external}$. So the moment I include a resistance in the armature circuit I am going to get clearly you know a variation in the speed while developing the same amount of torque, so this tells me basically I will be able to adjust the speed while adjusting the armature resistance external resistance, internal resistance I can't do a thing, it is set and stored.

So, I can include and external resistance to bring down the speed that is possible because it will only bring down the speed at a given torque value, so this tells me that speed control is possible by adjusting armature external resistance, Right? so this is one of the speed control methods which we will talk about eventually, so this is an important relationship in a DC motor which is a separately excited DC motor that we are talking about right now where we are going to be able to adjust the speed versus a given torque by adjusting the armature resistance, incidentally some of the motors may not have separate excitation instead they may have permanent magnet inside, that is the as good as a separately excited DC motor but with constant excitation.

Say, if I have a small permanent magnet with north and south poles already because of the magnetic material which is giving me fixed amount of flux that is essentially going to resultant you know the motor behaving very similar to a separately excited DC motor but with constant excitation, in which case I will also avoid $I_f$ square $R_f$ losses, there will not be any $I_f$ square $R_f$ losses that is the measure advantage so I can say basically permanent magnet DC motor and separately excited DC motor both behave the same way there is hardly any difference except for the fact that I cannot adjust the excitation. In separately excited DC motor I can adjust the excitation in a permanent magnet DC motor I cannot adjust the excitation. Right?

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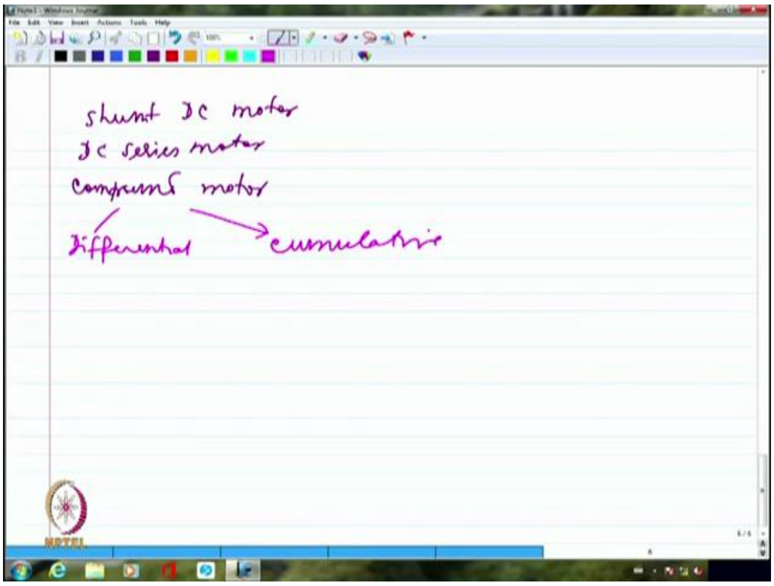

So, the next one we will be discussing I am just not going to immediately start discussing but the next things that we will be discussing will be shunt DC motor, DC series motor and we will also be looking at compound motor. So in compound, of course, we will be looking at differential and cumulative both we will be looking at and then we will be deriving the speed torque characteristics for each of this motors, we will be deriving the speed torque characteristics or relationship for each of these motors.