Electrical Machines - I
Prof. Tapas Kumar Bhattacharya
Department of Electrical Engineering
Indian Institute of Technology, Kharagpur

Lecture - 67
Load Characteristic of Shunt Generator

So, welcome to 67th lecture on Electrical Machines - 1 and we have been discussing about DC generator.

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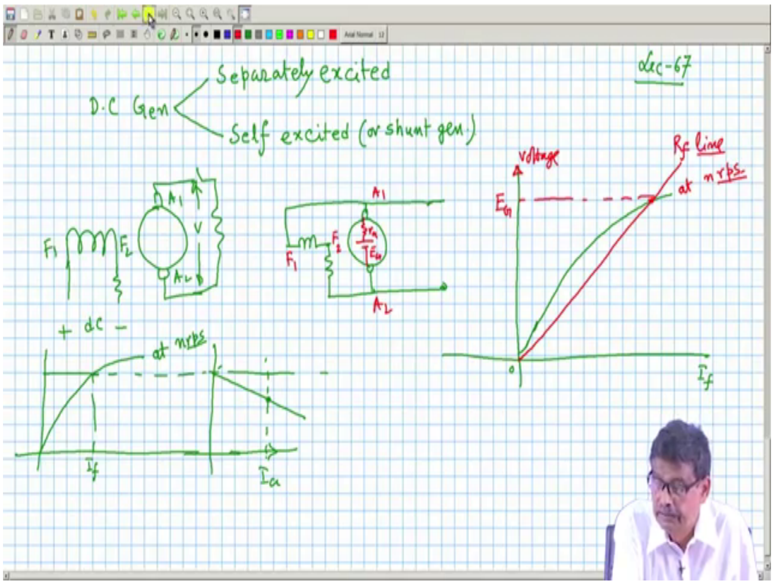

And DC generator primarily are of 2 types we have discussed, one is a separately excited generator and another is called self excited or shunt generator self excited or shunt generator. Why it is self excited? You do not require any DC supply applied that is to generate a DC voltage you will not ask for another DC supply needed that is the beautiful thing about self excited generators or shunt generators ok.

Now, these are the things in case of separately excited generator you have this field winding and excited from a separate DC source with the resistance connected whatever it is DC source and you get the generated voltage. In case of and these are the armature terminals F 2 field terminals and in shunt generator what you do is this, this is the field winding same field winding F 1 F 2 connect an external resistance connect in parallel with the armature and this will be these terminals.

The value of r a is much smaller compared to the total resistance of the field coil and we have seen that it is open circuit and load characteristics is where it was like this, o c c of this generator was like this. And at, but do not forget to mention at what speed attain rps said it at speed and this is suppose the rated voltage. This is the nominal field current and at the load characteristics of this generator will be load characteristics is always sketched against I a and terminal voltage that is air I will connect load terminal voltage is this voltage v.

And we have seen this will be a grouping characteristics try to draw more and more armature current of course, there is a rated current of the armature beyond which you will not go. So, from no load this voltage will drop because of no load voltage it is E G minus I r a minus brass drop and because of armature reaction also a little bit of voltage drop takes place and armature reaction aspect I will take later as I told you, but this is a the overall thing here.

In case of shunt generator that is you are discussing all right now it will it will be like this. That is you have to run the machine as a separately excited generator and what will be the voltage available under no load condition is decided by and mind you here I should be also drawing correctly it is like this there is a residual field must be there it will not pass through origin, even if field current is 0 there will be some little induced voltage.

In fact, that is the reason you at the end get a very large voltage and how much voltage to which this machine will excite, it depends upon what is the value of the field circuit resistance this is called R f line. Which is just the V I characteristics of the field circuit, this is voltage axis and how much voltage the generator will generate? It will generate across the armature A 1 A 2 this generated voltage will be about E G is not.

To be very frank this is r a and here is your E G. So, E G minus with this switch open it will be minus this field current into r a, but r a is very small and I f is also very small because this is very high so, it is approximately this E G will come. Now and here also you do not forget to write at n rps when the machine was this characteristics I in fact, used here that you must understand to get a feeling of the amount of voltage available from this DC generator connected in a shunt fashion. Shunt means parallel armature and field windings are in parallels that is fine.

Now, what about the load characteristics? So, so I will go to next page.

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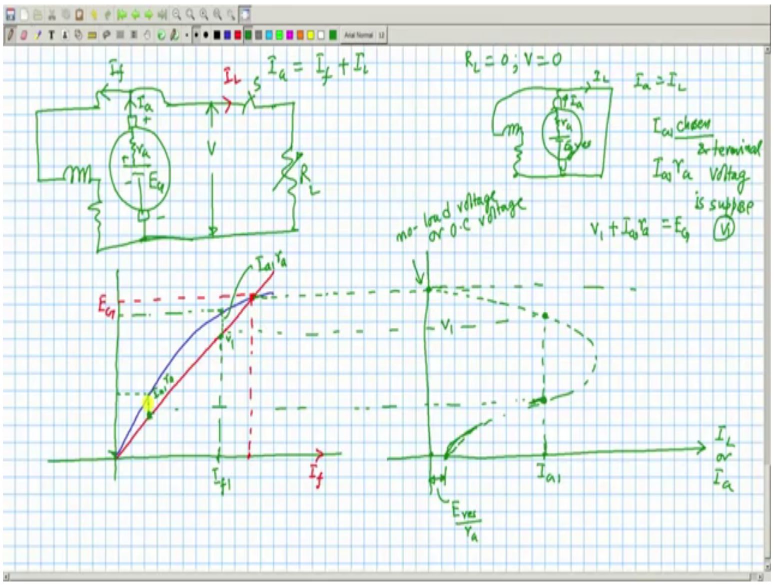

So, it is a nothing wrong if I redraw the things once more. So, this is the circuit diagram because that will be needed and this is your armature terminals and this is your field circuit terminals and here is the switch, where I will connect load, load means a resistive everything is DC load resistance and that is all.

Now, the open circuit voltage with is opened we know what is the voltage developed, that is this is the point of intersection this much is the voltage ok and in this axis mind you this is field current and this is the this voltage is the open circuit voltage. When the load current is 0 this current you can easily see this is not a armature current, because there is a junction armature current will be here if I draw it properly it will be here.

Suppose I show this branch also then it will be much more clear this is the thing I have parallel them this is I L this is I a and this is I f assuming polarity of the induced voltage this side plus the side minus. Mind you in case of generator if you want to reverse the polarity of the induced voltage E G is equal to k phi n. You can either change field current direction supply polarity of a separately excited generated if you reverse keeping the direction of rotation same.

If this is plus, this is minus, then if you reverse field current keepings direction of rotation same supply voltage will reverse it is polarity. If you reverse both of them both the direction of field current as well as direction of rotation polarity of the induced voltage will remain same, because k phi n. Anyway these are important things, but it should you should be very clear about that so, this is the thing.

Now, this one is called the at open circuit and what is the load characteristics, load characteristics looks like I can sketch for load current versus the terminal voltage or armature current versus the terminal voltage either of them I can do, because external load current whatever you are drawn drawing with respect to that how terminal voltage is changing I can find that out.

Therefore if I say that this axis I can sketch I L or I a and so, when I L equal to 0 then the generated voltage open circuit voltage is this voltage is not that is what I will get, terminal voltage here this voltage and as I told you this is r a here is your E G. So, little drop I r a you can neglect or whatever it is so, it is like this.

Therefore if you start drawing current I L it is expected that terminal voltage will fall, because E G minus I r a will come into picture more current I L, I L is approximately equal to I a. So, the anyway this can be written as k c l I a is equal to I f plus I L, what I am telling I f is pretty small because the resistance of the field circuit is many times more than real load resistance. Anyway, so this is the thing, about one thing I am sure that is with respect to a separately excited generator I told you if you go on reducing the load resistance and if by chance a short circuit takes place here that is zero resistance current will be very large armature current you recall that.

So, for example, here in fact, it is there I will show you. So, this is the thing if this terminal is shorted this current will be pretty high, terminal voltage 0, how much will be the current very large, what is the order of the current, that generated voltage E G divided by r a, E G by r a if it is shorted very large current will flow, now let us see that extreme point first in this case.

Suppose you will connect a load resistance next page I think I went yeah. So, suppose this is the switch it is connected, armature current is flowing which cannot now be neglected compared to I L, I a will be of the order of I a and suppose I make this terminal resistance load resistance suppose 0 that extreme case let me first tell you. If a short circuit occurs what is going to happen? How much will be I L? How much will be I a?

That is the question [FL], one thing is clear if a short circuit occurs that is R L equal to 0 with R L equal to 0 we must conclude v equal to 0 that is I have shorted terminal voltage.

If this voltage is 0, this voltage is also 0, what is the voltage applied across the field circuit 0. Therefore, field current will become 0 v by r f is the field current, r f is the total resistance, if somebody makes this terminal voltage shorted this 2 are then voltage existing between these 2 points is bound to be 0 and thereby I f will drop down to 0. If I f is 0 how much is the generated voltage, very little because of residual field then only residual field will generate the voltage which is very small this much and E G will drop down to a very low value.

Thereby the current in this circuit will be that small voltage divided by r a, mind you this circuit is in parallel with this that is with short circuited thing how the things will look like this is the thing, this is shorted and here is the another I resistance path parallel. Therefore, this I L and I a will be same no current will now pass through this, I a and I l are will be same and what will be the value of this, this is r a, this is E G, E G residual only now.

So, E G residual divided by r a will be this current very little current therefore, one good thing is that even somebody goes to short circuit this shunt generator momentarily current will shoot up, but final steady state current will be very little. See this was my starting point when I L was 0 and I am decreasing R L in order to draw more and more power out of the generator and if I go to the extent of short circuiting it then the final operating point will be here, see in the load characteristics what I want to see, how terminal voltage changes as armature current or I L changes.

So, one thing I am telling the other extreme point in this particular case it is so obvious that I can make it out this final current this current will be this e residual this much voltage E residual divided by r a, this current and there is no bifurcation of current here it is shorted this I a is I L it will be like this.

Now, the question is in between then what happens it is like this. So, this is the no load voltage this point we say no load voltage or open circuit voltage. Suppose I will increase the load gradually I have connected some I am drawing little current from the armature then I know this voltage will be equal to E G minus I r a. Therefore, terminal voltage is expected to fall initially like the previous your separately excited generator and what will be the reason of this fall, because of I r a drop because of brass drop and other thing and the because of armature reaction which of course, I have not discussed it will not take much time to discuss also, but I will come to that later, but terminal voltage will fall.

Therefore this characteristics must have somewhere bended towards this side to reach it is final destination when the terminals are shorted. So, the characteristics must be of this kind and to help explain this why this happens I mean like that got the point. So, so, load characteristics of a shunt generator will be somewhat like this, it will start with large voltage then you increase the load current there will be drops. In case of separately excited generator it was not like that it was going like this for separately excited generator.

This you must understand ok, now how to do it? See the it can be done in several ways you first tell that ok, I will pass some armature current listen carefully for some certain armature current what is going to happen I want to see I a you fix. Then what will be I a r a, I can calculate I a chosen generator is delivering this much current then what will be I r a drop I can calculate.

Then what I will do and what is I a r a drop, I a r a drop see this is the field resistance line this is the voltage across the field at any time. So, v plus I a r a is your E G getting me. This is v suppose you assume machine is I a is chosen and terminal voltage is v at that time found to be and terminal voltage is suppose this is very crucial v. So, I have chosen I a and suppose terminal voltage is v.

If terminal voltage is v voltage applied across the field circuit is also v, because they are in parallel this voltage if you fix then I will say field current will be this much that is I will write here. So, I have chosen a terminal voltage suppose this is the terminal voltage if this is the terminal voltage this v oh sorry this part is also very interesting also.

So, choose a v if you have chosen V I will say field current is this much, how much is the generated voltage, assuming speed remaining same generated voltage must be this much from o c c I can read. So, v then field current must be this much suppose say I f 1 say it is v 1 terminal voltage is suppose terminal voltage is v 1 I a 1 is the current at that time in the armature. Then I will say that v plus I a r a, v 1 plus I a 1 r a must be equal to your generated voltage, v 1 plus I a 1 into r a must be the generated voltage and what is the I a r a? I a r a is this drop I a 1 r a 1, I a 1 r a and I will say oh generated voltage is now this much.

Suppose I have some idea if you load the terminal voltage is bound to fall there is no doubt about it, let the terminal voltage be v 1 and at that time I find the armature current is I a 1. Then I will say look here at that time field current is I f 1 and the generated voltage at that time is this much v plus I a r a that is the thing got the point.

Therefore if you choose I a 1 and v 1 for that matter then I will say in this characteristics I can fix up this point maybe this is your I a 1 and this is your v 1 and this is not surprising terminal voltage is falling, but the interesting thing is if somebody draws the load characteristics like this which I am expecting it has to be like this we find that, this terminal voltage versus armature current is a double valued function that is for a given armature current I will discover oh, the terminal voltage may be either this one or this one is not I have to think in that way no other way, because these characteristics somehow who has to bend and come here. And then this for a given armature current if you draw a vertical line then 2 2 terminal voltage maybe there of which have taken one v 1 and I 1 r 1.

Now, then the question is what about this point, this point is maybe it will be here if you draw a whatever it is here and but nonetheless b plus I a r a is E G. So, so this length is also I a 1 r a and generated voltage will be then this much. So, this is once again I a 1 r a. So, to make matter now after understanding these I will I can now from the open circuit characteristics I can predict the load characteristics of the DC generator look in this way, after understanding this, this is the thing.

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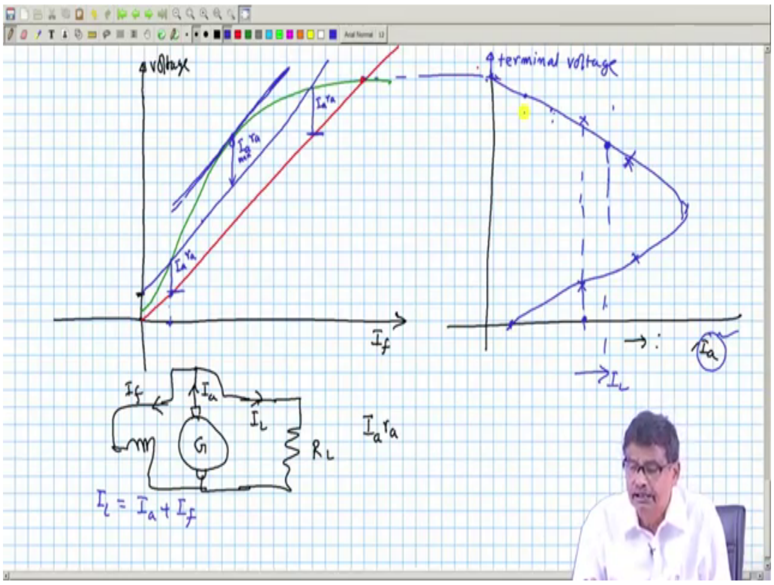

Suppose what I will do is this, this is suppose the V I characteristics o c c this is the field resistance line this is the generated voltage and here I will sketch the load characteristics. This is either I L or I a armature current ok, then what I will do? I will say that say that generated is loaded and do not forget the connection this is the thing oh I am sorry. So, that I can show you the armature current the separate thing it is always better. So, this is parallel here and this is this so this is your I a, this is your I l and this is your I f.

Now, what I will assume suppose the generator is loaded to deliver a current I a then I can calculate I r a now listen me carefully what I am doing I a r a I will calculate. Now this side is a voltage axis and this is current axis field current in this o c c therefore, I know the voltage scale I know the current scale what I will do, I will calculate this I a r a and then this part is most interesting what you do you cut a length which is equal to this I a r a.

So, I have assumed armature is loaded to deliver 5 ampere current 5 into r a I know so, 5 into r a I will calculate it will give me some volts. So, that voltage I will cut a length from this and then I will draw a line parallel to this field resistance line like this, then I am sure this length is I a r a and this length too is I a r a.

Then I am absolutely clear if you say armature is delivering so much of current then I will tell that it can do. So, at 2 terminal voltages what is that, this was the open circuit voltage as usual and suppose you are sketching I a only. So, I a value I have chosen I will go to that I a value here and I want to know what are the terminal voltages terminal voltages will be this one and this one because terminal voltage plus I a r a gives you the generated voltage.

So, one value is very little. So, I will get this point and I will get this point corresponding to this and this and this I will repeat for all the armature currents I like. Now the point of return will be a parallel line I a r a which will be parallel to field circuit resistance line, but tangential to this then only you will get one value unique value.

So, like that I will go on doing 2 values for another armature current and you will get this final value corresponding to a line parallel to field resistance line, but touching not giving you 2 point of intersections. There it is a single valued current this current is I a maximum if you call it I a max into r a and your characteristics will therefore, I am in I will correct it a bit this is the open circuit voltage it may be here may be there. So, so terminal voltage will fall like this bend here and come at this point where it is v by r f.

So, with respect to I a if you have open circuit and field resistance line at your disposal then you can predict the load characteristics of the DC generator shunt generator as well. In case of separately excited generator this point was like that it was going to very large current, but in case of shunt generator it is not like that it will go reach a maximum value and come back.

This armature the this axis can be converted to I L axis you can show because this I wrote I L and I a because I know that I L is nothing, but equal to I a plus I f is not this is the k c l here. So, what I will do, for a given this is suppose with respect to armature current we have drawn suppose armature current versus terminal voltage this axis I must write what it is this is terminal voltage.

Therefore what I will do for a given armature current I will go I got 2 values is not, this value and for this value I know what is the field current is not for this value what is the field current I know from this curve, because terminal voltage is this amount therefore, how much is the field current this current from the r f line you read that. So, field current will be known therefore, I will be able to tell what is the value of I L then because I L equal to I a I a plus I f similarly for that this point.

Therefore I can always translate map this I a into I L provided I also add I f I did I f from the corresponding points. Therefore, this is the story of a shunt generator where both open circuit characteristics and load characteristics I have explained. Here also from no load to full load of course, full load will be here do not worry about that I will not go to this extent or things like that whatever is the rated armature current corresponding to that I will get this point only.

These points are unstable points if you short circuit it will straight away I come here, but what I wanted to tell you it will traverse perhaps a path like this. Therefore, up to I a rated you will go and it will come here, in case of shunt generator the voltage drop or voltage regulation is slightly higher because of the fact not only because of I a r a drop brass drop these are common in separately excited generator as well armature reaction will be also there.

But because of the fact field current also drops a bit flux per pole is also reduced as you move from one operating point. Here whatever is the flux per pole at this point flux per pole is bound to be different because terminal voltage decides the field current which is absent in case of a separately excited machine, because separately excited machine filled coil voltage is independent of the terminal voltage of the armature because these 2 are separate totally but nonetheless the shunt generator has the advantage that you do not require any external DC supply to make it operate with this I stop here today we will continue with this in the next class.

Thank you.