Electrical Machines - I
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Lecture - 65
O.C.C & Load Characteristic of Separately Excited Generators

Welcome to 65th lecture. We have been discussing with DC machines and we are discussing simultaneously, the generating as well as motoring mode and in our last class, last two lectures maybe we found out the most important two formulas, which will be used often to study the performance of a DC machines and DC machine henceforth, I will be drawing like this.

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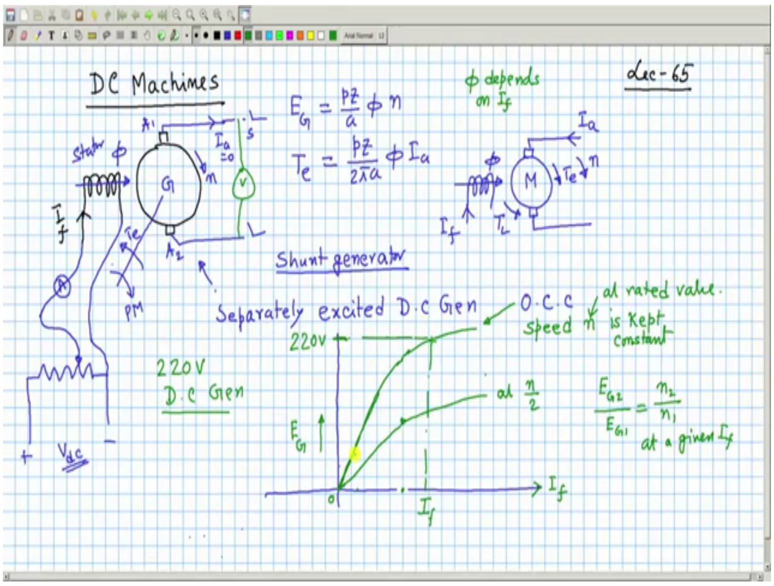

As you know these are the brush and these are the; this is the field coil, that is all and field coil to be excited from a separate DC source. When it is separately excited, DC machine I f and suppose, when field current flows like this, the flux produced per pole is in this direction, this is called phi and these two are armature terminals, which will be like this and these are the four terminals, which will be available to us.

So, if it is to be operated as a generator, I must connect a prime mover to drive the armature. Armature is on the rotor mind you and incidentally just I would like to point out, in case of other rotating machines, the rotor winding and stator windings can be interchanged. For example, in a synchronous machine, AC machines, you can have field winding either on stator and AC windings on the rotor or vice versa. it is equally true. Similarly, induction motor, you can supply give supply to the rotor terminals stator terminals can be shorted and it will work nicely but in case of DC machine, it is not possible to put the field on the on the field winding on the rotor and armature winding on the stator.

Simply, because that this commutator actions, commutator and brass which makes DC will just not be there. With the advent of power electronics devices very fast switching can be done where such a thing is possible field winding on the rotor and on the armature winding the mechanical way that we are rectifying the ac input voltage can be done with solid state switches.

If the armature is on the stator that is of course, outside the scope of this lecture will be conventional DC machines, field winding and armature winding cannot change their places that is armature cannot be on the stator and field winding on the rotor. So, this is the thing this is stator, always stator. Anyway and we found out that the induced voltage generated induced voltage across the armature, we found out as E E G, if I write it was equal to some p z by a into phi into n, n is in r p s and if armature carries current, the electromagnetic torque is p z by 2 pi a into phi into I a, where I a is the armature current and also we noted that if the machine is operating as generator, then there is a prime mover.

Prime mover fixes the direction of rotation n and electromagnetic torque which will be acting on the armature conductors when armature conductor carries current electromagnetic torque will be in the opposite direction, in case of generator. On the other hand, in case of motor mode this is the brushes and this is the field winding, separately excited machine we are considering. If you excite this, there will be field here flux per pole produced and the armature current if it is I a, then this will develop the torque, electromagnetic torque and electromagnetic torque will decide the direction of rotation and opposing load torque will be in the opposite direction that is TL like this, got the point always remember this thing.

Now, today I will first tell you that about shunt generator I will be talk about ok. Before that a so, generated mode and shunt generator I will talk about. Shunt generator, will be the primary topics of today but before that a separately excited DC generator and it is open circuit characteristics must be understood very clearly and there is another phenomena called armature reaction and its adverse effect that I will take a little later. First, we rather go straight to a DC machine, which is operating as a generator and as a separately excited DC generator. Now, so open circuit characteristics.

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So, a first, this is the; is a separately excited DC generator. First, we take this DC generator, means this one, this is the separately excited DC generator clear [FL]. In this generator suppose, the armature terminals are open circuited, AC is off, there will be no armature current. We test in open circuit condition, we are not going to load the machine. What we will do is this, we will change the value of the field current.

We will make this circuit like this connect a circuit like this, where there is a DC supply like this plus minus DC, you should have a separate DC source and then you make a potential divider connection. So, that you can gradually increase the voltage from 0, if you put the video stat variable point towards left and if you connect an ammeter here, field current can be increased.

So, this is separately so, the characteristics of this generated emf versus field current is called OCC or open circuit characteristics ok, open circuit characteristics and if I do that the characteristics will look like if you, if the field current is 0, induced voltage will be 0, phi is generally proportional to I f.

So, as you go on increase the field current, I f here the generated voltage will increase and it will increase linearly at the beginning, but after some time as you go on increasing field current, the flux produced will not be in proportion to the field current, because of saturation which will set in.

So, what happens is this OCC characteristics is goes up and then take a bend like this. So, this is the open circuit characteristics. So, here you sketch field current and here you sketch the generated voltage E G. So, it will follow the actually the magnetizing curve of this B-H curve sort of thing. So, this portion is the linear zone.

So, this equation depends on phi mind you not directly, I f phi can be replaced by some constant into I a provided that the generator operates in this zone, otherwise not, because if you increase the field current the flux produced will become lesser and lesser. For 1 ampere increase in field current in the initial portion changes the flux by a large amount, but same amount of increase in current at this end will increase the induced voltage or flux per pole very little. So, this is called the saturation.

Now, while carrying out the open circuit test, note down the field current and you connect a voltmeter here and just plot them ok, but during this experiment keep the speed constant, speed that is n is kept at related value. If it is a 1500 RPM machine on the nameplate it is written, run it at 1500 RPM and get the open circuit characteristics speed n is kept constant while taking down this reading, then only it will be proportional to only phi.

So, n is kept constant speed. So, in this equation n constant p z by a is of course, a constant of the machine phi depends on field current phi depends on I f and the relationship of phi and I f is linear initially, but later it is non-linear ok. So, this is the open circuit characteristics at certain fixed RPM, rated RPM. Now, if I ask you that what will be the open circuit characteristics?

Why it is called open circuit characteristics, because I am not going to draw any power out of the armature that is why it is open circuit, s is opened. If suppose, I carry out the same experiment at half the rated speed, how the OCC will look like? OCC will look like lesser, I mean in scale I have not proper drawn properly. What I mean to say, it will be like this, it is like this for a given field current here, suppose at this field current at this field current, this was the induced voltage at n RPM.

If you make speed half this induced voltage will also become half that is it will be here got the point. Therefore, it will be like this, such that the generated voltage E G 2 by E G 1 will then be proportional to n 2 by n 1 at a particular field current at a given I f, because field current will decide flux per pole and speed is the factor. Therefore, one can easily get the OCC at any other speed he likes at speed n by 2.

Similarly, if you increase the speed OCC will be above this, like that, it is suppose at rated value at rated value ok. Now, on the nameplate of the machine DC machine, some voltage will be specified. So, you increase the field current, such that the rated voltage is reached. Suppose, it is a 220 volt DC generator, 220 volt DC generator and suppose, this is the 220 volt and the field current necessary at rated speed to generate 220 volt is this value, these characteristics only tells that. You can ascertain or know the value of the field current needed at rated RPM to generate 220 volt, if you have OCC at your disposal.

So, this is the thing we will do, we can now do the load test on this DC generator that is you generate this rated voltage that is the open circuit voltage. Now, what you do you start drawing power out of the generator. So, that characteristic is called the load characteristics and how it will look like very simple that is, I will go to next page and explain to you.

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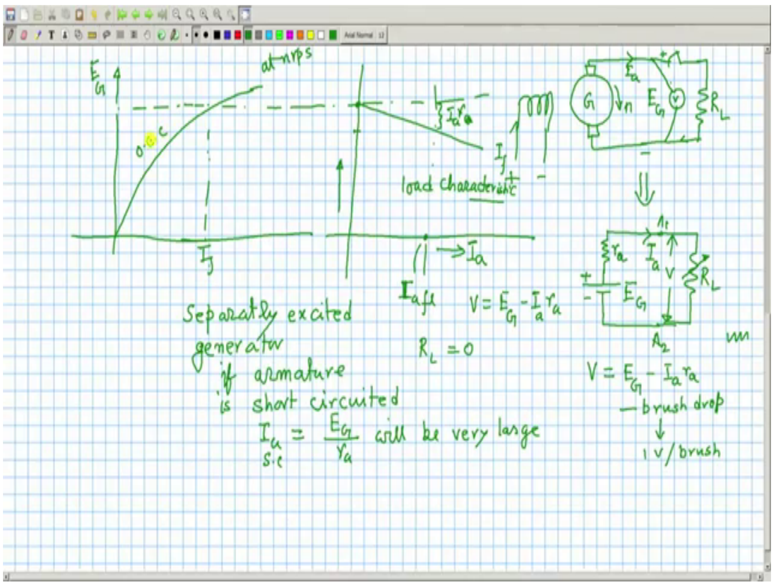

So, we have got these no load voltage, this was the OCC, this was E G across the armature and this is suppose the rated voltage and this is the field current, there is the normal field current and OCC whenever you draw you must specify at what RPM at n r p s. So, this is about this and what is the connection diagram. Keep it in your mind that this is the diagram which is relevant now.

So, we are passing an I f here and generator is driven at some RPM n r p s and here has the induced voltage V or E G and then you have a switch to use the power which will be resistive in case of this is apply after all E G. So, with this opened the load characteristics will be like this therefore, on this side I will sketch I a and here, I will sketch this V, I will connect a voltmeter here.

So, with I a equal to 0 voltmeter will be this value generated voltage I f is maintained. So, open circuit voltage is this one. Now, if you close this switch it will deliver current and I a will flow, this terminal voltage what will happen? It will be increasing or decreasing or remain same, it is expected it will decrease because the armature has got a resistance.

So, what is the equivalent circuit here equivalent circuit is armature. This resistance is very small made of copper this is r a and here is your generated voltage E G and here is your armature terminals mind you A 1 A 2 and here you have connected the load, load resistance R L, at that time some current will flow. So, this voltage, this voltage we are measuring V, then will be equal to terminal voltage across the load will be E G minus I a r a and minus there are some two brushes are there. There will be some voltage drop in the carbon brushes and we write it as brush drop brush drop which is little, sometimes it is neglected.

Generally, what people assume is that 1 volt per drop and things like that the reason for that is carbon brushes. No matter what is the armature current, you draw people assume brush drop is some 1 volt per brush like that therefore, maybe 2 brushes are there minus 2 volt extra apart from the armature resistance, which is inside this armature, because of the armature winding. Now, the brushes are carbon and carbon has a negative resistance coefficient that is with larger current drawn from the armature carbon brush will have lesser resistance, because of temperature rise.

Therefore, as if so, so what I am essentially telling armature winding is represented by resistance over, but carbon brush cannot be represented by fixed resistance instead, what people try to find out what is the voltage drop per brush and that is the reason is the carbon brush has got negative temperature resistance. No matter what is the armature current you draw, larger current resistance is smaller. Therefore, the voltage drop across the brush, which is resistance of the brush into armature current that will perhaps remain fixed that is the idea.

So, some brush drop is strengthened. So, for our understanding we can neglect also that ok, I just so, if brush drop can be neglected the simple equation will be from circuit point of view, it will be E G minus I a r a, this will be the drop minus this small brush drop I a r a drop is also small therefore, if you vary this resistance if you load it means you are decreasing the value of the resistance you are delivering more power but at the same time terminal voltage will fall from this as you increase the armature current and in fact, it will be like this.

This way it will fall and at a given armature current I a load current, this then will represent I a r a plus brush drop whatever, it may it may not be a straight line nice like this, because of brush drop present but E G is this level minus I a r a drop is your voltage now across the terminal of the generator. Like transformer we can then say regulation of a generator that is from no load to full load current, if it is full load armature current I a full load to full load armature current terminal voltage will drop by this amount and regulation as we know, we want a small value. A little change of terminal voltage should take place as you load the generator from no load to full load, this is how things will go.

Remember that in this case, if you somebody if you put a short circuit that is R L is 0, then how much will be the current. So, with V is equal to E G minus I a r a, it is like this but suppose R L is equal to 0 means short circuited, if it is short circuited then current will be very large. So, it is a separately excited generator separately excited generator.

If armature is short circuited, armature current which it will then become equal to E G by r a what is our a armature resistance which is very small that will be very large I a short circuit will be very large very large and if that short circuit current is allowed to continue your fuse. If you have not connected any fuse, where for protecting these it may burn the armature winding event therefore, short circuiting at the separately excited DC generator armature should be avoided like any other sources, why a battery, why should I short it.

All power will be drained out, but in case of generator, it is much more it assumes importance, because the armature winding will be at stake, because of large current brushes may burn things like that. So, these are the main points of a separately excited generator, you excite the generator from a separate DC source, run it at rated speed, adjust the field current so that rated voltage is generated under open circuit condition, then start loading the generator but during this test you must maintain the speed of the machine constant that is if speed changes a bit it will in fact, tendency will be there.

Will be a drop in speed because the prime mover torque and electromagnetic torque has to balance and electromagnetic torque acts in opposite direction, for whatever reason you have to always adjust the prime mover to maintain this speed constant to get these characteristics. So, this is called load characteristics this is load characteristic and this is open circuit characteristics ok.

So, separately excited generator good, it is fine at one time it was used, but only drawback of this generator is you want to generate DC voltage, but at the very beginning you are asking for another DC source, that is the problem. See earlier, to this power electronic devices diodes, this that DC generator was there is not, batteries were there, fine it was no so, obvious that you in fact, people started with DC generation only but only objection to this method is you require a DC supply at that time it was not there.

So, this is nice DC generated regulation will be better ok. I will discuss at length apart from this armature resistance drop to get the terminal voltage because of armature reaction there will be an extra voltage drop that I will discuss in the next class.

Thank you.