Electrical Machines - I
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Lecture – 68
Qualitative Discussion on Armature Reaction

So, welcome to this lecture on DC machines. And we have been discussing about the no load and load characteristics of Separately and Shunt Excited DC Generator.

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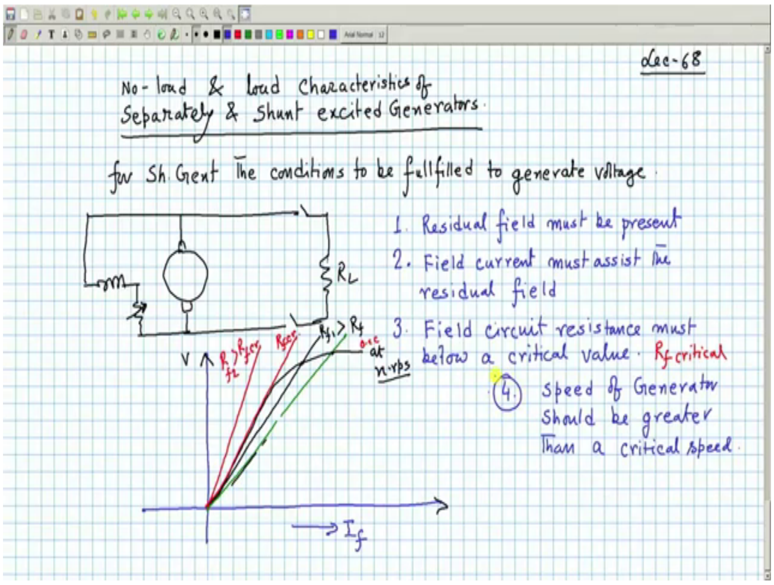

Separately excited generator field is excited separately and in our previous lecture we have seen, that how the no load and load characteristics of the machine can be found out. Anyway, no point in repeating that.

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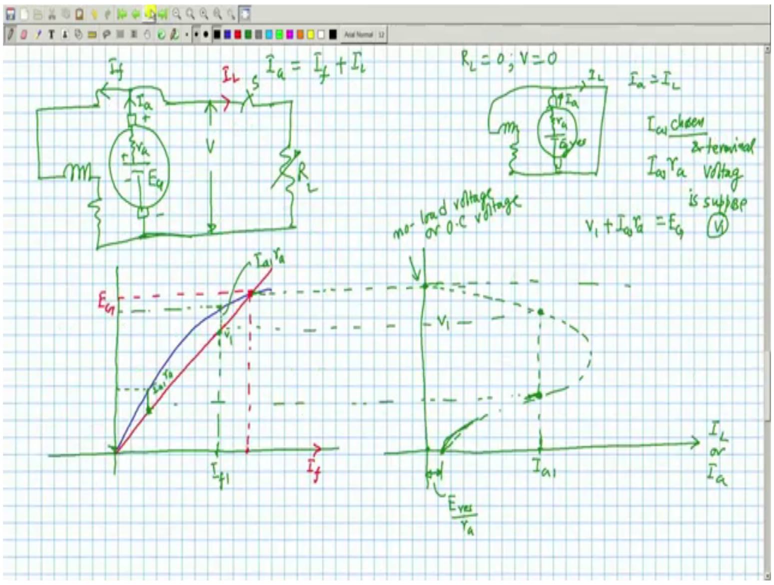

But, in case of shunt excited generator. This is interesting because of the fact to generate DC voltage you do not require any extra DC supply. Only thing is that you just connect the machine in shunt and drive it run it by a prime mover, may not ensure any voltage to be induced. There are various conditions to be satisfied that I will list out here today formally first for shunt generator; shunt generator. The conditions let me write it down. The conditions to be fulfilled; to be fulfilled double l or l fulfilled, to for shunt generator the conditions to be fulfilled to generate voltage; to generate voltage.

And here is the circuit diagram brasses, and here is your field winding and here is your load, load R L. So, first point is that point number 1. Generator must have some residual field must be present, residual field must be present, present that was one thing. Second thing is that armature and field winding should be connected in such a fashion for a given direction of rotation the field current, field current must assist the residual field, residual field, ok. And third point is the field circuit resistance field circuit resistance must be below a critical value.

The meaning of these things, I will just tell you that we know these things, but perhaps formally I did not tell that if this is your characteristics, occ, how in the open circuit a shunt generator builds up voltage it is something like this. This is the open circuit characteristics. There is a small residual voltage and this is the field resistance line.

Field resistance line must pass through the origin because it is only V I characteristics of this circuit, that must pass through origin, but this open circuit will start above it. So, this is the open circuit and do we know that the machine will under open circuit condition must develop this much of voltage, point of intersection that is known.

Now, and this occ as a separately excited generator is at rated speed that we must always write. At what speed this occ is drawn? Suppose it is at rated speed and to generate rated voltage, this is suppose the field current and you get that is fine. Now, suppose if this resistance value R f line is increased, this field circuit resistance I am going on increasing then what will happen? The this mind you this is the voltage axis and this is the current axis field v by i is R f.

So, its slope will go on rising. If you make R f was the original value now make it R f 1 which is greater than R f induced voltage under open circuit will become less. In this way, if you go on increasing the field resistance line a time will come when this field resistance line will gets passed through this occ. And this resistance field resistance is called R f critical red one critical value.

And if you make it bigger than this then there is no point of intersection existing and no voltage will be induced. So, R f 2 suppose is greater than R f critical, no voltage will be induced. That is what I just wanted to mention. Perhaps I did not tell it how it goes on and what is critical resistance R f critical.

If you find residual field is there it is assisting you are sure it is still not generating any appreciable voltage then better check the total field circuit resistance, that is the R f external and R f. This two together of course, you cannot do any change here because coil is inside the machine, so you have to reduce this and check whether it is adjusted to a value less than R f critical than you will get of course, voltage.

Some people also say of course, after telling this it is obvious, somebody says that another point which is also include here, but separately some people mention that this speed of the generator should be greater than; greater than a critical speed. What does this mean, the fourth point?

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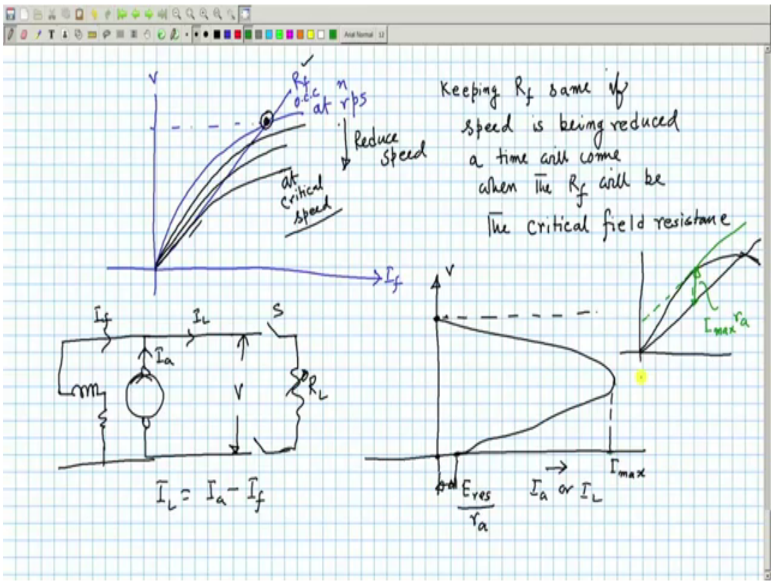

It simply means this because shunt generator we have seen, this is occ, and suppose you have seen that field circuit resistance is below critical field and it is at n rps. And it will in the open circuit generate this much voltage and this is field current that is quite good. Now, you start imagining that this speed of the field resistance, I will keep whatever it is for which it generates rated voltage under open circuit condition.

Now, you imagine that somebody or rather the speed of the prime mover is being decreased, in that case keeping this field resistance line, if the speed is made lesser then the occ, position of occ we know it will change it will be below this line. So, suppose the field speed of the machine is reduced, then the occ will be something like this, ok. Keeping R f same, R f same if speed is being reduced then occ will be below this because for a field current we know ratio of speeds gives you the new voltage for a given field current. We have discussed that.

Now, in this way if you go on reducing this speed, reduce speed, reduce speed then your occ will come here. So, a time will come you will get an occ which will be tangential to the present field resistance line, ok. A time will come, a time will come when the occ when the present R f line, present R f will be the critical field resistance, field resistance. I am not wearing R f. What I am simply doing? I am reducing speed present R f is constant. A time will come when this value of R f will be tangential to an occ and this speed because each for each occ I must mention speed. So, this is occ we say at critical speed, critical speed. I think you have got the idea.

So, this is what I wanted to tell. Apart from the fact that last time we discussed, a shunt generator load test will be when you close the switch and the load characteristics will go like this. So, for shunt generator always draw like this, this is armature, this is field and there is your switch and here is your load resistance R L which can be varied and this is the terminal voltage, terminal voltage.

So, in the load characteristics, the main points to be remembered for a shunt generator is this, this terminal voltage V will be when at the site can be; mind you this is your I L load current and this is your I a and this is your I f. So, that I L is equal to I a minus I f. So, in this case the when the load current this is I a or I L or I L, when I L or I a is practically 0 this generated voltage will be corresponding to this point. And then we have seen interesting thing, that in case of shunt generator it will go like this then finally, it will come back here. And this current value will be nothing but generated voltage due to residual field divided by r a very small current, residual field voltage is very small this value.

So, if V equal to 0 means direct short circuit. And therefore, from a shunt generator you cannot draw any current you like, there is a maximum value of the current and the maximum value of the current which can be drawn from a shunt generator and easily be found out from can be estimated experimentally. Last time I discussed, what you do? You draw a line parallel to this line here so that this will be your I max into r a.

So, if you have occ at your disposal field resistance line, then draw a line parallel to field resistance line like this, then at that point wherever it touches it will be a one valued function for a given current giving voltage. Otherwise, it is a double valued function. This we explained in my last class from which you can estimate how much maximum current it can deliver, ok.

So, this is about the characteristics of separately and shunt generator. And voltage drop takes place, I told you because of armature resistance and because of brass drop which is sometimes neglected. Otherwise, it is taken into account by considering one volt per brass. This much voltage also you subtract from the generated voltage and then you get the terminal voltage. But there is another cause for which the terminal voltage will fall and that is due to armature reaction.

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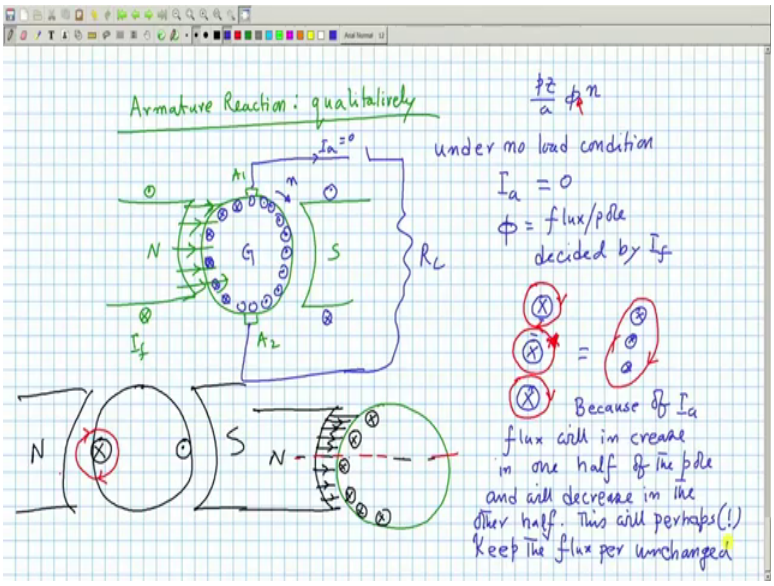

So, first what I will do is this I will discuss about armature reaction. First, I will discuss qualitatively. Let us discuss. It very simple idea. See, I will consider say generator mode of action only and I will be showing the poles also just symbolic, ok. These are the poles and here is your armature, this is the thing.

Suppose, it produces this side produces a North Pole, field coils I am not showing, it must be field current must be in this direction I f, so that lines of force will come out and here is the South Pole. This is qualitatively intuitively we are trying to of course, with reason nothing like that and these are the armature terminals we know. And these are the armature conductors which are staying here. And this armature conductors are what? They are pseudo stationary coil recall that.

So, for as production of magnetic field, by this conductor is concerned field will be stationary in space although conductors are physically moving, ok. Now, suppose I say that the generator is moving in this direction, n rps, that is the prime mover is running this armature of the generator in the clock wise direction then I can decide about the polarity of the induced voltage by applying. So, it is generated voltage will be like this. Now, if you apply right hand rule not the velocity it will be cross, all these conductor under the purview of North Pole will have cross and obviously, the other side will have dot like that, the field will be we know this many a times we have discussed [FL].

Under no load condition and what will be the generated voltage? P z by a phi into n across the brasses. Under no load condition what is under no load condition I a is 0. No matter whether it is a separately excited generator or shunt generator it does not matter, although I have shown it separately. Armature will carry current when you connect some load, otherwise it may carry current, but very little current. It does not matter. But generally under no load condition means I a is 0. This is the current. So, this will be the situation.

Now, under no load condition when I will be loading the machine this is 0, but when I will be loading the machine that is I will connect some load resistance here, across the armature, then only current will be flowing and the direction of the current will be dictated by this only that is direction of the current will be also cross under North Pole dot under South Pole. And it will be because the torque experienced by this electromagnetic torque will be then this way T e, if you apply left hand rule. So, it has to be in this direction the current is.

Now, the question is what happens to this field. When I a was 0, field I am sure it is decided solely by the field coil. Symbolically, I am showing you one term for the field coil, it is north to south lines of force will be like this. But when armature will be carrying current then armature this coils two will produce their magnetic field.

Therefore, we should then ask ourselves that whether the flux per pole in the machine will still remain what it was earlier when I a was 0 and based on that I calculated the generated voltage and so on. See, what I assumed? Phi is the flux per pole recall. And decided by whom? Decided by I f that is all. That is what I told you. I never told that armature current is going to do what. But now after learning that after you load this generator, this is generator mode armature will carry current and naturally the question is it will also create its own field.

So, armature field and the field produced by the field coil, the resultant of this two is to be now considered to calculate the generated because machine conductors does not know, it only knows it has to generate this much voltage phi n, n is rps, phi is the flux per pole. Whether this flux per pole is disturbed by somebody else that is the armature in this case is to be investigated now.

Now, in the qualitative explanation it is pretty simple to understand what is going to happen. What? Consider that each coil, see if you consider conductor by conductor here, if you have suppose a conductor which is carrying cross current, the magnetic field produced by this will be like this, we know. There is another conductor here see I am drawing this side, that is another conductor which is also like this, circular like this, this is carrying cross. It will produce its own magnetic field like this, sorry, sorry, this will be producing like this, this will be producing like this, same direction, ok, clockwise.

Another third one. I am just drawing because it is qualitative explanation this is another conductor cross and it will produce it is magnetic field like this. You know that is how it will produce. Therefore, in this diagram now after learning this because this diagram will be then quite clumsy if I go on drawing this circles here like that.

What I understand is that see this is equivalent to, this is equivalent to for example, this three conductor, this intermediate point it is going like this they will cancel out and you can group all the coils together and show aligns of force like this. Are you getting? It is very easy to understand this part.

Now, you see the original lines of force produced by the field coil. It was like this, it was like this, uniformly distributed when there was no armature current. Now, what I find that for each of this conductor here, this was the original flux and there is an mmf here, here. So, this will be more, this will be more and when you come to this side it will be opposing this. In other words, what I am telling is this scenario will be something like this, very interesting scenario. That is your armature is like this, then the conductors, this was your say North Pole.

So, lines of force in this up they will become much more dense and here lines of force will be redefined because of this opposing thing that is what is going to happen. That is in one up of the pole as if the magnetic field strength will increase and in the other half of the pole it will be decreased.

Earlier it was uniformly distributed. So, the moment you pass armature current. How do you pass it? You load the machine, this was the direction of generated voltage, DC it is same direction current will flow. And because of this cross current here, here we understand that the lines of force on this side will be more because in this case best way to tell this you consider a single conductor. See, it is effectively like this. This is the armature. Direction of the field is like this, for this is cross, this is dot.

So, you just represent it by an effective current, this side cross, this side dot as if all taken together. This was my North Pole, this was my North Pole, this was my South Pole, good. Now, the lines of force of this thing what I am telling will be like this. So, here it will be this armature current because of this lines of force will nullify some of the lines of force produced by the field. And here it will be strengthened on the upper side there is what in effect I am telling.

Therefore, in one half of the pole the lines of force or the flux per pole will increase, flux will increase, in other half of the pole flux will decrease. If that be the case, then it looks like that it is the flux per pole which decides the induced voltage across the armature, when you are not loading the flux per pole was phi.

Now, if I load it then I know that in one half of the pole flux will increase and in the other half it will decrease. Therefore, flux per pole perhaps will remain same this is the most interesting part. So, the conclusion is oaa in one half because of armature current because of I a flux will increase in one half of the pole in one half of the pole and we will decrease in the other half.

This will perhaps, this will perhaps keep the flux per pole unchanged, from no load to full load condition, full load say full load armature current is flowing. In no load armature current is 0, draw the rated current then the argument may be like this, flux per pole in one half increases, other half decreases, it is the flux per pole which decides the generated voltage that then will perhaps remain same.

If that would have been the case life would have been much more easier, that sort of arguments. That arguments is nice, but it has a only got one thing we are not considering. The next statement I am going to make is the increase in flux in one half will be always less than the decrease in the other half. So, that effectively there will be a net decrease in flux per pole. Why I am telling that?

It is because here whatever will be the flux produced will be decided by in the upper half, the mmf of the field coil and the mmf of this armature conductor here. And it is carrying rated current, I am talking about rated current. At low value of current this is precisely what will happen. But at rated value large value of current this may not happen that is what I am telling.

Why? Because this part in this part saturation may take place. More mmf is causing this flux to increase. However, it is unsaturated portion here it will decrease in proportion. Therefore, I put this sign here perhaps it will remain same. We will keep the flux per pole phi unchanged. May be true for a lesser degree of loading low value of armature current, but may not be true at large value of current. In fact, since the increase in flux per pole in one half will be less then decrease in the other half, net flux per pole will suffer a loss of value. Therefore, the induced voltage itself will become lower compared to no load condition.

Then, after that armature resistance drop, brass drops these are there always. That is why people say when you load a generator the voltage drop takes place because of armature resistance drop, because of brass drop and because of armature reaction effect. We will continue with this discussion further.

Thank you.