Electrical Machines - I
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Lecture – 66
Voltage Build up in Shunt Generator

So, welcome to next the lecture on Electrical Machines I. And in my last lecture, I was talking about separately excited DC generator and what is open circuit characteristics, and what is load characteristics.

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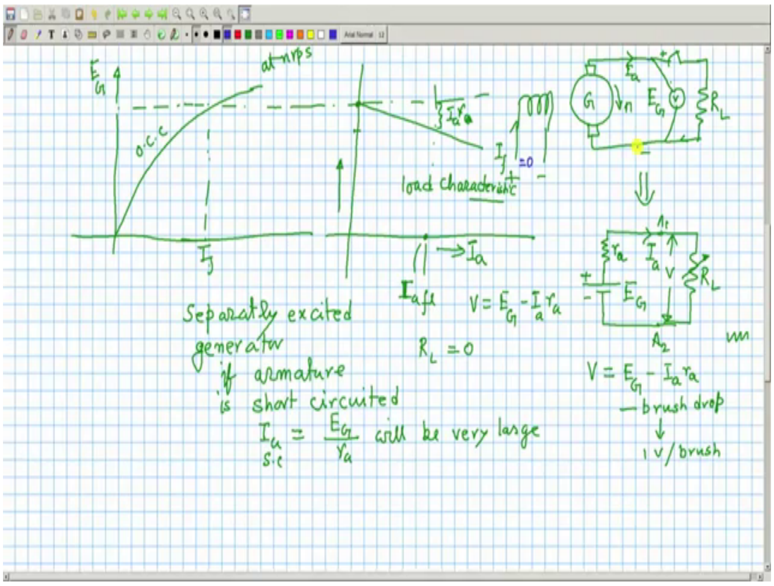

So, open circuit characteristics you pass run the generated by a prime over at rated rpm, adjust the field current with this as opened, get the rated voltage, and after you get the rated voltage start connecting load, means electrical load to use that power, ok. So, armature will deliver power. And your terminal voltage of course will not remain at E G that is the open circuit voltage and it will decrease.

And the voltage decrease will take place because of armature resistance drop, because of another voltage drop in the brasses. And another term I used that is called armature reaction. We will come to that after I discuss a bit about shunt generator, ok. So, today I will just tell you about shunt generator.

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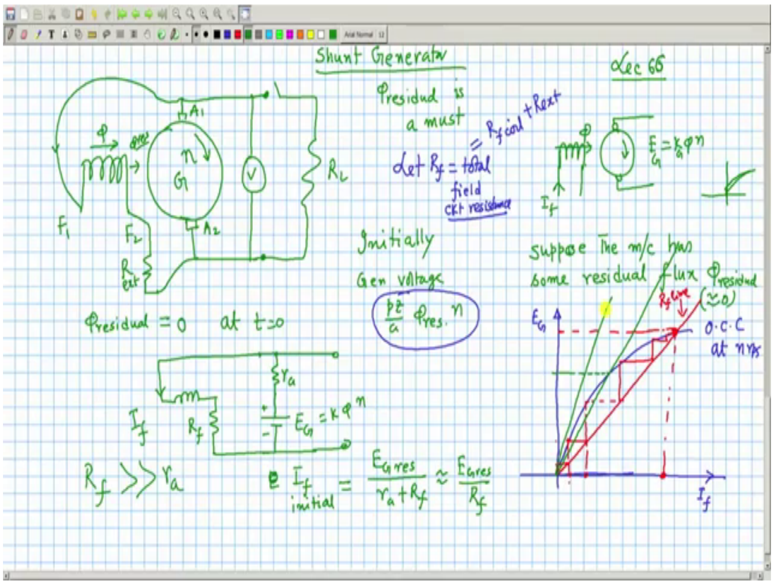

Now, in a shunt generator what happens is this, this is your armature and this is the field winding F 1, F 2, same separately excited generator you take. Mind you, you are having these four terminals with you, you if you excite the field winding from a separate DC source it becomes a separately excited generator. Now, what we will be doing is this, we will be connecting some resistance in series with the field winding called the external resistance and connect this field winding in parallel with the armature winding which is market as A 1, A 2. And then I will run this generator this generator is driven at the rated rpm, ok.

Now, the in contrast to a separately excited generator, you can which I will draw it here for ready reference. This is the armature, this is the field winding and here you pass DC current from a separate source and it creates flux per pole. Now, so, this is the connection of a shunt generator. Now, the first question is if you compare this situation with this, I can very confidently tell here will be generated voltage E G which I equal to some k phi n, p z by a phi into n.

Here I am not sure, you connect like this because I am not now asking for a separate DC source. What I have simply done is that field winding, I have connected after connecting an external resistance series with field winding, this combination I have connected in parallel, with armature and I am claiming these are the two terminals of the generator where I will connect load that is what I will I am going to do. Now, apparently it looks like that. What? Do I will expect any voltage to be developed here? Answer is no because who will create the flux per pole, this phi.

Here I f was responsible for creating that part here I do not find any field current which will establish this stator flux phi and generated voltage is proportional to phi into n. Mind you, no matter how you connect field winding armature winding this relation is always true. Generated voltage across the armature is what is the flux per pole, what is the speed, product of this two. Therefore, that terminals a question now. Do I expect any voltage? The answer is most probably no, because there is no field current no phi and generated voltage depends on both speed as well as flux per pole. That is fine.

But one thing you just see suppose this generator I have connected as the separately excited generator earlier, what happens? After you complete this experiments switch off everything what happens is this, even with field current 0 there may be a residual flux because of retentivity of the magnetic material. So, the term I am telling is suppose the machine has some residual flux, phi residual which is small not that large field will be there retentivity, b h curve you know you use it make the current 0, it will have some residual flux, left in the poles of the machine.

Therefore, perhaps in very small residual field may be there, may not be there, if it is a new machine may not be there. So, if phi residual is 0 which machine might have inherited because of earlier operations, if phi residual is 0 then of course, my answer is very straight forward, no voltage will be available, game is over. Now, I have to think a little bit what happens if there is a residual field, whether under that condition some voltage may be generated?

The answer to this question is yes. A substantial voltage may be generated across the armature like you are separately excited machine although, there is apparently no source to excite the field winding apparently. We will see how this is possible. So, to for a shunt generator to work we will first conclude that phi residual is present. So, phi residual for a shunt generator, phi residual is a must, is a must. Therefore, if it is a very new machine, if you are not sure better excite the field winding from a DC source disconnect the DC source some residual field will be present. That way one can easily make a machine to have some residual field, some residual field is there.

If that residual field is there, and if it is running; running means it is driven by a prime over, I told you it is generator mode of operation. I must have a prime over to run it. Then is it not I should expect a small voltage induced across the armature following this relationship that is initially generated voltage. Although, there is no field current, but for some phi residual is there, generated voltage will be p z by a or k into phi residual into n this must voltage, but phi residual is very small. A little voltage will be induced across the armature.

Now, what is the circuit now? It looks like this is the equivalent circuit field, electrical equivalent circuit, this one; this is connected in parallel with the armature. And what is this armature? This r a and there may be some brass drop here small and then there will be some generated voltage E G and this toward the terminals where I am planning to connect a load. Therefore, what happens is this there is a residual field because of this residual field E G will have a very small value. But the moment E G is having some value with this polarity, so I will expect there will be a field current here because E G divided by with this switch open, nothing is connected. E G divided by r a plus R f will be the field current.

So, I would expect then a field current at the initial stage at initial stage at t equal to 0, ok. I have started driving the machine at nrpns. It will be I f initial, will be equal to this E G residual because of residual field divided by r a plus R f. Now, in case of separately excited machine or shunt connected machine, they are one and the same machine you can connect it as the separately excited or a shunt machine, this r a value the total field circuit resistance R f is many times higher than small r a. If armature resistance is 1 Ohm this R f total may be 250 ohm, it is of that order 200 times like that.

Therefore, this is approximately then equal to I can say E G residual by R f because r a is much small then R f. So, a little field current will flow. See, earlier when it was not running there was residual field because of no current; because of its previous history it acquired some residual field. Now, the moment you run it they run the generator we say oh there was residual field that is fine, but there is now a little field current will flow. Therefore, it will produce additional field, on top of the residual field which was there already, is it not.

Therefore, it looks like you started with residual field, but because of the self mechanism this small generated voltage will drive some current in the field circuit and this flux will be the residual flux. And also, plus the flux created by this new mmf that is number of terms of the field winding and little field current of course, that will be little, but none the less this two will now decide the flux per pole. Now, there may be two situations, one situation is that the polarity the way it has been connected that this because of new field current this mmf acts in opposite direction of the residual field.

This is suppose phi residual was there, but I am not sure whether this field current strengths this initial residual flux or not. Suppose, it does not, they knew because of N f I f, suppose it is acting in this direction therefore, this situation will be worst. What will happen? It will try to nullify this residual field and a time will come when the residual field will be destroyed, and 0 residual field no question of any voltage E G here. You must understand this point.

However, it may so happen that this new mmf also produces flux in the same direction as that of the residual field. Then what is going to happen? Then this E G will rise, E G is equal to k phi n and phi has now become more, and the phi has become more this I f will further increase and if this I f further increases phi will become even more and this voltage will further rise. In this way, this E G will grow up it will have more and more voltage. Therefore, for a shunt generator we now know at least qualitatively that to make a shunt generator work I will demand that there must be some residual field.

Second point is you connect the field winding in parallel with the armature and depending upon detection of rotation whatever it is. You must ensure that because of residual field whatever little voltage will be produced that will create additional flux in the poles of the machine which will strengthen the earlier residual flux, then only this growing up of voltage is possible. For example, if I find that this way if you connect this additional flux strengthens phi residual, this is called additive mode in this correct mode if you connect and you may get some substantially large voltage generated.

If that be the case, then one can one thing you can do you stop the machine and interchange these two terminals and start building voltage then you will find it is not building up voltage. Because, if F 1 is connected to A 1 F 2 is connected to A 2 then we have seen, it builds up voltage, large voltage you are getting. This being known what I am telling, you now stop the generator, then you interchange this polarity F 1 and F 2 parallel connected I will connect this side now to A 1 this side to A 2, then I would expect because there will be residual field no doubt from left to, right, but the polarity of the voltage will be such that it will decrease. Anyway, we will come to this much more.

But this is the qualitative assessment, but I am, I want to know how much exactly will be the voltage. Merely stating that it will grow up voltage and things like that we will not do, I must know how much a real voltage if I want to generate 220 volt what should I do and how should I explain to that, ok. It grows up voltages, will it grow up in definitely? Somebody will stop that process and make a finite substantial voltage to appear across the armature, is not. These are the issues we have to now discuss. And we, this can be very nicely explained. I will first do it here.

Suppose, I have connected the machine in shunt fashion; shunt means field winding is parallel with armature, another external resistance of course; you connect then connect this in parallel with armature. Suppose, this machine as a separately excited generator I know what is the occ because same machine can be used as a occ as a separately excited generator or a shunt generator. In the previous case, we have seen the same machine I have connected like this I know what is occ all about.

So, I am telling that for this shunt generator, I know the occ for this machine when it was connected as a separately excited generator. Mind you, this characteristics is for separately excited generator this is field current and this is the generated voltage. And I am telling that now only thing I will tell you is this that this machine has some residual field; in the. Then the occ even with field current 0 will not start from 0 because it will have a little voltage induced because of this residual field and let that residual voltage be this much. I will make it nicer.

What I mean to say is this, that this curve, this curve with field current 0 this is occ. If you carry out the occ and if this machine has been earlier used, so that it left some residual field there then even with field current 0 at rated rps, at nrps, you will find that is in this circuit with no field current I f equal to 0 you may expect a little voltage here because of residual field. Because k G phi n is the generated voltage and that phi is the residual flux. So, this amount of voltage is your this thing, it is this, this, this small voltage will be induced, ok. So, that is there, fine.

Now, I will use this information to explain what is happening in a shunt generator. How? Let, first thing is let R f is the total field circuit resistance, total field circuit resistance. That is field winding has got a resistance that will be not very small like r a plus any external resistance you have connected. That is this two together is the total. So, R f total is R f coil plus R external whatever you have connected this two together is R f.

Now, what I will do is this part is very interesting. You just sketch the V I characteristics of this resistance which will be a straight line like this, this is the R f line people call it R f line. Mind you, it has nothing to do with machines etcetera just V I characteristics of this field coil that is you have applied some known voltage here what is the current drawn, applied a higher voltage what is the current drawn; V I characteristics of a resistance, R f total.

So, that characteristics I will super impose on these occ of a separately excited DC generator. Then I will say that look this is the sequence of events it will go on. Initially, there was some residual field and you are running the generator at nrps at that time how much will be the generated voltage this much. But if this much is the generated voltage field current should be this much, from this red curve I will read this must have become now the field current. If this is the field current occ tells me generated voltage must be this much. It increases to this.

And if this is the voltage because R f is connected in parallel with this one field current will further grow, it will become this. And if this is the field current generated voltage will be this. If this is generated voltage field current will be this much, because you know field current is E generated voltage by R f, R f plus small r a, r a is small r a you neglect because as I told you R f is 100 times more than r a. What is the point of adding that? So, so this way it will continue.

And finally, where it will settle down? Where will be the stable points? Stable point will be here. You need not worry about that machine will seek its own stable point where this occ of separately excited mode that is the occ and the field resistance line wherever they interact intersect that point will be the stable operating point, field current will be now this much, and your generated voltage available across this terminals is this much that is the thing.

So, it is nothing left to chances, that is it will grow I cannot say where it will settle down. Why I am saying it is the final intersection point? Because it is at this point generated voltage is this much and field current is this much, everything is satisfied, ok. Therefore, the final generated voltage will be this.

So, so a shunt generator, although apparently it looks like, it cannot generate a voltage. But with some residual field present and with proper connections of field and armature coils in parallel that is very important, because if it is connected in such a fashion that knew this field current mmf opposes phi residual then this process will not go. It will instead nullify that phi residual back to 0 and everything remains quite no voltage can be induced. But if properly connected and the resistance value of the field winding is like this, then voltage will build up and this voltage is substantial voltage, and this voltage may be 220 volt or whatever it is you want.

So, mind you, a shunt generator can generate a voltage only one point. Suppose, somebody connects a very high resistance in series with the field coil such that new field resistance becomes say this much. Then only this much voltage will be induced R f increased, is not. If you increase R f further it may go like this, no point of intersection. So, we can list out another points that will look here a shunt generator having residual field and you have properly connected it, still it may not have any appreciable induced voltage if the field resistance value is very large.

We will continue with this in the next lecture.