Electrical Machines - I
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Lecture - 76
Estimating Armature and Field Resistance from its Rating

Welcome to next lecture. And in today's lecture what I will do is this I will rather go to motor operations, generator operation we have seen is it not that is load characteristics of separately and shunt generator. It must be told that the rating of DC machines, voltage rating particularly is very much limited because of commutated segment and mica insulations. You cannot have a machine DC machine, whose rating is 5 kB, 6.67 know out of question it may be at best 1 kB or so, because of its limitations and the commutator segment, and brushes there will be flash over ok.

So, DC machines as generator nowadays is almost obsolete. Let us be very clear about this point. If you want to get DC ok, AC supply is there convert it with a solid state rectifier, even you can get variable output DC voltage by using controlled rectifier, silicon controlled rectifier SCRS, or convert it to DC, then use some AC, DC, there are so many good options are there.

So, nobody really generates DC power in bulk hundreds of mega volts and tries to transfer it, no, because the voltage is the limitation, you cannot transmit bulk amount of power over a long distance with a little voltage of 1000 volt generated in the terminals. Because if it is DC, you cannot step it up, in case of synchronous machine also the voltage generated is of the order of only 11 Kelvin, but you have transformers ac step it up then transmit ok.

Therefore, DC generators are nowadays not used practically so, but still DC motors are in use. And we will first tell you how to calculate the performance of a DC machine in terms of how to calculate efficiency, how to calculate torque this that.

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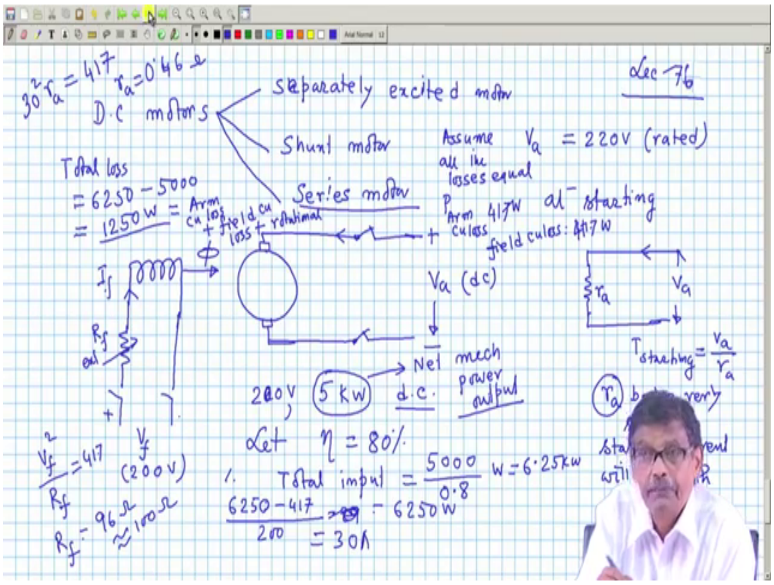

And about DC motor, I will tell that there are two kinds one is shut motors or separately excited motors, shut motor and another interesting motor that is called and we will try to understand each one of them. There are compound motors also about compound things I will make general statement at the end the computations are similar ok. There are the compound generators and compound motors also.

In case of separately excited motor, what is done is this. The field winding is this one, this is your armature winding. And here the field circuit is given supply from a separate DC source v field DC source fixed DC voltage, then you have a field resistance, this is your field coil. And if you switch on supply, there will be some field current I f. And it will produce flex per pole phi ok.

Now, if you simply energise this machine with field excitation nothing is going to happen, because there is no prime over in case of motor mechanical load may be present. So, you have to apply a voltage, supply voltage which I will call it armature supply voltage, which is also DC of course, it is there. Now, if you apply the rated voltage, machine is suppose stationary, if you apply the rated voltage suppose the machine rated voltage armature rated voltage is 220 volt, armature voltage is suppose 220 volt DC rated. Field circuit voltage rated will be also 220 volt.

I have just indicated in this V f and v a wave, because I may vary them in future, separately excited so maybe I will have some control. So, apply some 220 volt DC. Now when you switch on this machine without doing anything etcetera, at the moment you close these switches how much will be the current because machine was stationary, machine has got some inertia.

So, at t equal to 0 plus immediately after you have closed this circuit, the current drawn from the supply is called the starting current. And the at starting at starting condition, I am sorry this is the armature can be modelled as some armature resistance r a, and the supply v a nothing else, because machine has not yet started moving. Therefore, there is no generated voltage by the by the machine which is called back emf in this case.

So, starting current will be pretty large I starting is equal to v a divided by r a; r a being very small starting current will be very large, will be high, may be there will be problems in the machine. Now, first of all just merely saying that armature resistance is small does not make any sense, is it minimum, is it 1 ohm, is it I mean high low is a very selective term. I will first tell about that a little bit, we know that in a DC machine or for that matter any rotating machine, let us assume the machine has been well designed ok; whoever has designed the machine has designed it well.

Then the efficiency of a well designed machine a rotating machine, may be 80 or 85 percent very well designed machine, but certainly not 90 percent and above like transformer, transformer 99 percent very good there is no rotating part. But in case of DC machines or say induction machines whatever it is, the order of efficiency may be 85 percent 80 percent like that ok. So, you just see globally that suppose you have a 10 kilo Watt 220 volt DC machine or I will take for simple calculation 200 volt, so that I can compute easily.

Suppose there is a 10 kilo Watt or 5 kilo Watt let us take a 5 kilo Watt, 200 volt DC machine. What does this mean? It means that your rated voltage you can apply to the armature is 200 volt, rated voltage you can apply to the field is 200 volt. And when the machine will be fully loaded, it will give you an output of 5 kilo watt that is the whole idea [FL]. Now, let us assume to understand how to estimate the value of r a. Suppose, we have purchased a machine this one it is delivered. Now, I will say that let this I am choosing I may be wrong little bit here and there, but as a practicing engineer it is very useful.

Suppose let efficiency of the machine is 80 percent, then I and this is the output power mind you. Whatever will be written on the motor, in case of induction motor also we have seen, this is the net mechanical power output, net mechanical power output ok. So, when the machine will be operating at full load condition the input total input must be 5000 divided by 0.8 so much watt, is not how much it is?

Student: 6125; 6125.

61.

Student: 0.25.

6 oh kilo watt you are telling, 6 point.

Student: 25.

25 kilo Watt that is equal to 6250 Watt, it gives you 5 kilo Watt this is the input. Now, where this remaining power goes, remaining power will be the total losses in the machine. Assuming it is a well designed machine, this thing I assumed I have not yet tested the machine I assumed ok, total input will be of this order. So, total loss will be this 6250 minus 5000, how much?

Student: 1250; 1250.

1250 Watt. Now, let us have some idea this is the total loss, total loss comprises of what, there will be some copper loss I a square r a, because armature has got resistance. There will be some field copper loss I f square R f, all things considered efficiency is to be calculated. We will tell you about that in much detail, but as a common user there will an armature copper loss here, field copper loss here. And not only that there will be another called rotational loss, three losses takes place primarily that is the armature copper loss, field copper loss; so this will be equal to armature copper loss plus field copper loss plus rotational loss.

Frictional and some eddy current loss takes place in the armature we will come to that, but this is these three losses are the primary losses. Now, we do not have any idea of how this 1250 will get will be distributed in this three points, ok. I do not have any data; let us assume equal weightage let us keep one-third, one-third, one-third. So, assume all the losses are equal losses equal and say armature copper loss will be one-third of that how much it is?

Student: 417.

41.

Student: 7.

7 so much watt, field copper loss also say 417 that is what I have assumed is it not [FL]. Tell me what will be the rated armature current from this data, input is this much input power that minus the field copper loss will be the power coming from the armature is not, this input power will be.

Student: That minus will be copper loss, 2.

So, 6250 minus the field copper loss which one-third of this, how much it is?

Student: 5833; 5833.

No, no that 417 [FL].

Student: Hm.

6250 minus 417 divided by 200.

Student: 29 ampere.

29 ampere, say 30 ampere will be the armature current ok. Then I will say that this armature current I a square into r a is equal to 417 Watt. So, r a is how much?

Student: 0.46.

Point.

Student: 46.

0.46 ohm, 0 point this is causing problem. See try to understand what I am doing here, I am telling a DC machine is given, we say armature resistance is small, it does not make any sense; small means what, milli ohm, micro ohm or 1 ohm whatever it is. You can easily see, see rated current of the machine I have estimated 30 watt. If somebody says this machine is having 2 ohm resistance armature, you calculate what will be the copper loss when rated current will be flowing; it will be very high, efficiency will be very poor, 2 ohm is also small what is.

Similarly can I estimate, what is the value of field resistance how much? So, this is this is an important thing I am telling, which you will not be discussed in general books how much. I am just estimating machine is there, how much is the order of armature resistance of this machine about 0.46 ohm. When you will measure that it will not be 0.46 will be nearby, may be 0.5 ohm, may be 0.6 ohm also I am not sure I do not care, but I have got some idea of the order of the armature resistance that is important. How much it?

Student: Armature.

Field; field winding resistance.

Student: 96.

That is V f square divided by R f is equal to.

Student: 417.

417. So, the field circuit resistance R f will be I mean field coil resistance this is R f external I mind you, field coil resistance will be.

Student: 96.

96 ohm, say 100 ohm, may be 120 ohm. So, what for a well designed DC machine, armature resistance for this DC machine will be of the order of 0.46 ohm or 0.5 ohm or 0.6 ohm. And field circuit resistance will be of the order 100s ohm, I mean may be 120 ohm, these are not at all the measured value at all.

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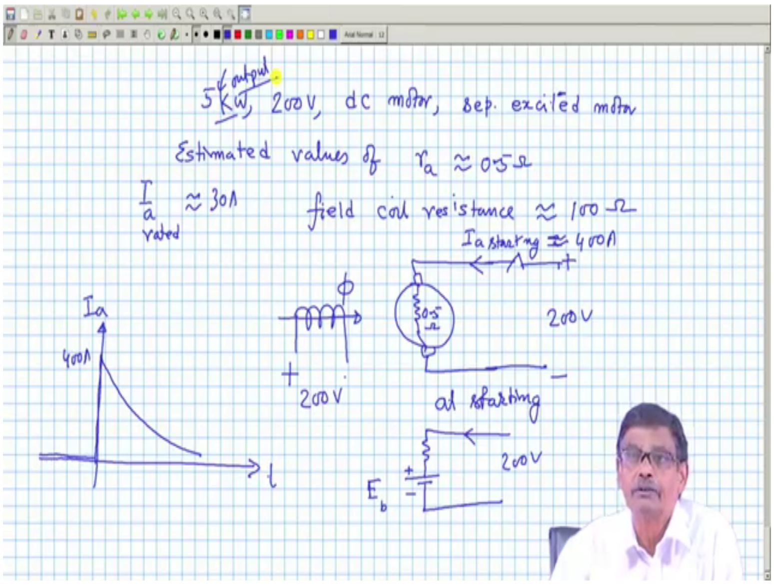

Therefore, if I now come to the starting problem of the DC machine whose rating is 5 kilo watt, 200 volt, dc motor somebody writes, say separately excited it will. Separately excited machine can be connected as shunt machine, like generator separately excited motor. Estimated values of r a is about 0.5 ohm that is what we have found out. Field coil resistance mind you it is not external resistance; field coil resistance; field coil resistance is of the order of the 100 ohms like that, that is what we have got.

Now, if this machine and its rated current we have already got I a rated is how much? 30 ampere, approximately 30 ampere. Now, in such a machine what I am trying to tell if field is given full voltage, no external resistance 200 volt you give, it develops rated flux phi and then you apply full voltage 200 volt here and the order of armature resistance is at starting there is no back emf coming in at starting, this is 0.5 ohm.

The current drawn will be I a starting will be 400 ohm, 400 ampere, rated current is 30. So, many times the rated current will be flowing 400 divided by 30 if you do about 14 times the rated current will be flowing. This may cause problem armature may burn this that, but depends on because machine will not such a large current will flow, but machine will also start running. The moment it starts running, the equivalent circuit changes 200 volt, it is at the time of closing the switch 400 volts. Then machine starts picking up speed, this voltage appears which will oppose the supply voltage and this current will fall.

Now, the question is if the inertia of the machine is large, this level of starting current will persist for a longer time if machine picks up speed very slowly because of high inertia. This level of current will be there for longer time and then it is really a problem, but if the same machine is having very low inertia, then 400 ampere, but quickly picks up speed that may not be that alarming, it depends upon so many things.

But the point is we will always try to avoid such a scenario that give full voltage at the time of starting a DC motor. In absence of any back emf, it is only the armature resistance which will limit this current. Field current is no concern, because it is r l circuit that initial transient, but it will steadily go to 2 ampere. What is the rated field current, it will have R f we have estimated some 100 ohm, so 200 by 101 ampere there is no problem in the field circuit it will settle down, but in the armature circuit it is.

And always remember that field never participates in energy conversion, you apply voltage it will develop. Therefore, the application of the voltage the current will be armature current if you plot, it will be something like this I a. Apply the full voltage here; it goes to 400 ampere. After that with time it will decay down to some finally, to some study value ok.

So, what I have discussed in today's class is that given a DC machine if you know the rating of a DC machine, which is a separately excited DC machine. And I will only assume that machine has been well designed, therefore I want to guess what will be the order of armature resistance, what should be the order of field circuit resistance. How did I do it, assumed efficiency some realistic figure ok, very well designed machine 80 percent or things like that kilo watt rating was known, I calculated input power total input power. Difference of these two must be the total losses at the rated condition; this is output mind you for a motor, mechanical output power. So, difference will give me the losses.

Whereas the primary losses takes place, some losses will be in the armature circuit, some losses in the field circuit and also some losses which will be rotational loss. And I do not have any idea about them how they are really divided ok, let us assume one- third, one-third, one-third from that I will get how much will be the power loss in the armature circuit. I can estimate always the rated current for this machine, even rough estimation is 5 kilo watt divided by 200 volt, so it is about 30 ampere; from that I could guess the value of r a to be some 0.46 ohm or things like that that is absolutely I am not claiming that will be the correct thing, exact value that is what you will, but you will be expecting close by.

It is not that I will not be struggling with the fact, is it not milli ohm or is it not 5 ohm no, it is of the order of 0.5 ohm, may be 0.7 ohm also fine. Similarly the field circuit resistance, V f square by R f is the field copper loss. Therefore, from that if I know the voltage rating of the field circuit, I will be able to estimate R f value; R f value will be of the order of 100 so. Anyway today I stop here, we will continue our discussion on DC machine operations in my next class.

Thank you.