Electrical Machines - I
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Lecture – 90
Hopkinson Test

Welcome to the lectures on DC motor testing’s. So, last time we learned about the Swinburne test which is one of the simplest tests, but at the same time it does not tell you anything. I mean you will never be able to predict really how machine when carrying the rated current will behave those things they are not there in this Swinburne test. You estimate the rotational loss and on pen and paper you go on predicting what will be the efficiency, how much torque will be produced is that?

But, another way of testing that looks like by direct load the machine, but as I told you loading a machine by connecting the mechanical load of a large machines are 50 kilowatt DC machine; 50 kilowatt load is very difficult to obtain. In any case what is done is this that is called break test.

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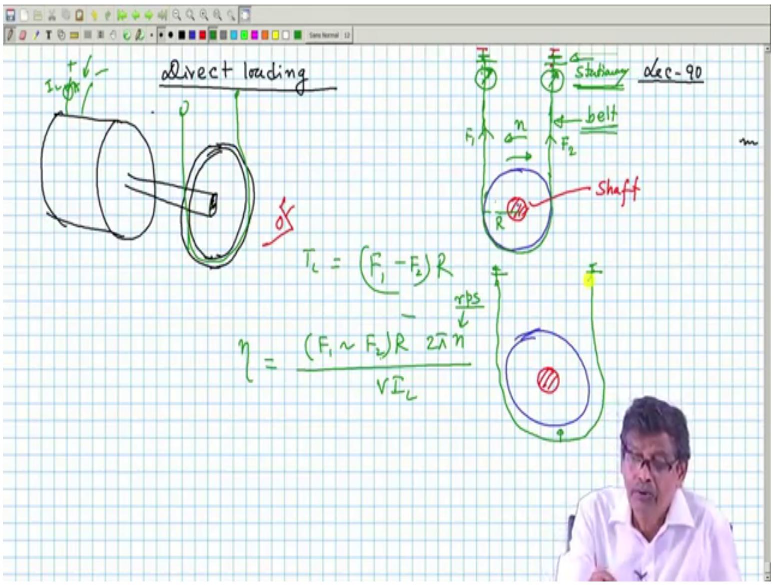

See DC break test direct direct loading, sorry this method is called direct loading. And so, the second method is direct loading, what is done or it is also called DC by using braking mechanical braking, we will do the test, let us see the arrangement; arrangement is simple.

Suppose, this is the motor this is the motor ok; this is the motor, this is the shaft of the motor shaft ok. Now, on the shaft of the motor a another drum type thing is connected on the shaft of the motor, it is coupled. And, here so this is called pulley sort of thing and what will happen is this I will just tell you the arrangement.

So, from the end if you see this end it will be like this that will be easier, this is the shaft of the machine shaft. Now, here there is a grouped pulley is connected ok. A cylindrical thing is inserted and firmly connected here. Now, and the machine shaft is like this so motor is there. So, this is the shaft of the motor shaft.

And, what you do is this now you connect a belt, this is the belt, which will go through the group of the this pulley ok, this b. And, there will be and this these sides are connected you can adjust a you can move it like this. So, that the tension in this pulleys can be adjusted. For example, there will be some like your nut and bolt arrangement.

So, you can move this either this direction or that direction. It may so, happen that the tensions. So, that it will develop tension, in these strings. It may so happen that what I mean to say that this is the pulley drum this is a drum; drum you call it and this is the shaft of the machine, shaft of the machine is this. And, these two are very loosened the screws are loosened, then how it will and it is honest a stationary structure it is fixed here.

So, this belt will then hang like this it will it may. So, happen if the tensions on the strings are loosened, it will be like this, it is not touching these. Now, adjusting the tension here, you can push it up and so, that it comes into the group and which is connected to the shaft got the point. And, there will be an indicator like a weighing machine, mechanical weighing machine, which will give you the tension you have applied to this 2 sides of this string belt, this is belt.

Therefore, if these tensions are not there it will just slack like this and if the motor is running it is running under no load is not. If the motor is so, the pulleys are here in this diagram if I want to show this is the belt here, it will go like this and on the top it is connected to these are stationary. So, you can adjust the tension of these strings. Now, what you do it was loosened very much the tensions you tight them. So, that it will fit in there in the group and then, suppose this will give you the force applied here, how much and this is force applied there. How much force?

Therefore, the difference of these 2 will give you the torque produced torque you have applied to this rotating thing is F, if this is suppose radius of the pulley F 1 minus F 2 into R. So, this is the mechanical opposing torque you will apply on the shaft of the machine. So, you are directly mechanically loading it any the moment this is very it will go inside the group with F 1 and F 2 and you have applied an opposing torque. If, F 1 is greater than F 2 the torque you will apply like this and machine must be rotating in this direction, then only it will be loaded clear.

So, this is the load torque present on the shaft of the machine. And, suppose the machine is running at a high speed 1000 rpm and you have loaded the machine. So, this will give you the net mechanical torque on the machine, where that power will go. It will only heat this pulley and the belt in this junction. It will not do going to do any mechanical work, the same power is to be drawn from the supply for this machine. And, that power majority of the power will be dissipated on the shaft it will become very hot. So, it is called direct loading method.

So, you calculate this is the load torque, multiply the load torque with 2 pi n n is in rps, you will get the mechanical power output and here you measure what is the input power. The moment you load the machine directly you will see armature current emitter rating is increasing. And, therefore, you can calculate the efficiency of the machine directly this output power will be how much, the difference of the tension into what is these R, no resistance it is the radius of the pulley, effective radius into 2 pi n omega in rps. This is the output power and your input power is V into I L got the point.

So, this is called direct machine. And, this time armature will carry the rated current, it will draw whatever power it delivers to the so called load here, which is dissipated as heat simply as heat, that power of course, is to be drawn apart along with that power of course, the other losses will be the input power.

So, it is not a very efficient method of doing this just directly loading the machine, but there are a couple of small problems you will be able to solve it. So, what I do here on the shaft we connect directly with the load. At least I mimicked the load, it is not running a pump and raising water in the laboratory I cannot do that, but laboratory arrangement I can do this. Knowing fully well all the powers will be wasted here, this you cannot touch after doing this experiment it will become too hot, this pulley inside group and the belt as a friction heat power it will be lost. But, nonetheless it will give you idea you can see whether in the commutator segment from the end view of the machine, whether it is doing perfectly armature resistance at high current will be higher is not.

So, the efficiency that you estimate will be better and also you can see the performance of the machine visually ok, there is no problem. So, far as commutation goes no flash over very large flash over taking place, those things were never possible in case of Swinburne test that was the problem.

So, it is by direct loading you can do this solve couple of problems that will be the there thing, but certainly for large machines this way of testing the motor not good, you are wasting all the powers just like that. Although, physically the armature will carry the rated current, it is like asking that a hundred kilowatt transformer tested directly in the lab ok, that power will be wasted.

So, in case of transformer for example, there was a better method. Instead I will pass the direct current, you can see in case of transformer do no load and load test from that you can predict efficiency. Once again the drawback of that method is actual temperature rise of the machine will not be understood by that test. And, also all the only little power is strong that was a advantage of that method.

Similarly, in case of DC motor when you do no load test on these Swinburne test, that is fine very good, only little power it will draw and from that you predict the efficiency or want to see the performance of the machine physically, but the second objective will not be made.

Because, it is after all armature you are not allowing the rated current to pass. So, the direct loading method is this where actual real current will flow in the armature direct loading you do, but disadvantages all the powers will be wasted.

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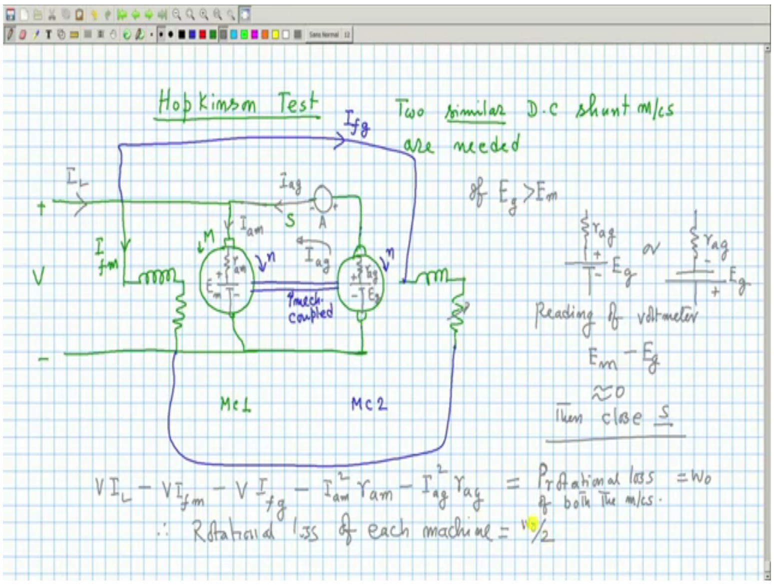

So, there is a another better method and that is called Hopkinson's method, Hopkinson Test; very interesting method, it is equivalent to some contest in a transformer ok. What you do is this in Hopkinson test as it will unfold you will see that machine will carry rated current, armature currents will be rated I will be able to pass. But, the power drawn from the supply will be very little that is the whole idea, but the condition for carrying out this test is that you require two machines; you cannot do on a single machine this test.

Two similar machines, similar DC machines this is a shunt machines are needed. Similar means it is rating voltage rating, current rating, kilowatt rating, all these things. Now, what is the connection? Connection is this, this is one machine it has got it is field and this is it is armature.

So, connect the first machine, machine 1, as a shunt motor and give rated supply voltage I have not drawn yet the second machine. So, applied rated voltage; so it will run as a motor. So, this machine I will machine 1, I will run it as a motor [FL]. The second machine whose ratings are similar identical sort of thing, it will have it is armature, it will have it is field, and I will insist that these two motors should be mechanically coupled, that I am showing it by this line, that is mechanically coupled. What does it mean? Mechanically coupled means their speed will be same.

[FL] Now, what I will do is this. So, the second this is the machine 2 idea is very interesting machine 2 is this one. The field of this machine 2, I will connect it like this. Second machine separately excited, because supply is connected it is field will be present. And, the so, this is the connection ok.

And, then I will follow the connection this I will connect. And, here I will connect a shorting switch and connect like this. Now, let us understand give supply here, this sorting switch is opened initially ok. This current is fill current of the motor, it will draw because V by rfm will give you this current. Similarly, this supply is there therefore, this current will be the generator field current Ifg fields are excited all the time. Now, I have given supply to this machine it is armature and filter energized.

So, this motor is going to run at some speed n. Similarly, the generator speed cannot change; because it is mechanically coupled it will also run at their speed. And, that will be the thing. Now, look at this second machine. Second machine, this field current is there and it is running at some speed. Therefore, there will be induced voltage bit across it is armature K phi n. It is phi is there, n is there, therefore, there will be induced voltage between these 2 points.

Now, if I connect a voltmeter across this shorting switch, what do you think this voltmeter reading will be, you should be careful? See, if you look at the armature circuit, if you allow me to remove this, it is a coupled I know that mechanically coupled. Here inside this machine, what is the equivalent circuit there is some r n and back EMF of the motor E m.

And, what is the equivalent circuit here? rag and the generated EMF. Now, this generated EMF this I am drawing here rag it could be this way Eg or it could be you do not know nah when you are starting this experiment is not. Therefore, the reading of the voltmeter depends upon, whether generator has developed a voltage such that the upper side is plus, lower side is minus or lower side is plus upper side is minus either of this one this 2 will happen here. Therefore, reading of the voltmeter will be either E m plus E g or E m minus E g.

So, if it is the E m plus E g that voltage will be very large. And, I should never operate this switch. If, I find this reading of this voltmeter is about twice this supply voltage E m will be close to V, twice V of that order then better stop the machine, either interchange the field terminal. So, that the supply polarity becomes like this, this must be ensured, this is E g. For doing this test this must be the polarity of the induced voltages in the motor that is the back EMF air and this is the generated voltage of the generator.

So, under these circumstances reading of the voltmeter; reading of voltmeter we will be the difference between these 2 E m minus Eg this will be the difference. So, up to this point supply voltage this is running as a motor this switch is open, the field of the generator is also excited because it is drawing a current. So, it will develop a voltage I only I should ensure the polarity of this voltage is same as this one and S is opened. And, then this voltmeter reading is difference of these 2. What you first do is this try to make this voltmeter reading close to 0.

How can I do that, I will adjust the field current of the generator? This resistance I will adjust, such that Eg and emr same and this will be close to 0. And, if it is close to 0, then what I will do is this I will close the switch, when this is true then closes. So, that you are sure there will be no circulating current ok.

Now, so, the final circuit after you have closed the switch voltmeter reading will now become 0 so it will now be like this. So, I will so, successfully you have what is called parallel them and this voltmeter reading has no meaning now. So, it was connected earlier, but I am not showing that time. So, this will be the thing [FL].

Therefore, now both the motors are mechanically coupled their speed cannot be different they are same and it is steadily running as this one. Now, what is done this as I told you is already running as a motor. Now, what this fellow is doing? Is it also running as a motor or a generator? What I will do is this; I will increase as. Suppose you imagine there is an emitter connected here; emitter connected here, DC meter with this side emitter polarities plus minus MC meter moving coil meter.

I will if I increase the field current, then E g will become greater than Em and current will flow like this, it will try to drive current in this direction. Provided if E g is greater than E m, how it can be greater than? I will increase the field current of the generator, greater than V close to because this armature resistance drop is neglected, what I am trying to tell, this will be greater than we no doubt, but anyway that is close to E m that part will be coming. So, that it will circulate current like this and this current I will called I ag this will be the thing clearly.

So, now, the situation will be that this machine will be running as a motor, this machine will run as a generator, because through the plus current is coming out, through the plus of this back EMF current is entering. And, this is I ag armature current of the generator and this is the thing. That is both the machines are loaded now let us see what is the implication, whether this armature currents, how it relates with this currents? What will happen is this mind you in this circuit as was correctly pointed out this voltage is same as V all the time.

So, generated voltage V plus I ag r ag is E g, similarly V minus this I a m if I call this current is I a m armature motor current. So, V minus I am r am is your back EMF those things are prevailing like this. [FL] Later this current be called the line current drawn from the supply mind you, there is only one supply V I L. [FL].

What is the total input power to this set? It is V into I l, the goal is to first estimate the rotational loss of the machine. So, what I will do is this, I will do rather quickly here. So, that you can understand the understand that the it is not at all difficult, I will first not write in the next lecture I will write, but first what I am telling is what is this quantity power drawn from the supply.

[FL] From this I will go on subtracting the losses, what is the field copper loss V into I f m. V I L is the total current drawn by this whole 2 sets subtract the copper loss of the field circuit of the motor, also subtract the copper loss of the field circuit of the generator, because this is also coming from the supply. So, V minus I f g this is the thing.

Then, I will subtract the copper loss of the motor, how much it will be I am square into r a m this is the copper loss of the motor minus the copper loss of the generator I a g square into r a g is not this is the total input power V I L. So, this is the only source of power. So, from this go on subtracting the losses, say it is running at some speed there is I a m there is I a g I f m I f g so, so, I subtract the copper loss of the field of the motor copper loss of the field of the generator this term, copper loss of the motor I m square r a m, copper loss of the generator I a g square r a g.

And, mind you on the shaft of the machine I have not connected any mechanical load, I have not connected. Therefore, if I subtract all this losses this must be equal to the rotational loss of both the machine of both the machine is not say it is equal to W naught if you call it. Therefore, I will say rotational laws of each machine; of each machine is equal to W naught by 2. So, I will continue with this in the next class.