Electrical Machines - I
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Lecture – 92
Field Test on D.C Series Motor

Welcome to the next lecture on Eelectrical Machines – I. And, we were discussing about testing on D.C machines. So, we discussed with Swinburne test that is essentially a no load test from that we try to predict the efficiency and performance of the machine.

But Swinburne test is a light load test no load test practically therefore, it will not really give you the correct temperature rise and whether the at the commutator segment and brushes, when it carries full load current everything is fine those things you cannot observe. For that we another test was suggested, which is close to load test, that is you take two similarly rated machines which are mechanically coupled and one machine will operate as a shunt motor another will operate as a generator.

And, by controlling the field current of each of these machines, you can produce different level of load currents and that is armatures will carry rated currents it is possible. However, the power drawn from the supply will be only the total losses that is taking place in the machine. So, it is equivalent to some Sumpner testing transformers sort of phantom loading, that is motor will guide the generator generator will give supply to the motor in that principally to works we discussed that.

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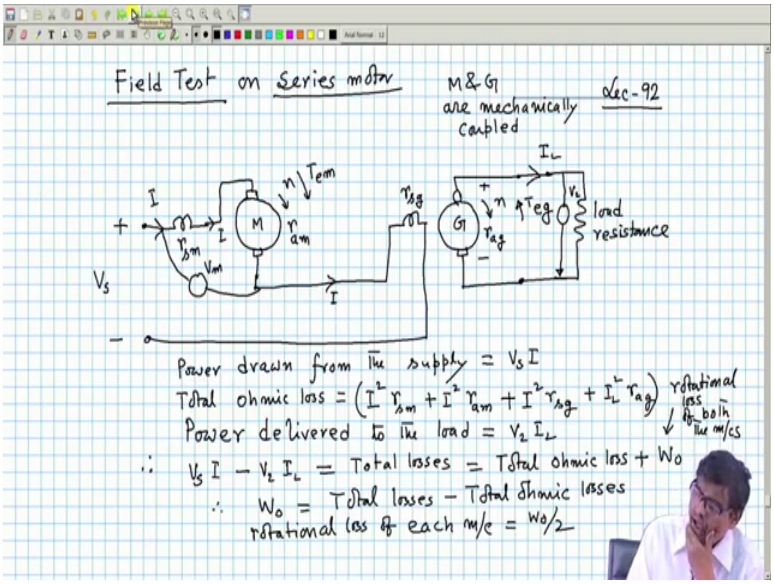

I will just mention another test that is called field test and it is carried out for D.C series motor fields test, fields test ok. Here, test field test on series motor. Here once again you require two similarly rated machines. For example, you have a series motor here, this armature, this is the field of the first machine ok, this will be connected like this.

And, you have the second machine, whose armature is here and whose field winding is here. Series field machine phi 1 number of turns very less resistance of these coils, comparable to that of armature. Now, what is done? Since series motor cannot be started, should not be started should not be attempted to start under no load condition. So, what is done you must ensure, this machine I will make it operate as a motor and this one this armature I will connect it like this got the point.

And, here this machine will act as a generator and that is the field of the second machine is connected in series with the first machine. And, you can connect them in series, because the resistances are very less. And, then this generator you must make an arrangement, such that it is loaded, load resistance.

And, these two machines are mechanically coupled M and G are that I am not showing are mechanically coupled, which essentially means that speed of the both the machines will be in the same direction, if it is n this will be also of same value m in the same direction.

Therefore, here you give the supply voltage, supply V s ok. Therefore, you will see when you switch on the supply it is connected like this, is there is load and then both field current and armature current exist for this machine, when it is switched on. Therefore, it will start running field of the second machine is also energized. And, it starts rotating therefore, it will generate voltage and it will deliver load current I L with time of course, things will increase.

And, therefore, and the electromagnetic torque developed by the machine is opposite to the direction of rotation for a generator we know this is the electromagnetic torque. For the first machine that is electromagnetic torque of the generator and for the first machine electromagnetic torque for the motor is in the same direction of rotation like that. Therefore, on the shaft of the generator a torque appears which is opposite to T e m. This machine will treat that torque as load torque, opposing torque. Therefore, that the motor is loaded from the very word go when you switch on the supply is the ensured.

So, and I should not connect a switch here, which is which will be opened, then ensure that some voltage is developed, then you close this switch I will not do that, I will permanently connect it without any switch, because let us try forget to close the switch; that means, this motor is under no load condition, that is no opposing torque opposing torque will be there very little friction. So, these things we have learned.

So, M and G are mechanically coupled and this. Now, calculations are very simple. In this case as you can see the current drawn from the supply is suppose I. Now, what will be the power drawn from the supply, this is the only source of power here. So, power drawn very simple calculations power drawn from the supply is equal to your V s into I where V s is the supply voltage ok.

And, this is suppose the resistance r s series motor there will be the resistance of the armature rs r m a m armature resistance r am. And, here is say r this is field of the generator r series generator. And, here there will be an armature resistance r ag this will be the thing. So, this is the power drawn from the supply. And, from this supply this power drawn, I will subtract the ohmic losses of this machines ok.

So, what will be the ohmic losses of the machine? Total ohmic loss will be I squared the copper loss of the motor r sm plus sorry r sm I square r s m plus I square r am copper loss here, plus copper loss of this; copper loss of this, that is I square same I same I is flowing, because of my connection in this way I square r sg series field of the generator. This is the total ohmic losses is there any other ohmic loss yes copper loss plus I L square r ag.

Because, all these losses has to come from this apply apart from rotational loss that is this thing. So, total ohmic loss taking place in this whole circuit at these this loss here lost there ra loss here, loss here, that is all is not that is the thing. And, I will connect a voltmeter here V 2 suppose.

Now, power delivered to the load; delivered to the load to the load is equal to this V 2 into I L is not this much power is delivered. Therefore, Vs I input power minus the output power V 2 into I L this must give me the total losses, taking place input vsi minus output V 2 I L will give the total losses.

And, this total losses will comprise of total ohmic loss plus, the rotational loss of both the machines of both the machines is not this must be total loss total ohmic loss this I have already calculated. Therefore, W naught will be is equal to total losses, I am I am rewriting the same equation total losses minus total ohmic losses. Now, both these machines are running at same speed is not and their field currents are same, they are similar machines.

Therefore, I will then approximate that rotational loss of each machine; of each machine will be equal to W naught by 2 that is how I will approximate. And, so essentially you will be assuming you are estimating W naught by 2. Therefore, the efficiency of the motor I will be able to calculate and efficiency of the generator also I will be able to calculate, how?

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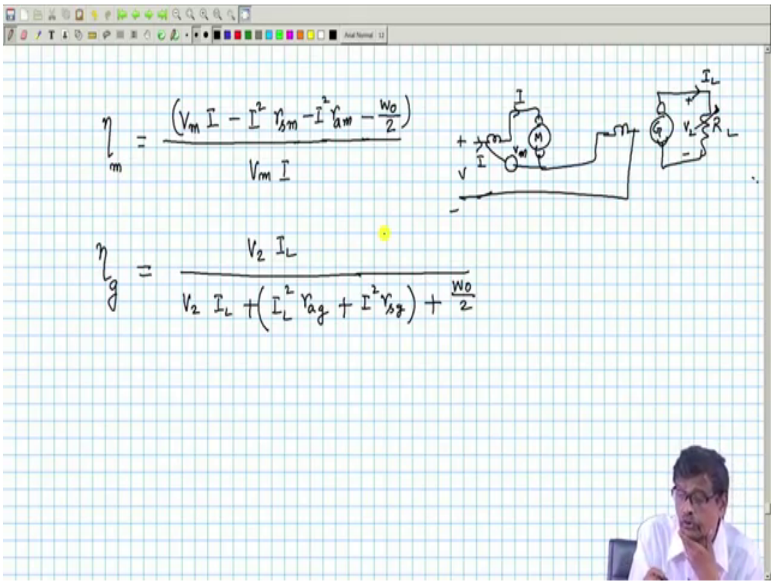

So, efficiency of the motor will be equal to for calculating efficiency of the motor the input power is easy to calculate. So, for efficiency of the motor you would note down this voltage connect a voltmeter here call it V n got the point field and armature supplied with V m voltage and this motor is drawing a current of I. So, this is the input power; so I will say. So, input power of the machine is V m into I, not V into I input, but on the top I must write output so input minus the losses, what are the losses minus I square field loss that is r s m, minus it is armature loss I square into r a m and minus the rotational loss, this will be the output and input is V m by I, I quickly draw the circuit here, so that you can understand what I have done.

So, this is the field and this is another machine, this is the armature. So, these two are connected in series and here is the load, this is the circuit for field test is not plus minus V, so I. And, this this voltage I am calling it as V m voltage applied across the motor and this is generator. So, V m into I is the input power to the motor from this if you subtract all the losses this current is I.

So, I square r s m, minus I square r a m and minus the rotational loss, that will be the net output of the machine, this divided by the input part which is the V m into I. Similarly, you can calculate the efficiency of the generator. As the output power this I told you as V 2 and this is I L, this is R L. So, output power of the output of the generator is easy to calculate.

So, first calculate the output of the generator V 2 into IL minus I divided by the output plus the losses of the generator. Losses of the generator will be plus, this is these are the losses that is I L square into r ag copper loss here plus it is field generator field each copper loss is of course, I square into r sg generator field ok and plus the rotational loss W naught y 2.

Therefore, at various degrees of loading you will be able to calculate the efficiency of the of both the machines and you can plot in fact, that is I will different degree of loading. But, I will never make R L open, infinity I will not make if you make this motor will have problems under no load you should not allow any D.C series motor to run.

But, in the field test mind you the power drawn from the supply will be large, but the only advantage of this method is I have avoided that the mechanical loading system with pulley, belt arrangement, those becomes very difficult. And, those spring tensions T 1, T 2 on the shaft of the machine they will vibrate when it will rotate correct readings are not easy to get.

But, in the simple experiment where the field of the second machine is connected in series with the first machine, then it is energized by noting down appropriate readings you will be able to calculate the efficiency of the machine. So, this is a very interesting test and it is of course, not true that you are drawing very little power only supplying the losses.

This machine is really acting as a motor and it is driving the generator, which is as if separately excited and it is delivering load. That is there, but anyway this is a very good test where you can observe how the machines are behaving, without any mechanical load and calculate it is efficiency and also observe how commutation takes place, physically looking at the commutator segments and brushes when it carries a rated currents and things like that ok.

So, this is the field test. I will rather close this chapter only making another small comments that for example, so, we have studied D.C separately excited machine, series motor, there may be compound machines also. In the notes you see you will able to understand what it all means. But, essential thing is the voltage generated in a machine is K phi n, where phi is the net flux per pole, if it is compound machine both shunt series DC filters there they will decide what is the flux per pole together.

And, torque equation is K phi I a where phi once again is the net flux per pole that will take place. Now, another comment I want to make is that that for example, this I will only show for a shunt motor, that in case of for example, a transformer. See, the losses that take place in any machines 1 part of the loss is called fixed loss.

For example, in case of transformer iron loss is fixed loss is not. And, another loss depends on the degree of loading. For example, in case of transformer what are the currents in the bindings, what percentage of rated current is flowing. This ratio of these two currents is essentially is the degree of loading x.

And, we found that maximum efficiency in a transformer will occur when the variable loss that is x square into PCU full load, copper loss full load is equal to peak core loss, at that time maximum efficiency occurs look at the transformer node. Similarly, in case of DC machines also the if you do not touch the field circuit; take the case of shunt motor. Condition for maximum efficiency is just few lines I will tell condition for maximum efficiency eta, you considered suppose there is a shunt motor.

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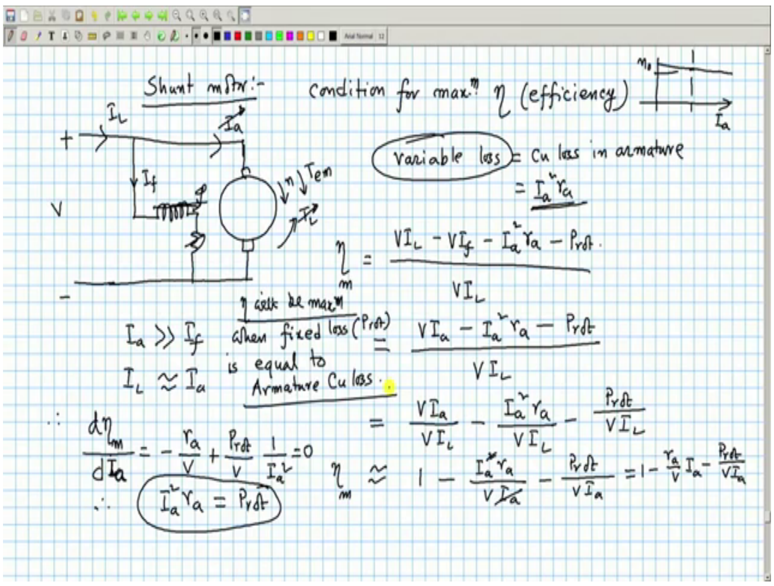

And, this is the field winding. And, it is suppose supplying some mechanical load such that it carries armature current. This armature current may be rated current, if your mechanical load on the shaft is sufficient, this is n, this is electromagnetic torque, always draw like that and this is the load torque.

Because of some load torque steady state operations it draws some armature current and this is I f. What, I have decided I will not vary the field current. Although, I will vary the load torque so, that different different armature current flows. And, try to find out what is the variable loss here. Variable losses is equal to copper loss in the armature, copper loss in armature, that is equal to I a square into r a this is the copper loss.

Because, I a will depend upon T L. So, Ia will be varying as T L varies opposing torque you put different different values more and more T L equal to 0 shunt motor will run at no load finite speed shunt motor has got a finite number speed series motor does not happen anyway. So, it will draw that and variable loss is this. Coal loss will it change from no load to full load not really, why? Because, the speed regulation of a shunt motor from no load to full load condition is only very little and here I am telling I will not touch field current.

So, phi is constant eddy current hysteresis loss depends upon the relative speed between this phi and the rotation n does not change much, recall that speed will fall very little slope is decided by r a. This is the no load speed, this is the full load speed, only little change and this side is armature current, we have seen that. Now, in this case so let us calculate when the machine is loaded to carry an armature current I a. So, what will be the efficiency of the machine?

So, efficiency of the motor will be eta m will be equal to input power that is equal to V into I L divided by mechanical power output. Mechanical power output I how I am calculating? I will subtract the losses from this input power. So, input power is V into I L minus the losses that is V into I f field copper loss here, minus I a square into r a armature resistance law minus rotational loss. These are the 3 things; this is how I will be able to do it ok.

Now, this one is nothing, but V into Ia I L is I a plus I f. So, V I f will cancel out and minus I a square r a, minus p rotational, divided by V into I L is not this will be the thing. Now, what I will do is this, I will separate this terms like via divided by V I L minus I a square r a by V I L minus P rotational V I L this will be the thing. Now, in a shunt motor the rated value of the armature current is much higher than the field current.

Therefore, what you can assume is this that I L is approximately equal to armature current, what is the order of this current drawn from the supply is surely decided by this at least at near at full load conditions. Light load condition these armature current will be quite small, but at in the vicinity of the rated current it will be somewhat like this.

So, if that be the case, then this will be approximately equal to 1, I a is equal to I L minus this I will write it as I a square r a divided by V into I a minus P rotational by V into I a, replacing I L by this one. And, then this is equal to 1 minus r a by V into Ia and minus P rotational by via, this will be the efficiency of the motor as a function of Ia.

Therefore, efficiency will be maximum if you differentiate this with respect to armature current d I a, if you I a efficiency will be maximum, when this is equal to 0 this 1, which is equal to 0 here and this will become here I a only 1 I a. So, minus ra by V; V supply voltage constant so differentiation of I a 1. And, this is minus P rotational by V and differentiation of I a is 1 over I a square with a negative sign which will make it positive and this is equal to 0. So, from this you can easily see when I a square r a is equal to P rotational.

This is the condition, that is once again variable loss is equal to fixed loss that is taking place in a shunt machines. So, eta m occurs when efficiency will be maximum approximately, when fixed loss. That is P rotational in this case is equal to variable loss that is I a square r n, this is the variable loss is equal to armature copper loss got the point.

So, anyway go through this carefully motor operation generator operation, then in the next class, what I will be doing one leftover thing, while I told you about the windings. I discussed the lab winding most probably at length, but I told at that time that way winding I will discuss at the later time and that I will do in the next class.

Thank you.