Electrical Machines - I
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Lecture – 89
Swinburne Test

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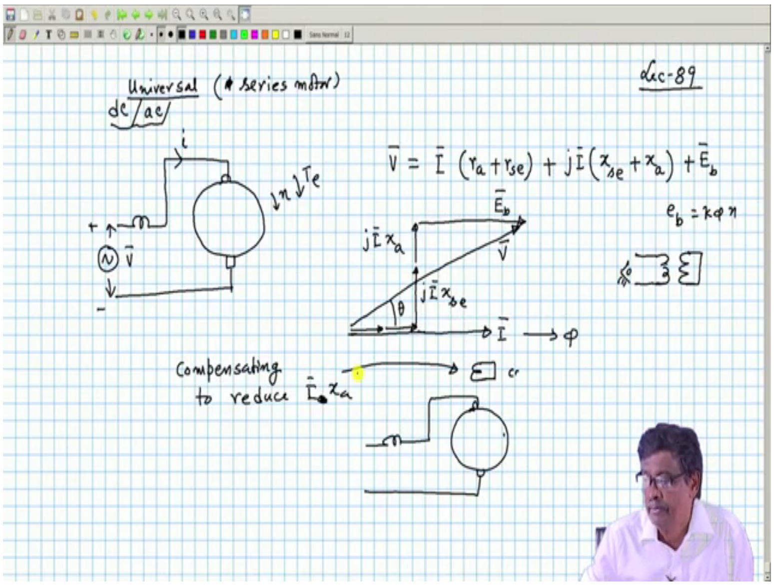

Welcome to next lecture and we have been discussing with a universal motor, universal motor which is actually series motor series motor. Why it is universal because it will operate both from ac and dc supply ok, and the because I a f and I a are in phase so, unidirectional torque will be produced even if the current reverses with time ok. So, what is essentially to be done is this, because it is to be supplied from ac supply from ac supply.

Therefore, if this is ac supply here and this is your I this I is same as ief and I a then torque is proportional to I square therefore, torque will be always unidirectional even if currently versus, but only point is if you want to any dc series motor designed for dc supply operational only, that should not be energized to with ac supply because then the coal losses will be very high on this stator.

Therefore if a series motor is to be operated both from dc and ac supply then you must see that the stator irons are also laminated, apart from the armature is laminated. Armature is laminated in any case in dc supply also. So, that was the first thing, and the second thing is I told you in this case if this is the supply voltage I will just indicate I will really not analyze, but tell you fairly o l, so that you will be able to also calculate power torque what not by drawing the further diagram of the machine.

For example since this is a series circuit this is the applied ac voltage V and suppose the machine is running at some speed n and electromagnetic torque developed is equal to load toque then it will run at steady speed. Those things are there this is the electromagnetic torque, then your thing is that the phasor diagram tells me that it will be equal to applied voltage, should be equal to this I this current phasor I into there will be resistance drop r a and r se r se plus of j I, city circuit reactance say x ac plus armature will also have some inductance x a. And plus the back emf plus the back emf this will be the equation.

Now, to draw the phasor diagram it is very simple because it is a city circuit you better start first drawing because current is same for field as well as armature. So, draw first current phasor I if this is the current phasor, then go on adding the drops that is I r a armature resistance drop I r a plus I r a c the resistances are of the same order very low this plus j I a I x series field plus, j I armature reactance. This will be this term this term this term this term this term and the remaining terms is your E b and the E b is proportional to k phi n phi is the flux per pole and phi will be here is not, because flux per pole will be in phase with I.

Therefore k phi n is the back emf produced and back emf will be therefore, in phase with this one, because eb after all is proportional to k flux per pole into n phi is time vary n is constant it will unidirectional torque rotor will respond to average torque whatever it is. And therefore, this thing will be the supply voltage, and this will be the power factor angle theta at which the machine will operate. Therefore, what you do is this if you know this supply voltage how much current the machine is drawing so, you will be able to calculate back emf Eb is equal V minus this drops take this on the left hand side, and then the power you can easily calculate how much a power is converted to mechanical energy that will be E b into I a just like that.

Sometimes what is done to, so you see compared to dc operation its drops in the machine will increase because of the reactances of the field and armature winding. What you can do is to reduce this drop further you can use a compensating winding, compensating winding to reduce I a I x a drop how idea is simple, this is the field this is the usual thing this is the armature like this, but here you connect a coil and this coil you keep it shorted this coil is kept shorted. It is like this one in case of a transformer for example, a transformer suppose I keep these secondary open circuited, what will be the reactance between these two points if you connect a supply it will see a very high reactance is not, but if you short circuit this what will be the equivalent reactance scene between this determinant only the leakage reactance.

So, here there is a coil here armature coil which is like this so, so it will have now armature flux which is time bearing therefore, there is a coil here whose access is same there will induced voltage and it is shorted therefore, reactance of this armature will be now only leakage fellow, just like this one therefore, some compensating coil maybe connected to reduce the drop here so, that E V will be more like that.

Anyway so, if all the parameters are given you will be able to solve since we will be concentrating on d c supply therefore, I will not go any further to this one, but only thing I will say mechanical power will be E b into I a or V into I into cos theta is the real power, from that if you subtract the copper loss in the field and the armature you will get the real power output that will be equal to the gross mechanical power developed by the machine.

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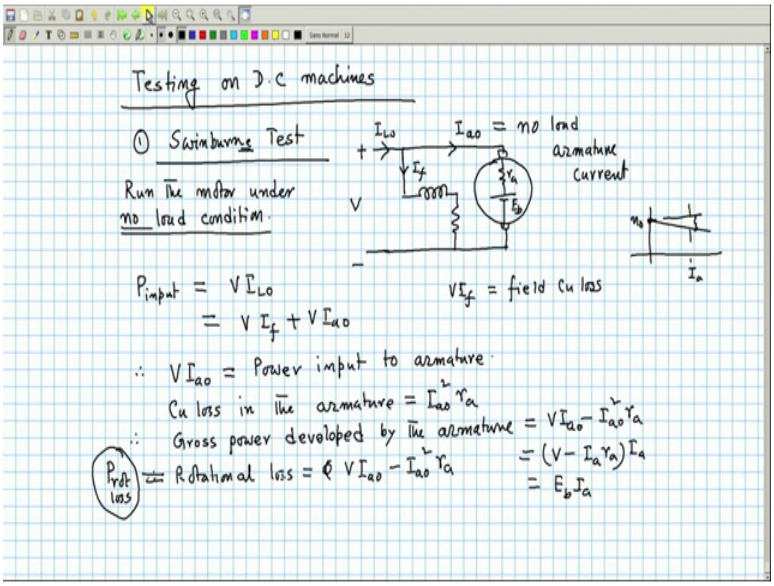

Testing on D.C machines

① Swinburne Test

Run the motor under no load condition.

I_{a0} = no load armature current

$P_{input} = V I_{L0}$

$= V I_f + V I_{a0}$

$V I_f$ = field Cu loss

$\therefore V I_{a0}$ = Power input to armature.

Cu loss in the armature $= I_{a0}^2 r_a$

$\therefore$ Gross power developed by the armature $= V I_{a0} - I_{a0}^2 r_a$

$= (V - I_a r_a) I_a$

$= E_b I_a$

$\boxed{P_{rot} \text{ loss}}$ $=$ Rotational loss $= V I_{a0} - I_{a0}^2 r_a$

So, anyway with this rather conclude the series motor as well ok. Now, I will today tell you about some testing on d c machines testing on d c machines. So, d c machines while you test you better operate as a motor and try to test this. One test is called a very simple test called Swinburne test Swinburne test spelling you just check Swinburne test in Swinburne test what is done for example it is a shunt motor you are running. So, you run the machine first on shunt or separately excited motor. So, a shunt motor you connect it like this and you give supply rated supply voltage you give.

So, this is the line current I L and this is the field current and this is armature current. So, in Swinburne test run the motor run the motor under no load condition under no load condition. What does this mean under no load condition that is on the shaft of the motor I have not connected any load torque no opposing torque is acting so, far as load is concerned; however, opposing torque is acting because of friction and wind age is not, some little opposing torque will be acting that is why it will run at a constant power and the current drown in the armature circuit is I a 0 is called the no load armature current because no load operation. So, whatever armature current it draws it should be called no load armature current ok.

So, a little bit of mechanical power is developed that will supply the that will supply the opposing frictional torque present or coal losses of the motor [FL]. Input power total input power P input is equal to V into I L which is same as V into I f plus V into I a 0. This certainly is the field copper loss so, V I f is equal to field copper loss therefore, V into I a 0 is equal to power input to the armature power input to the armature, here V into I 0 power goes to the armature power input to armature. Therefore, a and copper loss copper loss in the armature. Armature is equal to I a 0 square into r a is not what is this is r a and there is some back e m f, no load condition.

So, copper loss in the armature is this therefore, gross power developed by the armature developed by the armature, will be equal to b I a 0 minus I a 0 square into r a and you can easily see that is what we have been telling you repeatedly, that if you take this common I a common this is nothing but this which is nothing, but back e m f into I a gross power developed by the armature is always e b into I a back e m f that is what we get. Now this power Eb into I a or this one this gross power developed is nothing but the no load loss or rotational loss of the machine therefore, rotational loss.

And rotational loss consists of what It consists of the iron loss in the armature plus the friction and windage loss that is present on the machine. And this is nothing, but this quantity only is equal to V into I a 0 I am sorry I a 0 I have told I a 0 minus I a 0 square into r a this will be this thing. Therefore, in the Swinburne test what is done machine is operated on no load machine getting maybe high maybe 10 kilowatt D C motor, but it will draw only little power run the machine under no load condition. So, to conduct the experiment you require only machine will draw only the no load current I L 0 under no load condition I L 0 is I f ok

So, this a rotational loss is what is estimated from Swinburne test, then we will say that only this test I will do then I will be able to predict the efficiency or performance of the machine when the same machine is running either as a motor or as the generator we will see that under loaded condition. So, from this test this test merely will help you to estimate the pre rotational loss. Rotational loss mind you depends upon the speed of the machine and level of the flux if you are not wearing the flux rated field current is flowing and speed from no load to full load in a shunt motor changes only by a small amount is not you recall with no external resistance connected.

So, change in speed from no load to full load current is only little, speed regulation is quite small in a shunt motor because r a small anyway and this is I a, so, we assume that rotational loss is constant.

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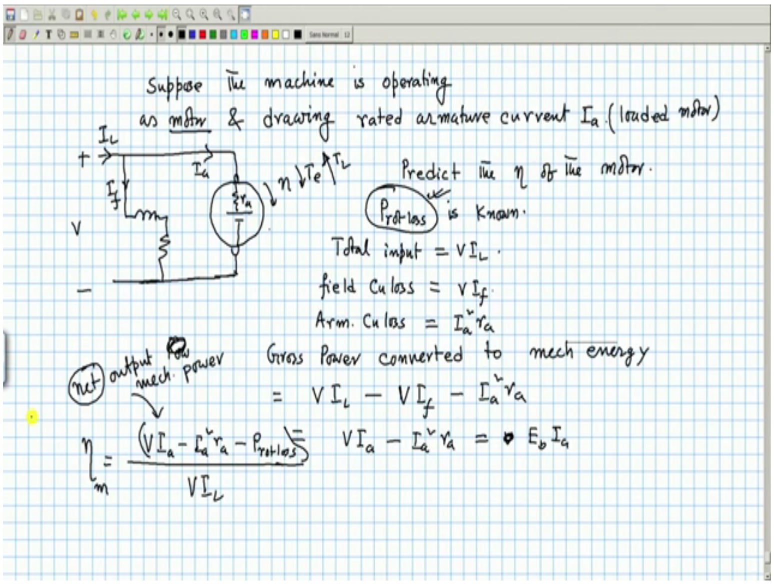

Suppose the machine is operating as motor & drawing rated armature current I_a (loaded motor)

Predict the η of the motor.

$P_{rot\,loss}$ is known.

Total input $= VI_L$.

field Cu loss $= VI_f$.

Arm. Cu loss $= I_a^2 r_a$

Gross Power converted to mech energy

$= VI_L - VI_f - I_a^2 r_a$

net output mech. power

$$\eta_m = \frac{(VI_a - I_a^2 r_a - P_{rot\,loss})}{VI_L}$$

$= VI_a - I_a^2 r_a = E_b I_a$

Then I will say that suppose the same machine the same machine is operating as motor and a drawing rated armature current rated armature current say. I a; that means, what I am telling this is the motor say motor now the machine is loaded this armature current is no longer I a 0 it is a drawing the rated armature current field current I have not touched. So, this motor that is loaded machine I have put now mechanical load loaded machine loaded motor. And same rated voltage I have applied field current is not going to change because I have not touched the field circuit V by rf is the field current, and now the machine is loaded direction of rotation there is sufficient electromagnetic torque and so on. And load torque is equal to electromagnetic torque and this is the situation.

Now, how to calculate the efficiency of the machine predict the efficiency of the motor now the motor? What is known P rotational loss is now known is known from where from Swinburne test ok. Then I will say that that input power I mean I am writing once again so, that you understand this is the line current now. So, total input is equal to V into I L, field copper loss is equal to V into I f. So, armature copper loss is equal to I a square r a is not this will be the thing.

So power input to armature copper loss is this. So, power converted to mechanical energy I could write straight like this here this is e b. So, from this you subtract this and this ok. So, power, gross power converted to mechanical converted to mechanical energy, will be equal to V into I L minus V into I f minus I a square r a like this. And I L minus I f is same thing I am really doing I a minus I a square r a which is nothing, but E b into I a this is the thing.

Now, therefore, efficiency of the motor will be this is the gross power converted to this is we are power input to the armature is that way also you can write V into I a is the power in this circuit inputed minus subtract the copper loss I a square r a. Then subtract the p rotational loss, this will be the output net mechanical power output net output mechanical power divided by the input total input V into I L.

And this will be the efficiency when it is running as a motor, got the point. Therefore, you assume many degree of loading 50 percent loading I a will be 50 percent of the rated current plug these numbers here you will be able to predict the efficiency of the motor at various loading condition.

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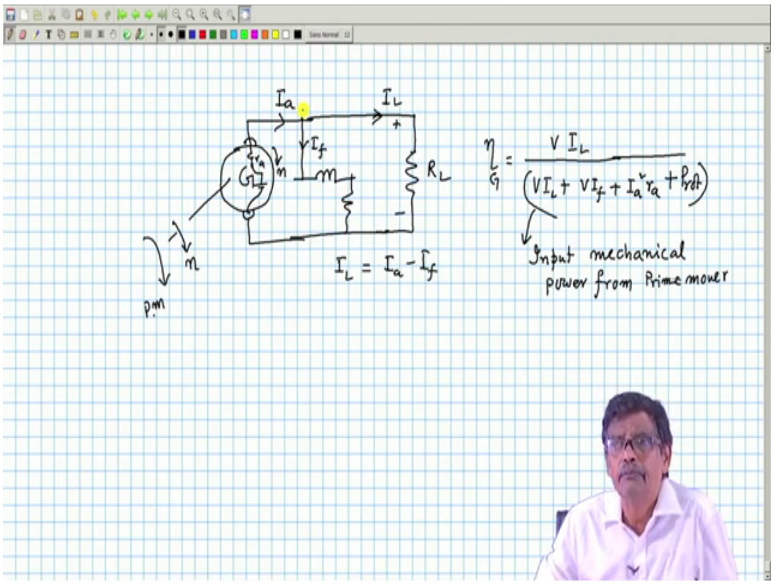

Similarly, if the same machine is operating as a generator, suppose as a shunt generator this is the field and here is your load. So, this is the load current and this is the field current and this is your Ia is not this will be the thing. So, here also I will say that and the machine is running at speed n which is close to the rated speed of the machine. Field current here it is rated voltage so, the efficiency as a generator it will be for a generator you first calculate it is easy to calculate the output power of the generator. What is the net output power if this is the terminal voltage V into I L, this is the power output to the generator, divided by input mechanical power mind you there is a prime mover prime mover which is driving the machine with speed N.

So, V I n is the output and what will be the input output that is V I L plus all the losses what are the losses V into I f field copper loss in this circuit plus armature copper loss I a square r a. This is r a and this is this here it is not generated voltage e g. So, V I L plus V I f plus I a square r a plus the rotational loss and this power I specifically write is the input must be the input mechanical power from prime mover from prime mover because in case of generator you have to connect a prime mover that is the source of all the power to the system. So, in case of generator it is very easy to estimate the output power divided and get the input power.

Similarly, here also you can predicted the efficiency of the generator at various degree of currents supplied to the load. Mind you here it is I L is equal to I a minus I f applying kcl at this point So, this is how you can do it. So, this is the simplest test Swinburne test run the machine as a motor run the no load condition, estimate the rotational loss estimate the rotational loss this fellow from the it is running as a motor since it is running as a motto in case of motor what happens is this input power is very easy to calculate V into I L from that you start go and subtracting the losses. If it is running under no load condition initially then I mean the earlier one if it is running under no load condition. So, current run is I a 0 I L 0.

There is some opposing torque present which is very little because of friction wind age and also here there is power loss in the code. So, these two together and power loss in the code is proportional to speed and the strength of the flux that decides the ad current and if these two are constant I am not touching field current speed is not changing too much because no external resistance connected speed regulation is only maybe two to 5 percent from no load to full load current therefore, you estimate what is known as the rotational power.

And that rotational power you freeze it let it now run as a motor fully loaded then he will be able to calculate efficiency because I now know the rotational loss this fellow is being known I will in case of motor from input power you go on subtracting the losses field copper loss armature copper loss and rotational loss then whatever power will be left that is the actual mechanical power net mechanical power this net.

So, I subtract p rotational loss an input is V into I L I will be able to predict the efficiency of the machine. Although this method is simple, but and it is attractive in the sense suppose it is the big machine 20 kilowatt machine. Base thing would have been you load the machine see the performance because this never tells you anything when these large current flows is commutation visually you can see commutation is fine nothing you can do about that, you only assume code loss to remain constant. So, in our next class I will tell you direct method of testing the machine I will just point out that method and then I will tell you another interesting way of testing the machine that is called Hopkinson Test so.

Thank you for the next class.