Electrical Machines - I
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Lecture - 88
Universal Motor

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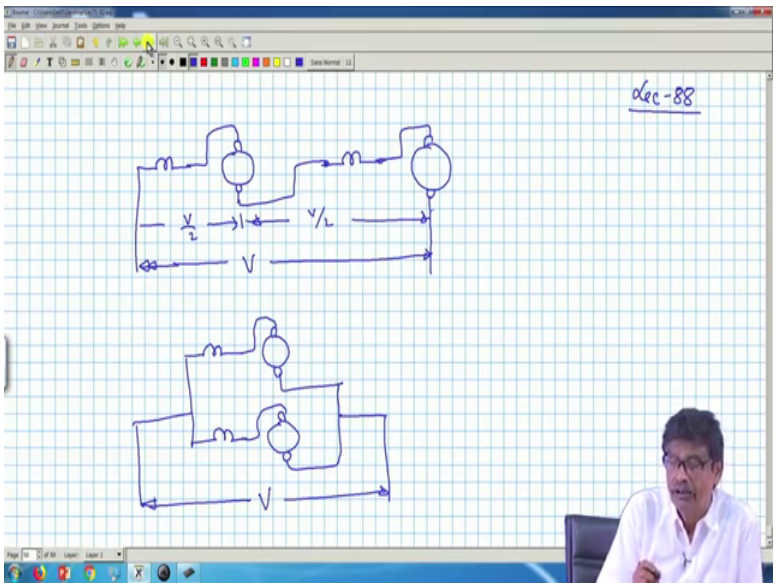

Welcome to lecture number 88. And, we have been discussing about series motor, and it is speed control I mean, controlling the applied voltage, as well as how to control the field current. Because, in general field current and armature current are same so, you must make a distinction between these two issue you want to weaken the field of the machines. Several techniques I have told you.

Only one point I will tell that, what happens is these for example, interaction purposes. Series motors are used because heat can give you large starting torque and running torque required is less; therefore, series motor had been very widely used for traction purposes.

But, nowadays as I am telling you, once again people are going for induction motor drive in traction even. But, nonetheless series motors were used for a long time; in fact, Calcutta Tram still uses DC motors or Kolkata Metro uses DC series motors to for traction purposes.

Now in general, what they do is this or in general for tractions, there may be several DC motors. So, at the time of starting, more than one DC motors are used. For example, suppose we have got two motors; this is one motor, series motor and this is another series motor. I mean, I will just give you idea, how to analyze these things. What they do is this at the time of starting the motor, this is one motor field and armature this is field an armature for another motor.

These two motors at the time of starting they will connect them in series and apply the voltage V like this. V is the rated voltage for each of the motor. So, you can connect these two motors in series and apply the same rated voltage V means you have applied V by 2 across it, half the rated voltage you have then applied it means that, is not. And also you can connect them in parallel. This is another motor connect them in parallel and apply V. That is perhaps at the time of starting, you apply half voltage may be some resistance will be also necessary to restrict the starting current, that is not the issue, but you can get two different speeds in this way. You connect them in series, then we have just indicated for a motor.

If you reduce the voltage by certain amount for same load current or whatever it is you can calculate the speeds and similarly you can connect them in parallel and you can get another voltage. And on top of it if you want to run it at higher speed then the individual field coils can be connected in series or parallel. Several options are now available to control the speed of the machines.

So, what I have planned in my next lectures, I will hold some tutorial sessions to solve some problems on DC motors, where this kind of problem also I will discuss. There is you can connect the two identical motors. Connect them in series, connect them in parallels and they might have field coils switch can be separated and they can be individually connected in series parallel to give you various speed options.

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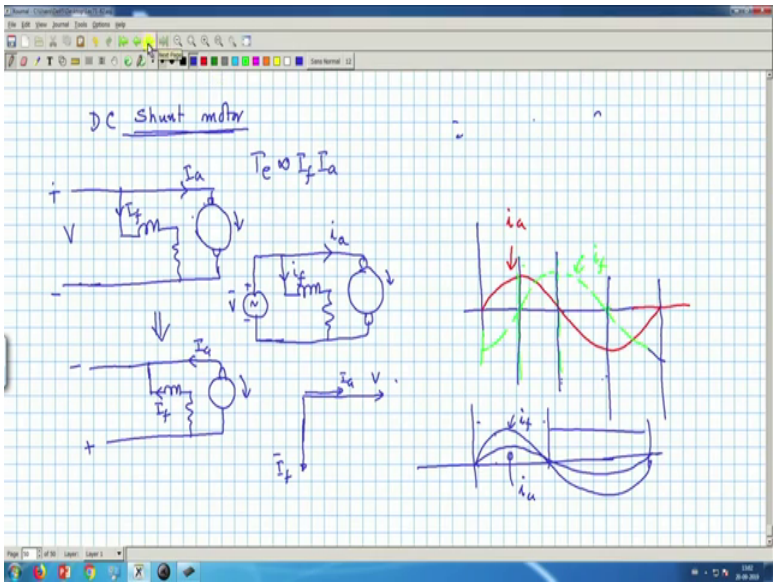

Today, what I am planning only one point about series motor I must tell to conclude this particular topic is that. Suppose, I pose a problem like this, suppose you have a shunt motor, ok and you have a series motor here. And their DC designed for DC fine. DC series motor DC shunt motor. We ask ourselves this question that, suppose it is a shunt motor, this is the field coil, this is your supply. Suppose, I ask you this question; that ok, rated voltage we have applied machine is running at some speed things like that.

Now, if I ask you that; the same motor, I will now disconnect it from the supply from this supply disconnect it and connection I will not change anything. But, what I will do is this? I will apply reverse voltage, once again restart the motor. What is the observation? Will the machine run in the same direction? The answer is yes, it will run in the same direction, because T e is proportional to the product of I f and I a. So, it was I a, it was I f. In the second case, this is I f, this is I a, is not, both of them has reversed; therefore, product will remain same.

So, electromagnetic torque will be in the same direction. If it was running doing like this, in this case also it will do like this, got the point. Therefore, a shunt motor if the supply terminals are reversed; in the steady state, it is it will be rotating in the same direction. However, if one of them either armature or field is reversed, then of course, electromagnetic torque in will be in the opposite directions. So, to reverse the direction

of rotation; what we say, either you reverse the armature terminals or the field terminals, then it will start rotating in the opposite direction, that is what we say.

[FL] After knowing this fact; that the, if the supply voltage terminal is reversed direction of rotation does not change, it remains same. Therefore, we ask our self; that ok, I have the same DC motor, shunt motor and I will do like this instead of connecting it to a DC supply. I now plan after knowing these facts; that if, supply voltage reverses torque produced in the machine is in the same direction, if that be the case, then, I will do one experiment. I will connect it to an AC source, instead of DC supply I will connect some B max sin omega T.

And I will see to it that the voltage applied to the machine is not exceeded beyond its rated value; such that V max I will select in that, V max sin omega T I am applying. And then I am thinking that this fact is known, now I have applied AC voltage; therefore, supply voltage will reverse on its own. I do not have to do that changeover myself. And therefore, this machine should work as a motor when it is connected to AC supply.

That is the question I am asking to you. Will it really work, if you apply an AC voltage instead of a DC voltage and you have undertaken enough precaution that this applied voltage magnitude is not exceeded its rated value. Therefore, then I say that machine is because, this currents will be now like this I f I a and instantaneous currents, time varying AC voltage I have applied whether it will work. Because I know this fact; if supply voltage reverses torque remains unidirectional, it is expected it should be work, this is this thing.

Now, the answer to this question is; that torque is I f into I a, product of I f into I a no doubt. But in case of shunt motor; you see; I am so sorry here, I have written like this, this is I a and this is I f. In case of shunt motor; at least at the time of starting if you see the inductance of this field circuit is very large. Why? Because number of turns of the field coils of a shunt motor is large inductance is proportional to x square, therefore field circuit inductance is very large. Whereas the armature circuit inductance is very small, only leakage flux is not quadrature axis reluctance is also high.

So, what happens is this? If this is the supply voltage, in this case what will happen? This is your voltage, the field current at the time of starting I am drawing ok. Machine was not running, I have switched on this AC voltage. Then what is I f and I a will be; I f phasor

will be approximately 90 degree lagging. And this I a, which is v by almost r a at the time of starting, no back emf nothing like that.

So, I a will be in phase with this current. Therefore, you see the field current and armature current will be practically 90 degree apart, which means that forget about this now we are not discussing. So, shunt motor only I am telling. So, what will happen is this? If this is armature current, this is I a. Field current will be lagging it here; field current will be 90 degree lagging the armature current. So, field current will be something like this here, is not. So, this is your I f. That will be this situation.

Therefore, you see that torque, which is proportional to I f I a, and this is mind you 20 millisecond 50 Hertz supply .Therefore, in this zone if you see I f into I a is negative this product. During this zone, I f and I a product is positive, is not during this zone I f I a is in one direction, negative. During this zone I f I a product is positive, then during this zone I f I a product is negative I f is positive, but I a is negative. So, over a cycle and during this zone I f I a both are negative, so, positive. Therefore, the average torque will become 0 and motor will not work, it will never start.

So, a shunt motor if somebody thinks that, knowing this fact that if I reverse the supply voltage terminal. Torque direction remains intact same direction torque. And then he thinks that I will then energize it with AC voltage 50 Hertz it should work, but it will not because, field inductance is very large or omega L is very large of the field circuit compared to armature circuit. So, i a and i f will be out of phase by 90 degree. Therefore, average electromagnetic torque will be 0 over a cycle and motor inertia will only respond to the average torque. So, it will not work.

So, a shunt motor will never work with AC supply out of question. Because I f and I a therefore, it is essential that if a DC motor works from AC supply. Then i f and i a must be in same time phase, is not. If i f and i a; if this is your i f and this is your i a, same time phase then this product will be always positive this up this up also.

So, unidirectional torque will be produced. This is suppose i f; suppose i f and i a are in phase time phase. Then the product of i f, i a will be always positive and torque produced will be always in the same direction. No matter; whether both of them are positive or both of them are negative, because it is the product of this two that decides the torque. Therefore, it looks like then i f and u a will be in phase provided if it is a series motor.

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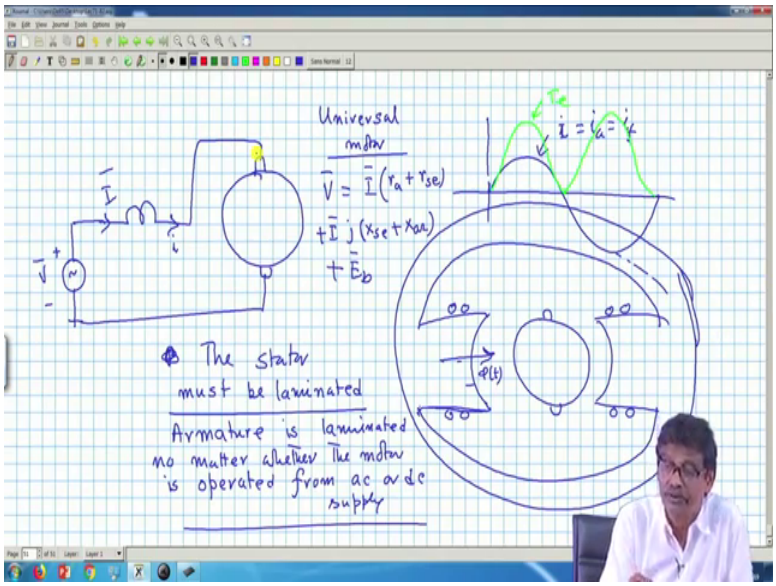

This is the field, this is the this one, it is a series motor; this is series motor. In this case, if you apply an AC supply, I do not care, because this current; armature current and field current are same and they cannot, but change together. That is in this case; both armature current and field current are same and their indistinguishable. Therefore, if I is like this; this is I suppose I say, small i better indicate if it is to be operate i. This i is nothing, but i a nothing but, i field.

Therefore, the electromagnetic torque produced will be i f into i a and if I sketch it like this it will be something like. This is the electromagnetic torque. So, always unidirectional torque and average torque a very good average torque exist and therefore, motor will start rotating in a particular direction. Therefore, a DC series motor is a candidate to be operated not only from DC supply, but it looks like from AC supply as well it will work.

The question is, whether it will be operating as nicely as it will operate from a DC source or not, that those things have to be investigated. But the point is, from the simple argument we can say that; it is only the DC series motor perhaps it will work also from AC supply, because i f and i a are same. Instantaneous and they are bound to be in time phase, because of this serious connection that is the whole idea.

Now when a DC motor, DC series motor which is designed for DC operation only should it be operated from AC supply. I now know that it will operate with AC supply as well,

but suppose a there is a DC series motor and it is written that it is designed to operate from a DC supply. But, I know these things, then I plan to operate it from AC supply will it be advisable or you can have a motor where it is written that DC series motor, but it is designed to operate from both AC and DC supply.

Therefore, what should be the differences between these two cases? Differences will be obvious, because you know the structure of any DC machine. This is the armature and these are the field structure. I will draw quickly like this, and these are the pole shoes it is like this. What I told, if it is a DC motor, what I told? This iron including the pole shoes, they are made solid iron because, it will operate on DC. But, I am not now telling these are the field coils.

I will I have planned these armature and field coils will be in series and I plan to excite it from AC supply. The moment you do the flux here will become a function of time. Therefore, this flux will be flowing like this here through the arcs. And if it is solid iron the eddy current loss, hysteresis loss will be taking place in the stated iron structure as well. In the armature, in any case in case of DC operation also eddy current loss, hysteresis loss takes place and that is why armature is laminated in normal DC machine as well remember this fact. For a DC motor, which is operated which is to be operated from DC supply alone. If you insist on that, then you solid iron for the stator iron structure, no problem.

Of course, armature is to be laminated, but the moment you say you will operate this machine from AC supply series motor, then you will have this problem that, this flux will be crossing through the cross sectional area of the stator iron. Therefore there will be eddy current hysteresis loss both in the armature and field coil. Armature is in any case laminated, but the then I will say that this stator structure too should be laminated, otherwise how to increase the efficiency of the machine. Therefore, a DC series motor; if it is to be operated from AC supply.

First thing we learn is that both the stator structure the stator must be laminated. Armature is laminated in any case; armature is laminated no matter, whether the machine, the motor is operated from ac or dc supply. It does not matter. That is the first thing we learn.

Then I say that this kind of motors which is designed in this way stator is laminated, armature is laminated, then perhaps you will say that from AC supply it will operate. It will operate not only from AC supply, but from DC supply as well and such a motor is called universal motor, universal. Will not go much detail into it, but certainly point out some interesting features of this universal motor.

And this motors are very much useful, in the sense that in your what is called mixi for example, universal motors are used in the kitchen mixies are used [FL] to crush nuts this that. Series motor characteristics is preferred, but your supply is AC, then use series motor, but with this change stator is also laminated. Because in that case starting torque will be very large if you want to crush something, say nuts you want to crush starting torque initial required will be large, but after those are broken into pieces torque required will be less.

So, very good torque slip characteristics torque speed characteristics of a series motor that thing can be utilized in such a situations. Of course you see the relationship of this supply voltage and this back EMF. Not only the resistance drop, but now also there will be reactance drop taking place here and also a little bit of armature will have its own inductance small inductance and its reactance drop.

So, supply voltage phasor will be something like this, it will be I suppose this current drawn is I in terms of phasor I am just indicating how things will look like, I plus r a plus r se plus I j x s e plus x armature plus the back EMF. So, additional drops comes in, in between. It will slightly reduce the performance of the machine. Earlier it was only resistive drop, but now reactance drop comes in. And this reactance drops can be avoided if you use some compensating coil, that I will indicate in my next lecture.

But, what I want to tell you is that; this is shunt motor cannot be operated from AC supply out of question, because of the fact field winding is having very large inductance I f and I a will not be in phase. Therefore, there will be some times positive torque sometimes negative torque average torque will be 0, motor will not be driven that is there. But in series motor, I a and I f by virtue of their connections cannot but be in time phase. They are forced to be in time phase. And torque is proportional to I f and I a, therefore, average torque will be there as I have indicated I f and I a in phase therefore, rotor may accelerate and supply the load torque.

So, in my last few lectures ahead, what I will do is this, I will conclude this DC fields motor and start some topics on testing on motors and some tutorial session. Maybe three four lectures I will further take. In the meantime go through the where notes are uploaded.

So, go through those notes and I will only request to you; see there may be some typographical mistakes or things like that, go through them carefully. And if you give me a feedback, I will further correct it hopefully it is not there no mistake. But still you know so many documents are there. So, read also books not that only the notes because no notes like that it is only supporting the lectures I am telling I have uploaded some notes. So, have a nice time.

Thank you.