Electrical Machines - II
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Lecture - 76
Synchronous

Welcome. We were discussing about our last topics that is Synchronous Machines. Let us see how far can we go; you recall that a synchronous machine has a balance three phase winding generally on the status, synchronous machines made generally of large powers power in the range of megawatts.

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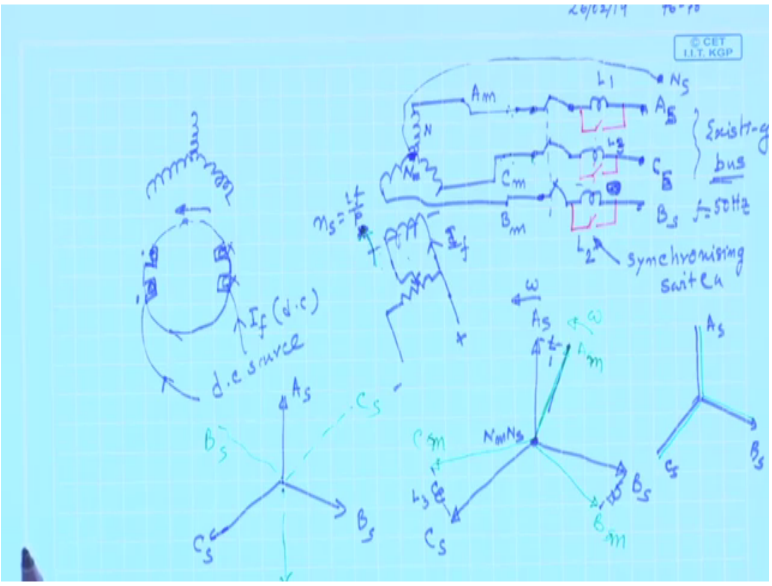

So, the stator winding is a balanced three phase winding just like that of this stator of a three phase induction motor there is not much of a difference. But on the rotor you have got a winding which gives you I mean d c d c current you pass and suppose you connect this to a d c source d c source of course, this will be a rotating member. So, it must be through slip ring and brushes, then connected to d c source and pass d c current this is called field current. So, this current is d c and suppose this is cross this is dot. So, it will become a sort of magnet and it will be rotating like this.

So, this is called the field winding and I will be just drawing this as I told you like this a field winding is there some d c current is passed I f and this is rotor it can rotate. Now if you rotate such a field, then this coils on the stator will become seat of e m f because flux linking with the coil is going to change and if you call this is machine A phase, then if it is rotating this way this must be your B phase and this must be your C phase to give you a b c phase sequence voltage this coil must belong to because whatever is happening to f s now after 120 degree electrical something is going to happen. So, the numbering is important this is B m this is C m. And then this induced voltage the number of transfer phase I know flux for pole I know, therefore, the RMS value of the induced voltage in each phase that expression is also known standard root 2 pi f phi k w n where phi is the flux per volt.

Now, so, this becomes a source of induced voltage here. If you wish you can use that power whatever voltage is generated you can connect a three phase load and you can deliver power to be load; however, a synchronous machine operation that is called isolated operation of a synchronous generator connected that is locally the generator is there you connect a local load that is all. But I will we will much more important is to study what happens if this machine becomes a member of your infinite bus. So, bus terminals are I do not know I name like that A b C b and or source I think I named a S B C S and this is source side and B S last class most probably I name like that or it can be. So, the this is this existing supply existing bus where the voltage is maintained voltage and frequency you cannot change it is decided by so, many generators connected in parallel behind this terminal. So, that is called a bus; infinite bus strictly speaking is one where the this voltage remains always constant and the frequency remains constant.

Now, what is done this synchronous machine is connected to the bus. The moment it gets connected to the bus you can understand that the terminal voltage of the machine becomes same as the terminal voltage existing in the bus machine terminal voltage I am talking about. So, machine terminal voltage gets fixed by this one nothing, I mean I will not be once these are connected here, you change the field current whatever you do, but this terminal voltage is going to remain same that you will not be able to alter. So, that is one of the boundary condition.

But the big question I was discussing last time is how to connect these three terminals to the bus, that is I want to parallel this machine with the existing bus voltage system. So, what you have to do? You have to take a triple pole switch and then what you do you connect some lamps ok. This let me go fast last time we discussed and across the lamps there will be switches, which will be in open condition initially and these are gang operated together they will operate.

So, with this switch which is called synchronising switch, you have to synchronise this incoming machine with the bus synchronising switch synchronising switch. this is ordinary triple pole switch now what you do? With this synchronising switch in off condition you close this switch after ensuring that this line to line voltage is same as this line to line voltage. With this open I know the field current if you change this voltage magnitude will be proportional to this field current I will be able to adjust. Suppose this bus voltage is 440 volt I will increase this field current most probably by a field resistance and vary this rheostat position field current you increase flux per pole will be created voltage you will get and adjust that field current so, that line to line voltage becomes base voltage. What about the frequency ok?

Whatever is the frequency of the bus based on that if you know the number of poles, it is presumed you are running the machine at that speed so, that same frequency voltage is induced. You can parallel two sources of a c voltages provided their line to line voltages are same as well as the frequencies are same no point in attempting to parallel a 50 hertz voltage source with a 25 hertz voltage source it has got no meaning in in fact, that will be difficult situations because the voltages will not match, frequencies are different they are rotating at different speeds. So, there may be large circulating current and this is out of question.

Therefore whatever if this frequency is 50 hertz, then I i am running this machine this rotor I am right running at synchronous speed so, that 50 hertz is also generated her. Now if you connect these three lamps L 1 L 2 L 3 and if the line to line voltages are same on both the supply side and also of the machine, mind you this two voltages are not still connected between them there is a high resistance incandescent lamps you have connected. So, they are not shorted yet, but ha how the lamps will then glow now. If this neutral and if this is the supply neutral N S let us imagine there also connected like that then what happens is this, this this three are bus voltages A S B S C S you must ensure phase sequence are same and C S, then the machine voltages will be A m B m C m and this is the supply neutral this the neutral which is N s and if you have connected it like this, N s is same as N m machine neutral. N s N m they are same. And then the if the switch is close. So, the this set of fazer is rotating with a speed of omega which is equal to 2 pi N s and similarly this machine voltages let us see green colour right A S B S they are also balance system C S, they are also rotating at a speed omega 2 pi N s. Then the question is what is the voltage across the lamp? Voltage across the lamp L 1 will be this length L 1 similarly voltage across the lamp 2 lamp 2 is suppose this one let us call lamp 2 this is lamp 3. So, voltage across B phase will be this voltage and this is voltage across this lamp.

So, if I indicate the lamp here also to understand what is the voltage across the lamp that will decide how it will glow and we observe that, if both of them are moving at synchronous speed exact speeds are same of the supply frequency, at the same frequency the rotor is running then as time passes this lamp voltages will be fixed and it will grow glow with equal brightness whatever is the brightness. Now the crucial point is when you are closing this week I do not know may be A S B S C S was a and this green I think this these are machine A m these are machine A m B m and C m. So, I am not sure when you close this switch lamps (Refer Time: 12:49) maybe will glow with equal brightness its certain, but at what brightness it will glow, it is not cleared it maybe even dark all the lamps because a you are lucky enough to close this switch that A S A m B S B m and C S C m they overlap then the voltage across the lamps will be change.

So, there are so, many possibilities it may be very bright if it may so, happen that your A S B S C S supply voltages are like this and your machine voltages are just opposite A S B S and C S. Then the voltage across the lamp will be twice the phase voltages, it will be very bright with highest brightness it will glow. Anyway when we say that I am going to parallel this, I have to close this right switch. So, that the lamps will be bypassed and then a m will be truly connected to A S B m C m will be truly connected to C S and B m will be connected to B S and then I will say I have successfully parallel this alternator with the bus.

It is quite obvious to demand that, you are allowed to close the switch only when all the lamps are dark. Then you are sure that this two sets of e m f are overlapping and there is no voltage existing between these two points therefore, no question of any kind of short circuiting you are doing no circulating current etcetera I think this point is clear.

Therefore, I am allowed to close the switch if all the lamps are dark that is the situation should be like this. They must overlap that will be the most favourable point of instant of closing this switches that is the whole idea, but as I have seen if this two frequencies are exactly same, there are so, many options of a brightness it may be anything it may be all bright all dark or any sort of brightness and that brightness will be maintained.

Therefore, to initiate synchronising what you have to do is this, this the frequency of the generated voltages across the machine terminals make a slight difference with respect to this frequency that is the crucial point. That is I will a run this rotor of this machine, if it is 50 hertz perhaps I will adjust the speed of the prime mover who is driving this machine to such a speed that it is if it is four pole machine it is suppose 1495 RPM. Where you getting suppose if it is a four pole machine then at what speed you have to run it to generate 50 Hertz at 1500 RPM, but what I will do it I will not run exactly at 1500 RPM, but at a speed which is slightly different from the synchronous speed say at 1400 r 90 RPM.

If you do like that then you see what is going to happen.

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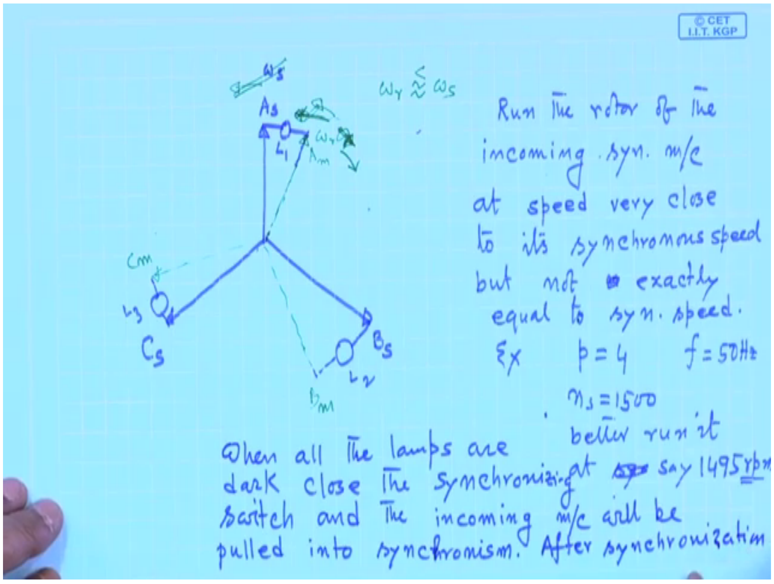

Then the bus voltages. So, the conclusion is run the rotor of the incoming machine incoming machine incoming synchronous machine at a speed very close to synchronous very close to its synchronous speed, but not exactly equal to synchronous speed, but not exactly I mean I am over emphasising this way, not exactly equal to synchronous speed. Example if p is equal to 4 of the machine, f is equal to 50 Hertz you want to generate, I am telling do not generate 50 Hertz what you do? You run the machine.

So, synchronous speed is 1500 RPM now your prime mover with the help of prime mobile you may run the machine better run it, run it at say 1495 RPM. So, frequency will be close to 50 Hertz, but not exactly 50 Hertz, then what is this phasors going to do? This is s supply phasors they are moving with synchronous speed then this this green phasors it is now moving at a speed which is lower than this omega is not 2 f by p e it is not equal to 2 f by p.

So, what will happen? It will happen then. So, it is moving with a speed omega s omega s and it is moving with a speed omega r. Omega r is very close to omega s. So, your this rotor the incoming machine voltages phasors it will be moving with a speed omega r or I can say that the bus voltage phasors then then what a bus voltage phasors therefore, if you must gain that A S B S C S are fixed then this green phasors will be moving with a relative speed omega s difference omega r. If omega r is greater than omega s then this green phasors will be moving in the clockwise direction and if it is omega r is less than omega s, this set of phasors will be moving with a speed omega r minus omega s is that clear.

So, that is the weight will be therefore, what I will do, I will pretend that this A S B S C S are fixed and this this phasor if omega r is less than omega A S, then e is it moving like this with respect to this or anticlockwise direction? Are you getting? That is if you free g a is with respect to A S B S C S this green feathers will be moving with the relative speed either in the clockwise or in the anticlockwise direction.

So, omega s is greater therefore, with respect to this it will be moving this way positive a this this one is it sitting here, it will see that it is moving in the relative speed either cloak omega s is greater. So, it will move in this direction, but at a very low speed 5 RPM if it is 1500 RPM if it is 1490 at 5 RPM. In that case I have created a situation this is lamp 1 this is lamp 2 and this is lamp 3 voltages.

Therefore, as it moves the voltage across the lamp will change very slowly, which my I can distinguish. See if you connect an incandescent lamp in a 220 volt 50 hertz supply there you will not find although the voltage applied sometimes is 0, sometimes is maximum that, but none the less a the current is changing from 0 to positive maximum and negative maximum, but brightness does not change my I at least will not feel that current zero thing, but imagine that same bulb is supplied from a very low frequency a c source then you will find the lamp is brightening slowly and then once again darkening slowly, your I will be able to follow because of persistence of vision is not at a very high frequency.

Therefore this lamps now you can easily see we will increase its brightness, it will become maximum when these are all opposite here f s f s f s machines these are opposite these are A machine B machine and C machine and sometimes it will be 0 also. Therefore, frequencies I have not met exactly equal then there is difficulty I do not know one should be very lucky to have that all dark that probability is very less. Therefore, you must create artificially to understand when this phasors will be overlap lapping. It is at that time when this to phasors will overlap there will be instance when all the lamps will be dark you close the switch. Now that is interesting thing at the frequencies were not exactly equal, but what they say the machine will be pulled into synchronising that speed deficiency what was their 5 RPM or 10 RPM, that will be if the machine will be locked into synchronisation that is the dark; however, this you cannot do when the machine is stationery [Laughter] are you getting.

So, these are very interesting final points to understand what that is synchronisation of an incoming machine is there. The point is when all the lamps are dark I will close this, then this rotor speed of this machine which was slightly different from the synchronous speed will be synchronous speed itself and the machine will be pulled into synchronous.

After that after this lamps are bypass this switch is closed, A S A m C m C S B m B S they are all same points and the frequency of the currents if any flowing that will be off the supply frequency. Supply frequency will now decide what is this speed of the machine, machine will be this this term is important. When all the lamps are dark when all the lamps are dark lamps are dark close the synchronising switch synchronising switch and the incoming machine and the incoming machine will be pulled into synchronism will be pulled into synchronism after synchronisation after synchronisation rotor speed rotor speed of the incoming machine of the incoming machine will be the synchronous speed will be the synchronous speed that is all.

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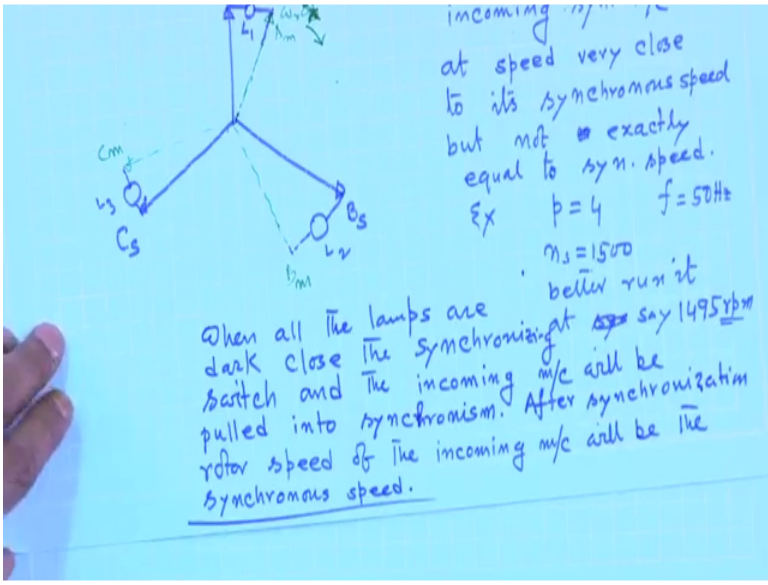

Now, there are other methods I will not go into that if you have understood this there is another method of lamp connection which is called two bright lamp method of synchronising, a incoming alternator or synchronous machine with the bus now after a. So, those things you will be able to understood of course, I have included those things in my lab including what is the voltage across the what will be the nature of the voltage you have form across the lamps, those things I have done there.

A this much is needed in order to further advance into this course, that is I will be dealing with synchronous machines which are connected to the bus. Now the question is what do you mean by a synchronous machine connected to the bus that is what I have explained. Now in my subsequent lectures I will assume that this synchronous machine a has been synchronised by somebody earlier, and it is connected to bus; that means, this terminal voltages are same as the bus voltages we will continue with.