Electrical Machines - II
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Lecture – 65
Introduction to Single Phase Induction Motors Sequence Currents

So, welcome once again and I was discussing about regenerative braking. In fact, we have almost discussed it.

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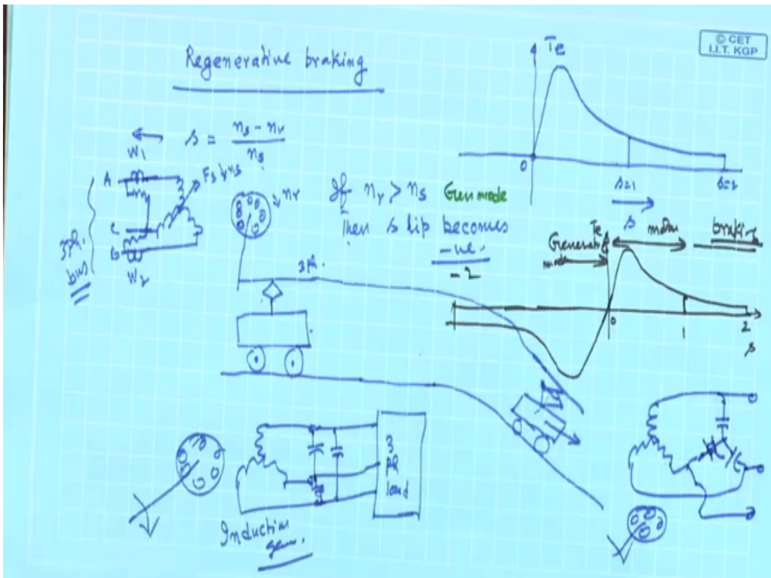

I will just tell you the ideas here; no question of going that ok, this was the motor if sum of the speed become greater than n s then generator mode; generator mode it goes. Then it looks like this top slip characteristics whatever I am drawing, it will be like this from s equal to 0 to s equal to 2. Between 1 and 2, it will be some braking mode it has gone.

And if slip becomes this is slip axis, slip axis. If slip becomes negative using that same formula go on putting negative values and you will get a characteristics like this; once again stable zone will be this that. See induction generator is not a popular; it was not popular at one time. Now a days once again interest is shown in induction generator because of solar conversion of power to AC system. Anyway that is beyond the scope, but what I am telling; so far operation of this a machine is concerned, it can operate as a motor between 0 to 1. Sometimes it may operate with slip 2 minus s when normal braking is executed say plugging.

Sometimes it may produce negative torque when it goes by regenerative braking. The term regenerative means this machine acts as now motor. It regenerates power and feeds it back to the supply bus like that. But as I told you, with the advent of power electronic devices the way you now execute braking that maybe also changed.

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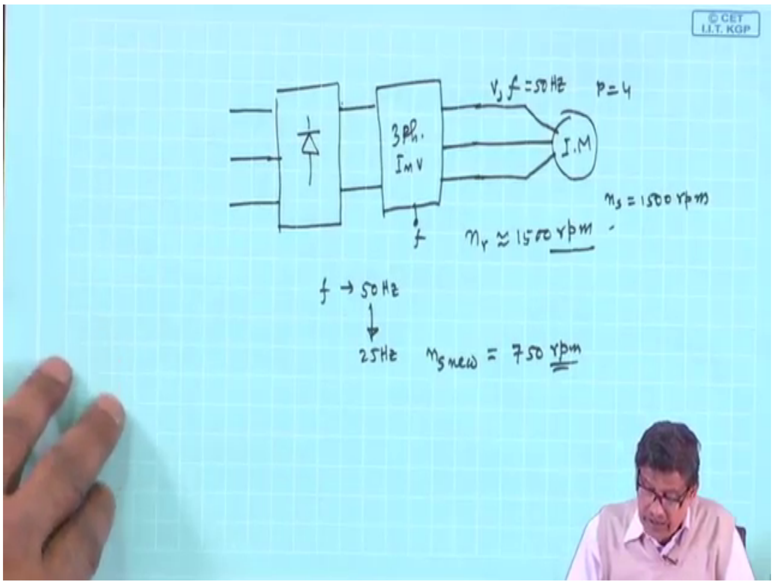

I will give you simple idea see suppose you have got this supply, your three-phase supply rectifier and DC and three-phase inverter. And I told you can both vary the magnitude of the rms voltage and frequency that is v by v and f can be varied depending upon requirements you do it like that and here is your motor and it is supplied, induction motor.

Now suppose I say that machine is running and suppose the p is equal to 4. So, that I can put some number, f equal to 50 Hertz these are the nominal rated value which is running; so speed will be closed to 1500 rpm; we know, no doubt. And it is running steadily. Now suppose when it is running steadily like this. What I do? I the decrease both the; I decrease the frequency to 25 Hertz. It was running, but here that frequency control I reduce the frequency to 25 Hertz. Should I decrease the frequency alone? No. Also supply voltage is to be reduced in the same proportion, so that flux remains same that is one requirement.

But in any case, frequency suppose I reduce to 25 Hertz. Here, the synchronous speed was 1500 rpm. Now suddenly e and machine was running at 1500 rpm close to that slightly below it. Now suddenly you have made suppose from 50 Hertz f you have made it 25 Hertz. So, at what speed this synchronous speed, new synchronous speed will be now 750 rpm. Is not? And rotor is running at 1500 rpm already and stator field is 750 rpm.

So, in which situation it has been put now? That rotor speed is much higher than the synchronous speed at which the field is moving when the supply is 25 Hertz. Therefore, this zone, negative zone for this motor I must apply. And motor will give you negative torque. So, electrical braking once again can be implemented. I am not giving you neither never think that this is the full scheme, but I am telling now with a very nice inverter supplying a induction motor starting, speed control as well as braking can be done in much more elegant ways. Well, though the methods we discussed there, traditional, nice; it will give you better concepts.

But also you keep now in mind that ok, I can do anything; voltage frequency everything I can change as an example, it will immediately go to generator mode of operation if you suddenly decrease the frequency to 25 Hertz or anything. Not 25 Hertz, 50 Hertz, 40 Hertz like that and it will develop different level of braking torque. And when you do that, you do not waste the kinetic energy of the rotor in some resistance or in friction. That energy will be pumped back to this system. Got the point? That is it will feedback power to the inverter whatever is supplying there.

So, this and then you read books and solve some problems traditional problems where we will be restricting ourselves. But, so three-phase induction motor remember there are three zones. This zone is then generating, generating mode and this is motoring 0 to 1 and then this is called braking in general ok; in three zones in full scale minus 2 to plus 2. S equal to minus 2 to plus 2. Anyway, you just have a idea of that.

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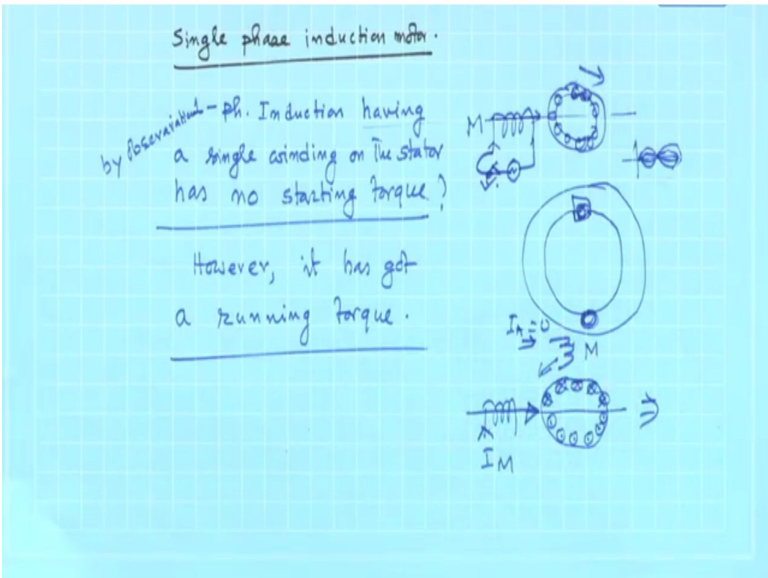

Now after telling all these things, we will now go to a another type of induction motor that is called single-phase induction motor new topic, single-phase induction motor [FL]. Just one comment about this generator operation, otherwise the discussion will remain slightly incomplete.

For example, here I told this induction machine is connected to the bus and you can operate it as a motor. If there is no prime mover, n r will be always less than n s it is operating as a motor. Now remove the mechanical load, connect a prime mover, make its speed higher than n s; it will act as a generator. Is it possible to have a to operate an induction machine as an three-phase generator in isolation? What is a generator? I will have some field control that is I will try to operate this machine induction motor this is the rotor, cage or whatever it is. I will drive it by prime mover can I expect some voltage to be generated?

And here I will connect the load. Load 3 phase load. See distinction must be made between these two cases; it is induction generator. After all you know diesel set, diesel generator often used. You run the prime mover diesel ok, motor IC engine, and you get supply and then load. No question of bus coming anywhere. So, can induction motor be operated in this fashion? The answer is yes. It can be operated, but as it is if you connect like this you do not expect any voltage to be developed. Remember that induction machine is a singly excited machine, you know. You give only supply to stator, no other supply is necessary.

Therefore to create the flux in the machine that magnetizing current source must be provided. IM is necessary. In this machine, what happens? Will there be any voltage? Do you expect here? Yes. I may expect some voltage if you run the rotor because of some residual field here. Some residual field was remaining on the stator and on rotor and on and you are running the rotor. A little voltage maybe 5 volt, 6 volt will be generated but story ends there. Nothing more than that is going to happen. And if you do not have a residual field; nothing is going to happen.

Why it will not going to happen? Who will create the flux? There must be some excitation provided to create the flux here. So, what can be done? Is that some capacitors are connected here. Capacitor bank appropriate value of capacitor bank is connected; I will draw it neatly. Suppose this is like this, you connect some capacitor bank it starts here. Oh my God, capacitor; this is the rotor and here is your generator output terminal. Understood? Across the stator terminals, you connect some capacitors of equal values in three-phases.

Then, I am telling the observation; no explanation. Then you will say, you will see that for some values of capacitance a reasonable voltage has appeared here ok. Because this capacitors will provide that initial excitation of the coil, but anyway this generator is not very good. The moment you load it voltage drastically falls. If time permits, I will discuss about that. But right now, what I am only telling is that an induction machine can be also operated as an induction generator, provided you make some arrangement so that the magnetizing current may be supplied to the machine ok.

It is almost somewhat similar to that of a shunt generator and it will be there. And a when the machine operates in isolation, there is no question of calling it as synchronous speed. Pass frequency decides that those things are there, but just you remember only this much at least that. to create regenerative braking, machine must be connected to bus and there is a definite synchronous speed. And if time permits let us see induction generator at least in open circuit how you get the voltage. This can be also easily understood, but anyway this is not very important.

Now, the important topic is single-phase induction motor. A single phase induction motor constructionally on the stator, there is a single-phase winding. And the rotor in general is a cage rotor. That is it can be like this a cage rotor and a single phase winding. No r y b single winding and a in the way if you see stator; suppose stator there will be coils here, I am sorry. And let this coil be called M. We are calling a b c coil; let us called M, M we will later we will say main winding. Suppose the name of the coil given to M and on the rotor there is a cage rotor, that is the thing.

So, a single phase winding we will motor, will have at least one winding call that to be winding M and a rotor. Now let me ask this question that if this machine if you connect a single phase source to this winding. What will be the consequence? Do you think motor we will run? Do you think there will be rotor current? What is going to happen? See the moment you have connected it to AC supply, this coil we will carry current, sinusoidal current. And this current it will create a field along this line and this field what kind of field will be created we have seen standing pulsating wave.

So, this flux will be this way, this way, this way, this way amplitude is also changing like this. We will do that mathematic. In space, the field will be distributed in this fashion. Is it not? Pulsating standing; will there be rotor current? Yes. Because if you consider this term through which there is a time varying flux, therefore there will be induced voltage. Similarly any this coil this conductor can be thought of another coil. All of them will carry current. It will just behave like a transformer whose secondary short circuited. So, this will be there and the rotor current then distribution; if at anytime this flux is in this way, rotor currents will be cross cross cross other things will be dot dot dot dot. Following Lenz's law it will try to oppose this; there will be also rotor field.

But can these two fellows produce a torque? No because the rotor field and stator field are acting along the same direction. Therefore, at least I can conclude this much. Although, the name single-phase induction motor is there, I expect it will operate from a single-phase source, single-phase source and it is expected to have a single winding leads on the stator like this. And then I conclude ok, if I supply this winding with a single-phase voltage; no way. If the machine was stationary, initially machine was stopped you have switched on the supply here; machine is not going to rotate.

And this conclusion therefore, people say that single-phase induction motor. One big conclusion I am writing at the very beginning. Induction, single-phase induction motor having a single winding on the stator, single winding on the stator, on the stator has no starting torque. Has no starting torque. No starting torque; no way. So, it looks like yes the thing is nipped in the bud what else?

Now, the idea is that a single phase induction motor, I will show that although it has got no starting torque. Somehow the experiment is suppose by hand you make it run ok, with some prime mover you give a start. Sufficient by some external agency if you start moving the rotor with this supply on, you will find to your surprise machine is picking up speed and we will settle down to some final speed. In which direction it will rotate is decided by the fact in which direction you have given that spin initially by some external agency. If you give it a movement this way clockwise, you will find that rotor is now accelerating. Remove your hand and settling down to some speed.

Similarly, if you have given a spin in the anticlockwise direction, you will find that rotor is accelerating once again and settle down to a final speed. So, very interesting that way; although the understanding is slightly difficult. Is not? So, one thing is clear, a single phase induction motor has no starting torque by observation. Let us write like this, by observation give; it will not observation; however, it has got a running torque that is the thing. Therefore, it looks like that a single-phase induction motor to make it work. It is no technical solution that you give a spin by hand or by some external agency there is a motor, you switch on the supply it must run; that is the whole idea.

Therefore you must do something with this motor so that, it is capable of producing this starting torque as well by maybe bringing another extra coil on the stator. That is what precisely we are going to do. Therefore, to incorporate starting torque, I will bring another coil and show that it is a feasible scheme. And after machine has picked up speed, I know machine is capable of developing running torque. Then I will disconnect that extra coil from the supply and therefore, motor will finally run on a single winding; truly like a single-phase induction motor because we know single phase induction motor we will have running torque that is the idea [FL].

So, that way it can be done.

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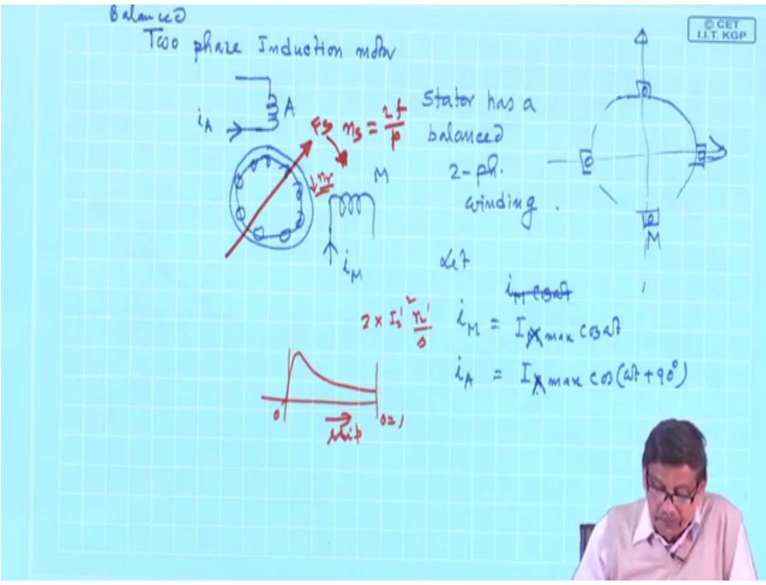

So, before really going to the single-phase induction motor what I will first today tell you is that; let us consider a two-phase motor, two-phase induction motor. It will take the way to have a best better understanding. Two-phase induction motor, balanced say balanced two-phase induction motor. No problem; this is the rotor ok and you have got two windings. Balanced two-phase winding is what? Actual thing, this is suppose M M coil whose axis is like this. Is not? And the other coil is here on the stator whose axis will be like this; equal number of turns.

So, this coil let me call M coil and this coil let me call coil A. Is not? And what I will do it is a balanced two-phase winding. So, stator has a balanced two- phase winding; two-phase winding. This, this an arbitrarily I have called them coil M and coil A. Later we will call this as auxiliary coil that is why A. Now if these two coils are supplied with balanced two-phase current, then it will produce a rotating magnetic field. Is not? Therefore, this conductor coil and this current that is i M and this is i A.

Let, let i M is equal to cos omega t and I am sorry. Let i M is equal to I M max cos omega t and i A is equal to I A max cos omega t plus 90 degree. We are telling 120 degree in case of balanced three-phase; so this is a balanced two-phase current. Suppose I A max is equal to I M max. So, this M you remove. I max cos omega t because these windings are balanced. So, balanced two-phase supply you connect these two coils will carry balanced two-phase current. And then, you can easily show; in fact, I told you to prove this or earlier I have proved also that a balanced two-phase winding will also produced a rotating magnetic field of constant strain. Speed of that field is synchronous speed to f by p, supply frequency.

Therefore a rotating magnetic field will produced. In which direction it will move? From the leading to the lagging phase; all these things will remain, in this case; in this direction n s equal to 2 f by p; this is known to me. Therefore, once this field is produced I am also telling several times, rotor is not at all aware of the fact that this rotating field has been produced by a two-phase winding or a three-phase winding. Therefore, the torque will be produced. I mean equivalent circuit can be drawn per phase in the same way as we have done in case of three-phase induction motor.

And motor will accelerate in this direction and finally, it will settle down to a speed n r and you can do per phase analysis ok. This current square r 2 dashed by s into 2 will give you the air gap power that is 2 into I 2 dash squared means that reflected current squared into r 2 dashed by s will give you the torque produced in the machine and so on. It will run as a balanced two-phase induction motor. Balanced two-phase induction motor are not popular I mean two-phase induction motor one can make it because supply is three-phase; so three-phase induction motors are very popular.

You can think of the fact that you have a three-phase supply and suppose fortunately or unfortunately you have a balanced two phase induction motor, you have to run it. What you will be doing? You require a balanced two-phase supply. So, you must have read in your transformer connection. You invoke Scott connection which will change the three-phase supply to a balanced two-phase apply, then this connect this motor.

So, in any case that is another investment you have to do. Therefore, a balanced two-phase induction motor is one which will work nicely. Its theories need not be separately told, so per phase equivalent circuit you draw and you get away with it; in fact, those things have been done. Toque slip characteristics will be similar like this s 0, s equal to 1, things like that. Is that clear? Therefore, this is the thing.

But in a single phase induction motor; then how to analyze it? Another thing will be necessary to make a, I will tell you first the idea with which we will be doing.

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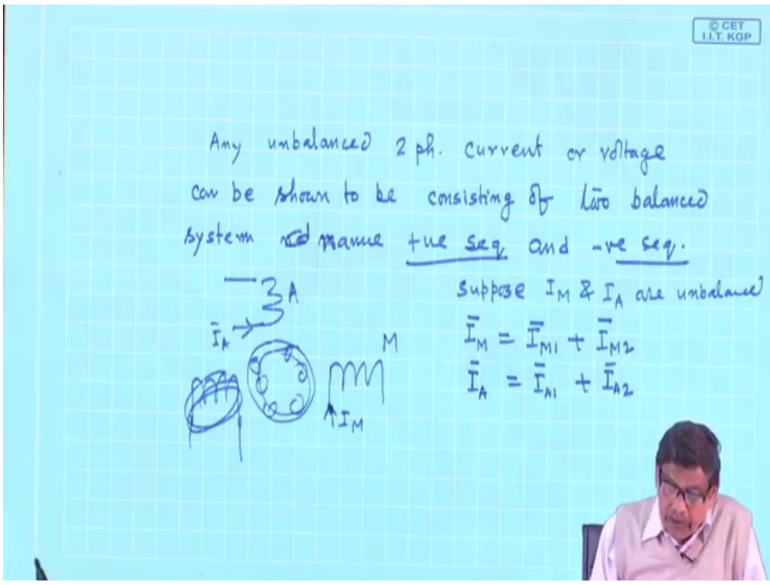

If suppose you have this knowledge will be necessary and I will apply that. Any unbalanced two-phase current or voltage; voltage can be broken up, can be shown to be consisting of any unbalanced two-phase current or voltage can be shown to be consisting of 2 balanced system, 2 balanced system namely, positive sequence and negative sequence voltage. Any unbalanced two-phase quantity. It means that, suppose there are 2; as a you know you must have applied, I am not sure. Any three-phase unbalanced current or voltage can be broken up into 3 balanced systems.

One is a positive sequence, another is a negative sequence of balance, another is a 0 sequence. So, if a circuit suppose is energized from a balance unbalanced three-phase voltage, How to find out the currents in the circuit? What I will do? I will break it up into a balanced three-phase positive sequence system. Find out the currents for that which is easy to find out. I will apply the balanced negative sequence. Negative sequence means, if it is a b c sequence that will be a c b sequence. I will find out the current for that and there will be 0 sequence where there will be all co phasal, and for that also I will try to find out the currents in the impedances and add them up to tell you what will be the resultant current.

In case of a an unbalanced two-phase system current voltage, there is no 0 sequence. So, suppose what I am telling is that, consider this motor only which has got two windings and I suppose I sometimes drawing it here, so let me draw it here. This is the main, this is the A winding. Suppose this current is I M ok, this current is I M and this current is I A, and this current need not be balanced two-phase current. Then what I am telling, this currents I M suppose these two coils are excited by currents which is unbalanced.

Suppose I M and I A are unbalanced, are unbalanced. Means what? Their magnitudes may not be same. The angle between them is not 90 degree, then only it is unbalanced. Then I M can be written as I M 1 plus I M 2. This is the positive sequence of I M 1, this one negative sequence and auxiliary winding current that is this current is I A 1 plus I A 2. Therefore, the whole idea is because single phase winding machine, let us assume even if the auxiliary winding is not there let us presume there is another coil here to analyze this situation. Only main winding present I will excite this and I will pretend there is an auxiliary winding, but it is not excited.

So, this and this are same I M is there auxiliary winding I A is 0. What is the point of its being there or not ok. Anyway we will discuss it in later detail in the next class this is very interesting topic.

Thank you.