Electrical Machines - II

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Lecture – 41
Equivalent Circuit of 3-phase Induction Motor (Contd.)

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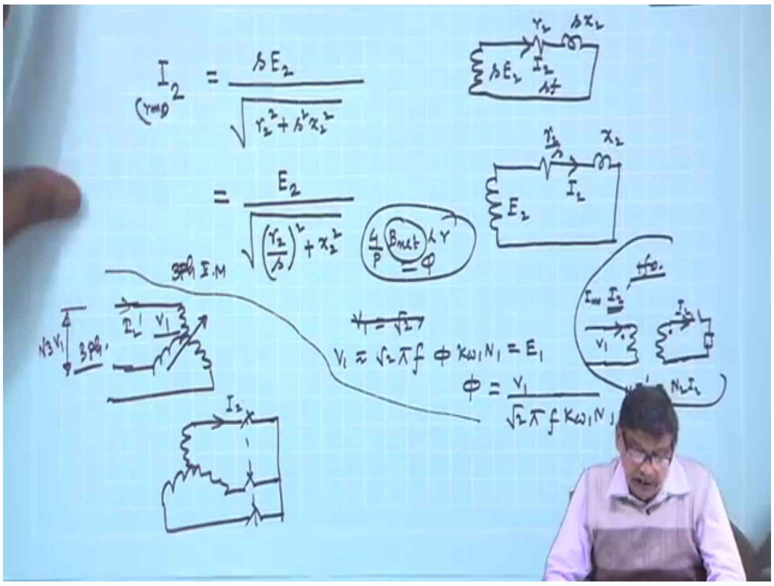

Welcome. Let us continue from my earlier lecture straight away. And you know I was now talking about 3-phase induction motor ok. Suppose, we have applied here line to line voltage root 3 V 1 star connected machines, so power phase voltage is V 1. And what I am telling this V 1 will be approximately equal to the induced voltage, because stated impedance, leakage impedance is small as I told you, so it will be closely equal to this.

Now, this phi, then will be equal to V 1 by root 2 pi f k w 1 into N 1 ok, I will get this flux. Now, what I am telling whether these secondary switch is closed or opened, it does not matter. The flux per pole this of course not phi max as in the case of a transformer, flux per pole has to remain constant. And what is this flux per pole, it is the corresponding to the net flux I told you last time 4 by P B net l r, this is this flux per pole. Therefore, this flux per pole will remains same. In other words, this strength of B naught, it remains same practically I mean from no load to full load operation, of course we have not explained what is full load operation here.

But, in other words, what I am telling, no matter, whether this switch is closed or you have connected some impedance on this side, this flux per pole has to remain same. Now, I am telling on one hand flux per pole has to remain same. And on the other I am telling I will close this switch. And therefore, there will be secondary current. Now, there is a second player coming into the picture apart from this stator to dictate terms that is its MMF should also be taken into account is not ok. Flux per pole how then it can remain constant, it can remain constant provided the moment you try to draw current.

Primarily, we will draw enough current I 2 dash just like the transformer such that the MMF or flux density created by this is handsomely balanced by the MMF, which will be created by this additional current that is the thing that is how a secondary current, any current is drawn on the secondary side of a transformer, primary current is automatically increased, because it has to satisfy the KVL equation here. Therefore, remember this B net value remains magnitude of B net remains fixed, it is position may change from one place to another that is different issue, but flux per pole is remaining same.

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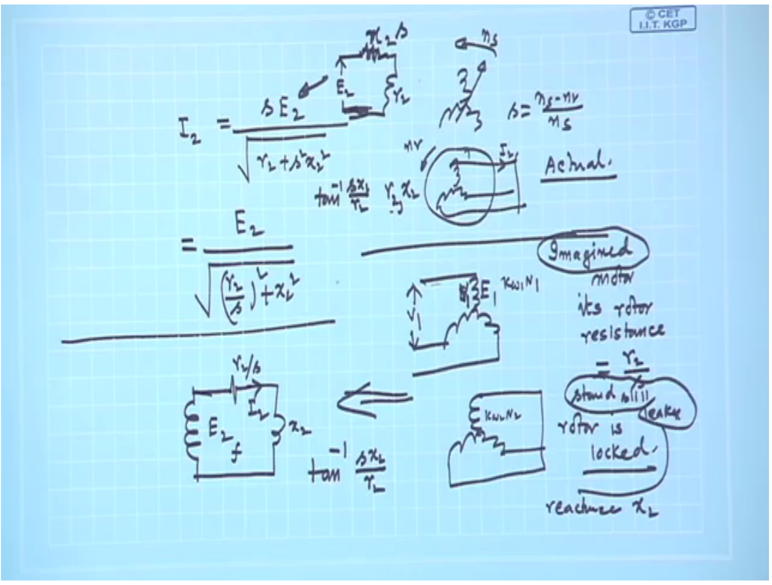

Now, why so much words I have spent, simply coming back to this equation. We have seen that I 2 AC to actual rotor currents is like this. And this is the case, when the machine is running. So, this is very quickly let me write, this is rotor, rotors are sorted. And suppose the rotating field is this direction, and rotor will also rotate in this same way. So, it is running with some sleep s is equal to n s minus n r by n s that is fine it is running. And this is the RMS value of the current ok.

Now, listen to this point. This I 2, when it carries current I told you, it will create a b r, and that two will be rotating in field. At what speed a stationary observer stator coil will see this field to move at to move at what speed, it is also n s with respect to a stationary observer in the same direction, then only that torque angle delta can remain constant ok, it will move like that. And based on that, it draws additional current to counterbalance that rotor rotating magnetic field that is the whole idea.

Therefore, rotor would has to react on the rotating magnetic field created by the rotor, and tries it is best to nullify this effect, how it can do so. By drawing additional current from this supply balance previous current I 2 dash drawn, and we will try to oppose that rotor rotating field flowing in this direction that is the whole idea. If that be the case, let us consider this is the another step I am telling you listen this is the actual motor, this is the thing we are trying to analyze draw the equivalent circuit. Then I saw that this can be written as E 2 by root over R 2 by s whole square plus x 2 square, this I wrote. [FL]

Now, imagine an induction motor which is stationery same stator winding, it is an imagined motor ok. This is very interesting point imagined motor; you imagine a motor exists whose stator is same like this. And whose rotor is also same like this except that that is number of terms, this that are same. Except that imagined motor it is rotor resistance is equal to r 2 by s, where s was this sleep of this motor, please listen to me carefully what I am telling. This is the actual motor, whose equivalent circuit I was trying to derive, then I got stuck up at this stage.

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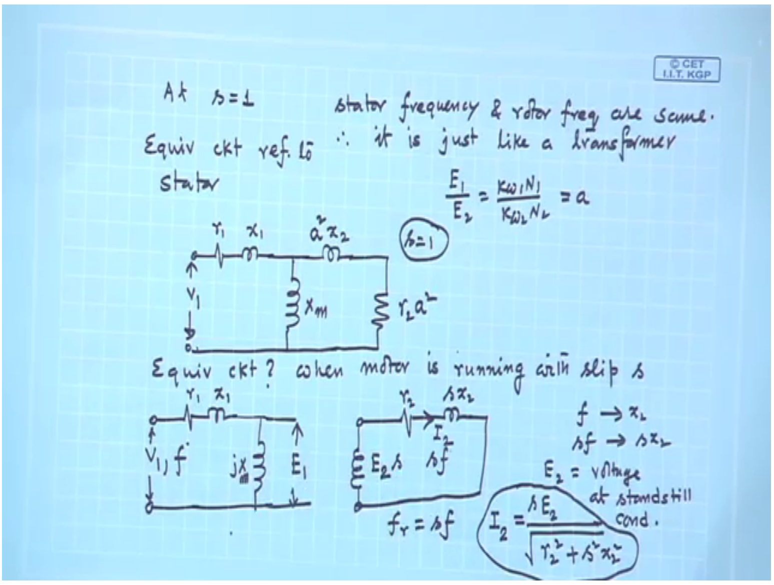

I find secondary there is induced voltage fine, but there is a very unusual term sleep is coming. Therefore, it is difficult to I cannot join this two points here, simply by multiplying this by S square out of question, because I will always question this frequency is f, this frequency is f. The ratio of the voltages is not also a constant number a, but it will in always. So, there we got stuck up. And then we know the flux per pole in the machine has to remain practically same from no load to full load, whether you have connected something here or not. Then we understood primary should, I draw additional current to counter the rotor rotating field produced by I 2 things like that.

Now, what I am telling, this is the actual motor stator field n s. Rotor is moving n r, and it is moving with a finite sleep. RPM is present here rotating machine. Now, what I am telling imagine another motor ok, whose terminals are shorted. And a rotor is locked, rotor is locked; I will not allow the rotor to move that is at standstill condition. It is per phase resistance only thing I am telling, this is imagined is you imagine that such a machine if it is there, whose rotor resistance per phase is r 2 by s. And what is this s, s is the sleep of the actual motor we are discussing about. So, this is r 2 by s, and it is it stand still a leakage reactance leakage reactance is same as this one. It has got per phase resistance r 2, and stand still leakage reactance x 2 per phase.

Now, for this fellow, I am telling that I have another machine, suppose whose rotor resistance per phase is r 2 by s. Leakage reactance is x 2 at stand still condition, and this motor is stationary. Therefore, what will be its equivalent circuit, here also I have applied V 1, here I get E 1, which is B 1 by sorry this is V 1 applied voltage, which is approx B 1. So, this circuit will be V 1, and this that and the rotor circuit will be what will be the voltage induced for this circuit, you have applied E 1 here. This machine is at standstill condition, this is important. Therefore, it will have an induced voltage E 2, this rotor is at stand still let us images. And then it is closed, and what is the resistance per phase of the winding, oh, I have told it is r 2 by s fixed number for this machine. And there is a reactance here leakage reactance, what is the value of this leakage reactance I should write X 2.

For this imagined motor, this machine is at standstill condition. It is rotor resistance per phase, I have imagined this to be r 2 by s suppose, number of turns etcetera are same. Flux in the machine purple is decided sully by the primary winding, rotor has no say on that. Supply voltage, supply frequency, what will be the flux per pole. Therefore, same number of turns k w 2 N 2, this I will maintain, this is k w 1 N 1, and this will be the situation. What will be the frequency of this voltage f, because this machine is at standstill condition. What will be this reactance stand still reactance, and this is r 2 by s. What will be the current I 2, because you see I 2 is E 2 under root this impedance same current will flow, but it will flow at 50 hertz. So, this 50 hertz current will flow.

Now, the most important point, somebody sitting on the stator of this machine, and this machine at standstill condition will not be able to distinguish, whether it is a stand still machine with this parameter or it is a rotating machine with r 2 x 2, it will never be able to distinguish why, because same current is flowing. So, rotor field produced by this machine; and this machine will be of equal strength. And with respect to stator, this field is moving with synchronous speed, and this field is also moving with synchronous speed. Therefore, stator should react in the same way that is how much additional current it will draw from the supply to balance the rotor MMF in both the cases.

There is no way rotor will ever know, I mean stator will ever know that it was a rotor was rotating at some slip s or some speed n r. And I have to draw an additional current between these two machines of which one is the actual machine with which we started, and got destroyed what to do secondary and primary can be connected or not. Then I asked you. And then of course, I did some manipulation here that is the RMS value of the current will remains same. If you if you have an impedance of this kind, then I am telling then let us have another induction motor, whose stator is identical with that of this machine.

But, the rotor is at standstill condition, and it is resistance per phase is not r 2 r 2 by s d s with which the actual motor was running. And it is leakage reactance at standstill is x 2 same as that of this machine x 2. And this machine is stationary, you apply your voltage V 1, E 1, then there will be induced voltage because this is an induction motor k w o o 1 N 1 by k w 2 N 2 will be E 1 by E 2, and it is at standstill condition. So, frequency of this router will have f frequency that of the supply here, and it is impedance is r 2 by s x 2. The power factor of this circuit, and actual rotor circuit of this machine E 2 which I drew earlier r 2 sorry r 2 x 2 and r 2 r 2 by s x 2 actual machine, this is the current how we got.

Now, in this machine the power factor angle with which this rotor current will lag this voltage E 2 is tan inverse s x 2 by r 2. In this case not only the magnitude of I 2 will remains same, but the power factor of this circuit is tan inverse once again s x 2 by r 2. Therefore, rotor in this imagined motor, we will have some RMS value of the current at some power factor angle with respect to E 2 will be same as this current of this actual induction motor, which is running at a sleep phase. And it is delivering a current I 2, this current I 2 with respect to this voltage will be also having same power factor angle that is why, I am telling stator will fail to recognize, whether you have a rotor r 2 x 2 rotating with a speed n r or this rotor is stationary now with changed parameter value winding resistance is changed r 2 by s, and it is stationary.

The reflected current, it will try to draw because it has to react based on the rotor current, how much current it has to draw from the supply with respect to stator. How rotor is recognized, and a rotating field has been created by rotor, it is moving with some speed that is all at some power factor angle. And power factor angle is important last time we also discussed. Therefore, it will be reacting in the same way in both these two cases, it cannot but do anything else.

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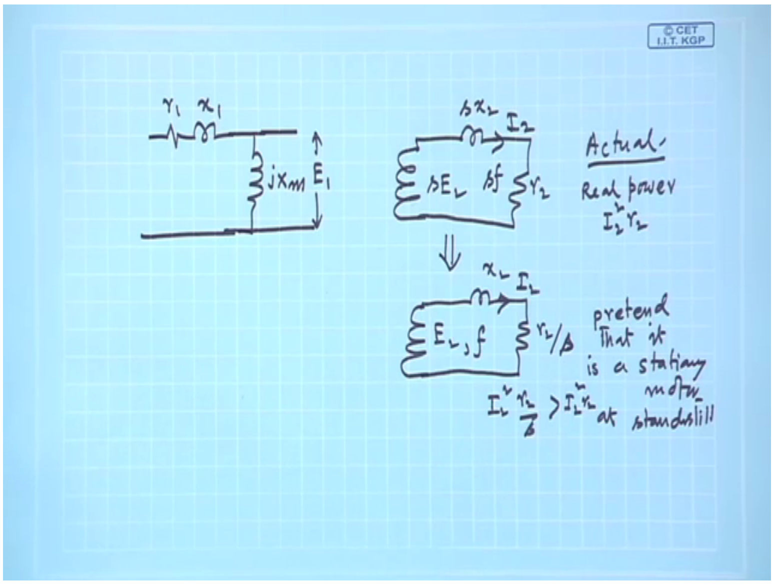

Therefore, what people do is this that I will once again draw this; we had this 1 r 1 x 1 ok. This is how I try to understand there will be other ways; this is your X m. And here is your E 1 on the rotor actual rotor, it was AC 2, it was a s x 2 and it was r 2 actual machine, and its frequency was s f. Now, I am telling oh this machine, this circuit is E 2 divide by s x 2, and this resistance is a r 2 by s. And pretend it is a stationary motor pretend that it is a stationary motor at stand still. Then this frequency has to be f, it has to be f a stand still motor. So, this two is simply not you divide by s, and because if you divide by s, what you do with the frequency s f?

So, so to translate this to this, then I am telling this motor with this secondary running with a sleep s is same as the same stator. And the rotor is replaced by another induction motor, whose rotor resistance per phase is r 2 by s. And x 2 and stator will fail to distinguish between these two cases ok. This is a I 2 RMS value, this is I 2 RMS value means, it is maximum value is also fixed. And maximum value of the current has to decide, what will be the strength of the corresponding rotating field 3 by 2 b r is not 3 by 2 b max something. So, it is RMS current if you keep constant, it is same.

Now, the question is somehow let us accept that. But, there is another problem means is these two circuits are equivalent in every respect. So, far as current is concerned it is equivalent. So, for as the power factor angle of I 2 in relation with AC 2 is concerned, and E 2 is concerned they are same that is fine, but there is a massive important difference between these two what is that. The thing is in the circuit, what is the real power in the circuit? Somebody is sitting on the rotor, you will say power consumed in the circuit is I 2 square r 2. And in this circuit, the power consumed here will be I 2 square r 2 by s which is not equal to that real power is not same. In fact, it is larger because sleep is a number, which is less than one. So, this I 2 square r 2 by s is definitely larger than I 2 square r 2. Then how to explain that thing, I mean what to do with that ok, now it is not at all surprising.

Because, if this case the motor is running, and motor will be running with some sleep which is not equal to 0, when there is an opposing torque mind, this we explained last time. At there be no opposing torque absolutely sleeping would have been equal to 0 is not, then this induced voltage is 0 current, no question of current nothing. But, when the motor has some opposing torque present, either in terms of frictional torque or opposing, load torque, which acts in the opposite direction of t, then only there will be some finite sleep with which motor will be running, it will it is speed will be less than synchronous speed. When it runs, then forget about this circuit here.

If you are sitting here, locally you will only see I 2 square r 2, but on the shaft the motor is running against a opposing torque some power is also dissipated there that is the mechanical power, dissipated or utilized whatever it is. So, I 2 square r 2 will be the copper loss in the rotor resistance no doubt. But, in this case when it is running, I know I am running with a sleep phase that means, there is an opposing torque also, it is not only this electrical power, but also plus the mechanical power which will be t opposing into 2 pi n r that that power, this two together are supplied.

Therefore, the primary will draw sum of those two powers, and it does so because there is a mechanical torque present. But, in this case what I am telling, I asked you to consider a an imaginary motor, whose rotor resistance is r 2 by s x 2, and it is not moving. Therefore, no question of any mechanical power comes in, because mechanical power is torque into 2 pi n r motor must run to deliver the mechanical power. But, in this particular imagined case motor is not running, but as I told you stator will not distinguish between this and this, this is also now corroborated by the fact that so far as total real power to be drawn from the supply in this case.

And in this case has to be same that is why this r 2 by s will take into account both the actual rotor components of the machine. In this in this case, suppose somebody says r 2 by s is the resistance, and there is no mechanical power story is over here. But, coming here I will tell because I do this, it draws enough power what will be the real power drawn, it will be I 2 square r 2 by s corresponding to this real power will be drawn.

Now, when I come back to this actual machine, I will tell oh this is the total real power drawn which is greater than I 2 square r 2, it has to be because it also supplies mechanical power. Therefore, it is not surprising that this power is not balanced in this circuit and in this circuit, but I will not be get disturbed by that. Because, I now know that in this machine, which I am telling stand still condition of that fictitious motor is powerless is I 2 square r 2 by s. And since the in the actual machine I 2 is flowing, so I 2 square r 2 is the copper loss I know.

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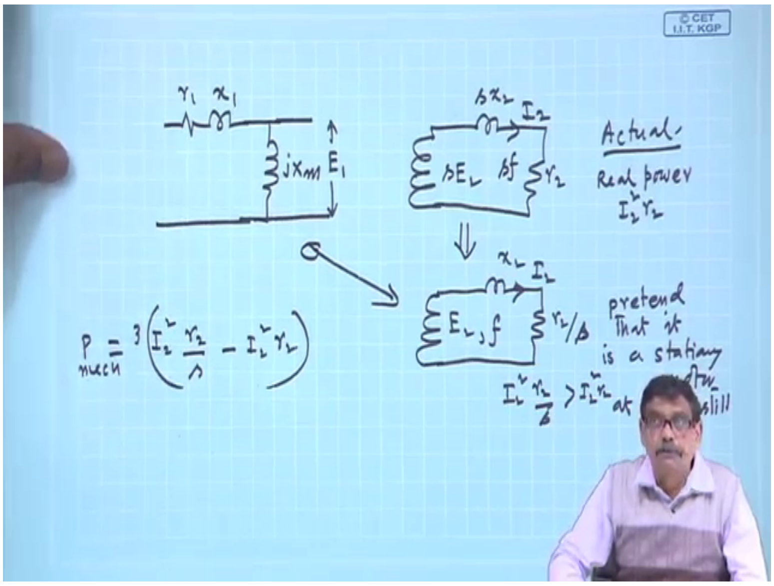

Then, I will say oh mechanical power per phase is I 2 square r 2, these are all the nicety about this way of thinking. So, this must be the mechanical power, and if it is 3-phase, multiply with 3-phase that is all. And not only that, then this two can be combined, we will continue this in the next lecture.

Thank you.