Electrical Machines - II
Prof. Tapas Kumar Bhattacharya
Department of Electrical Engineering
Indian Institute of Technology, Kharagpur

Lecture - 53
Exact Power Flow Diagram and Circle Diagram

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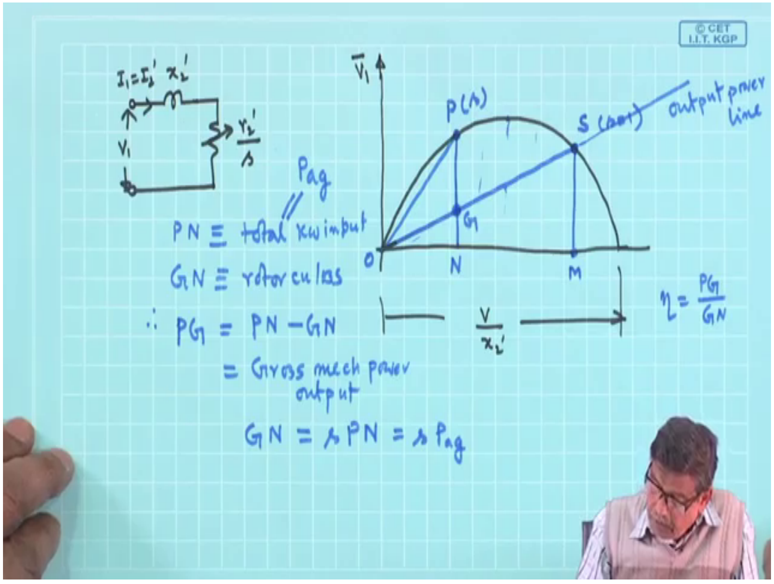

Welcome. So, we were discussing about the Circle Diagram of an induction motor, where only rotor parameters are considered, this was this thing. So, the conclusion we draw is this one, applied voltage is constant rated value mind you per phase. And this is your I 1, which is equal to I 2 dashed, there is no difference between these two.

And we finally got that ok. If consider this along this y-axis, we draw the voltage phasor, then current phasor will be a circle like this ok, this is the current phasor. The diameter of this circle is of course, v by x 2 dashed that is there. Then at S equals to 1 stand still condition, you draw a line, this is the thing. It is on this perimeter of this circle, tip of the current phasor drawn from this up lie will lie. So, it is at this point, I called it point S and I dropped a perpendicular here M. This point I just called O and I showed that this S M is a measure of air gap power as well as rotor copper loss at S equal to 1, because this is S equal to 1.

Now, when the machine will be running and S M therefore represents both rotor copper loss as well as torque developed in the machine. Mind you machine is not rotating, you have blocked it, but it is experiencing the torque. If someone wants to hold the rotor with applied voltage, you will fill the punch of that ok, it is trying to rotate your abstracting that is true. But, it has developed torque, but you are not allowing it to run. Therefore, no question of any output mechanical power comes in and n r equal to 0 that is why, slip is equal to 1 that is the thing.

Now, when the machine will be operating at a general operating point, which slip s, it was s equal to which is less than 1. Then you just drop a perpendicular here call it N and call this point as G just like that. Then I have shown that the total input power at this slip is P N; P N is total input total kilowatt input. Also I have shown that G N is the rotor copper loss, this length will also represent rotor copper loss at this slip. Therefore, P G which is nothing but P N minus the G N total kilowatt input and this also happens to be the air gap power P ag, because there is no stator copper loss, this is the power which has gone.

So, P N minus G N is P G must be giving you the gross mechanical power output that was the last thing I told and we have shown that, so this one. And for obvious reason you know this G N must be equal to s into P G P n P s into P N. P N is the air gap power that is s into P ag this I know. So, G N this will be s times the whole length, and there the things is over. Therefore, you see this vertical inception if it operates at this slip draw a vertical line, this will be the copper loss at that slip and this will be the mechanical power output.

Therefore, this vertical interception between the perimeter and this line which corresponds to stand still condition line that intercepts gives you the mechanical power output; that is why this line is often called output line output power line. If somebody says machine is operating at this point draw a vertical, this will be the copper loss there. And this will be the mechanical power output very simple, this way we can find out the performance of the machine.

So, whatever is the input power, only loss taking place inside this machine in this simplified equivalence circuit is the power loss simply the rotor resistance I square r 2. And therefore, remaining part will appear as mechanical power input. So, instead of so somebody says that I will vary this slip between this and this point for different values of slip, you calculate that. So, once for all, you draw this circle diagram. Decide what is the value of the slip, fix up this point, because power factor angle can be calculated from that I will fix up the operating point there. And everything only two things can be found out, and that found out.

For example, efficiency of the machine will be this mechanical power output P G by P N will be the efficiency of the machine at that time. For example, efficiency will be output power mechanical power by GN, something like that can be done very simply [FL].

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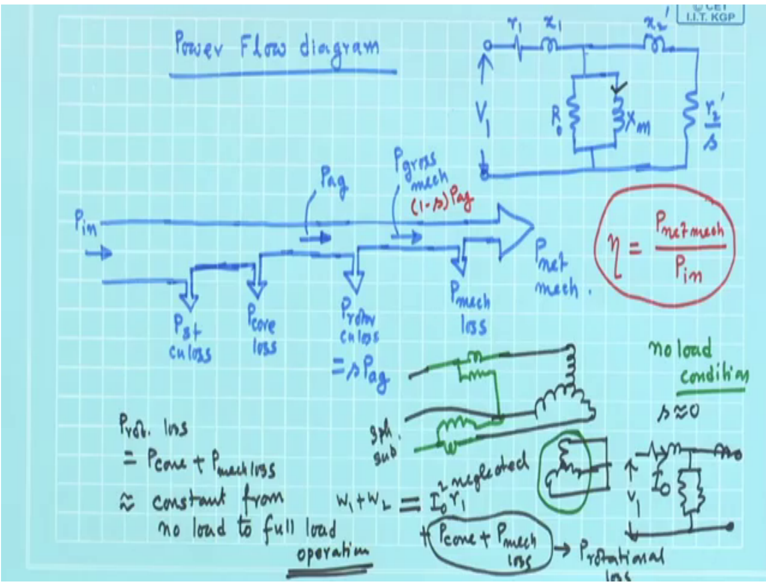

Now, let us take because all things cannot be neglected this is ok, it will give you some indication. But, if you want to get more accurate thing, then perhaps you should not neglect all the parameters of this status. Now, at this point I will before I go to the circle diagram of that original equivalence circuit, I will once again reiterate. Once I perhaps drew the power flow diagram of the induction motor. I will do this we already know power flow diagram.

Let us revisit it, in somewhat detail. I told see in the induction machine, I now know the exact equivalent circuit is something like this r 1 x 1, then that may be rotational losses is resistance will represent. Last time we were doing this and this is x 2 dashed and this is r 2 dashed by s. This is a more exact equivalence circuit, this is the applied voltage, this is r 1 x 1, all parameter values are there. And this is that R naught or whatever it is X m magnetizing current.

Now, in this case if we if I strictly go by this, I will I should draw the power flow diagram in this way power input, this is suppose power input P in. First I find there is a stator copper loss, I will go on subtracting the losses. So, P stator copper loss, then you see there is AD current loss P core loss, therefore P in minus this stator losses.

And then whatever power is here that is P ag air gap power. And from air gap power, you have to subtract the rotor copper loss P rotor copper loss, which is always true that it will be s times P ag that is all, s into P ag will be the rotor copper loss. Then whatever power you get, this power should be called P gross mechanical. Then after this if you subtract a small mechanical loss, then whatever power you get is the P net mechanicals. This is the exact thing, no doubt about it.

Input power, subtract stator copper loss, core loss component, then the power enters remaining power enters into the rotor air gap power, crosses the air gap as if an enters into rotor from that you subtract rotor copper loss, which happens to be s times P ag. And this mechanical loss is 1 minus s into P ag, we have done several times. And from that if you subtract a little bit of mechanical, friction, vintage losses etcetera, bearing loss, then the P net mechanical is here. And efficiency of the motor is P net mechanical mind you divided by P in, this will be the net mechanical power output.

Now, sometimes you will see a little bit of variation in this power flow diagram because of convenience, what do I mean by this is this? Suppose, there is an induction motor, listen this point carefully. Suppose, an induction motor is there, it could be cage or slippering whatever it is, this is the rotor, I have given supply.

First thing is suppose it is running under no load condition no load condition. And suppose we have connected some two watt meters to record, what is the power drawn two watt meter method of measuring power. Suppose, I have connected two watt meters to record how much and if they this is the three phase side, which is excited three phase supply.

Now, the question is when you excite this, what this watt meter is going to read. Let us take from the practical point of view. Here is an experiment, I am running the machine under no load condition means, there is no opposing mechanical torque. Is it true, there is no opposing mechanical torque not really, there is opposing little bit of frictional mechanical torque is present that is there.

And watt meter is going to read, then watt. So, this part is not there and then slip has to balance only the little bit of frictional torque present, therefore slip will be very small very close to synchronous speed, it will run. If that runs people say, under no load condition slip is practically 0, you are given this liberty it is very close to 0, so that this part will become open circuit.

Therefore, whatever current is drawn from this supply will be magnetizing current and this core loss component of the current. Strictly speaking this sum of this two watt meter readings, even under that condition that is at s equal to 0 means, circuit is like this, you can assume this to be open circuited so nothing. So, V 1 this is the no load current I naught, total current drawn.

Therefore, I will say this sum of this two watt meter readings must be equal to I naught square into r 1 is not. Similarly, there will be power loss in this resistance r 1 x 1 is small approximately same voltage comes close to that this divided by this r will give you this power. But, watt meter this is the only points through which power is inputted into this system and watt meter should read and there is a little bit of mechanical power output in the form of loss.

Therefore, watt meter some of the watt meter readings will record stator copper, loss core loss plus the rotational loss that is the mechanical loss that is sum of watt meter W 2 should be strictly speaking equal to I naught square into r 1 stator copper loss plus P core plus P mechanical loss. And it is under no load condition net mechanical power output is 0, there is the matter. So, strictly speaking, it should be like that.

But, the no load current is small compared to the full load current of the machine like a transformer, therefore majority of this right hand side will come from this sum of this two P core plus P mechanical loss, this can be neglected because of what? In compared to the sum of these two, these will be less. Why it will be less, because I naught is less, no load condition.

Therefore, sum of this watt meter readings will be equal to P core plus P mechanical loss, both of them are small. But, bigger than this I naught square r 1 that is what I am telling, but these two are of will be of similar nature, because in induction motor AD current loss do not occur in the rotor iron bodies. Only in stator iron body, it occurs in the rotor it occurs, but with frequency so small, it can be neglected or things like that.

Therefore, these two loss together is called P rotational loss. Let us right now, it cannot be separated. It cannot say how much of it is rotational, how much of it is frictional? But, anyway induction motor from no load to full load condition; no load to full load condition, mind you this statement. Change in speed is how much, very little 5 percent sleep. Little change may be 78 rpm from no load to full load.

Do you think because of this frictional loss will change? No, it will practically remain same, because against air it is running beheading friction will be similar, I mean why there should be difference, because speed variation is less. So, frictional loss remain same. Do you think, the core loss two will change substantially, no because of the fact although no load current and full load current, they will be different, they will be different by substantially amount the magnitude order of the current, but nonetheless r 1 x 1 is itself is small quantity.

Therefore, the flux produced by the machine is decided by this current, whether it is under no load in no load condition this v 1 practically appears here, I naughts is small r 1 x 1 is also small no problem. At full load condition, it is running with some sleep, so this current as now come up, which was otherwise open circuited will now come here. And the sum of this two currents will flow, this current will increase, because you are taking mechanical power output of the machine.

So, this drop will increase, but not by a very large amount because of the fact r 1 x 1 is also small. So, people say that from no load to full load condition, the level of flux also practically remain same. Therefore, what is the conclusion? Conclusion is this rotational loss, which is sum of these two P rotational loss, which is sum of P core plus P mechanical loss can be assumed to remain constant from no load to full load operation; no load to full load operation. It can be assumed to remain constant.

So, this exact is this, so sometimes what people do, I mean there are various versions of this power flow diagram, but there should be logic attached to each one of them. So, in the power flow diagram within find P core loss is there, P mechanical loss is there. They cannot be separated as such by this simple means, if time permits, I will tell you some experiments can be done to separate them out, but in general there will there some matters.

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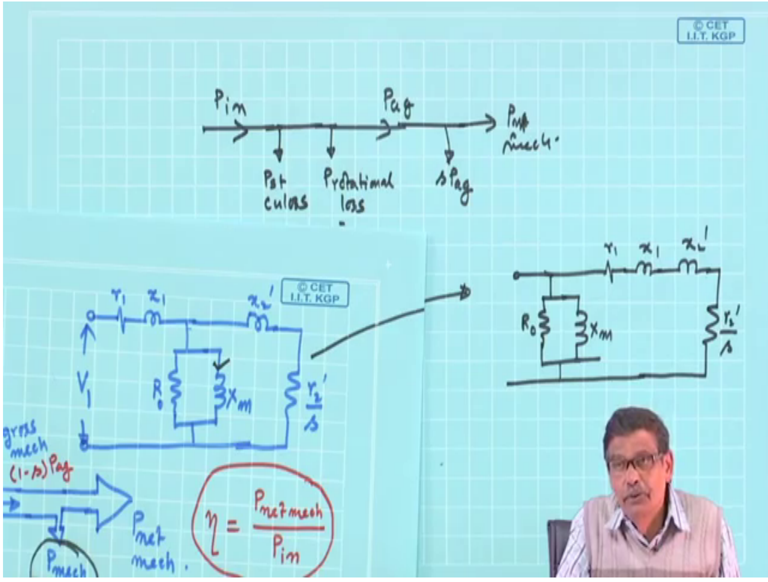

So, what people do, they will be saying that ok. This is input power I with a single line, I will draw P in. Stator copper loss of course will be there, P stator copper loss. Then you say that there is rotational loss not core loss alone ok. Rotational loss, I will take right at the input rotational loss. For that you will be making some mistake, because this is the exact thing a little mistake it does not matter.

So, P rotational loss that is equal to sum of core plus mechanical loss, then you say this is P ag, then you say this is s P ag. Then since mechanical loss you have already taken into account, you say this is then P net mechanical, I am reiterating this point. If this losses are known totally, then use this power flow diagram, depending upon the situation of the problem ok. Otherwise, there is no one way of telling use always this power flow diagram, it depends upon the problem at hand. But, anyway it gives you fair idea of what is the thing going on, therefore this is the thing.

Now, why all this words I have told you, before telling about the circle diagram of a three-phase induction motor. Considering all the parameters present, because the earlier case we have done obtain the circle diagram is a rather simply to simplified a thing only r 2 dashed x 2 dashed, where considered. Why this has I have done is this?

Next time that is this, next circle diagram I will draw. So, this was the original equivalence circuit is not. Now, in this circle diagram, what further another assumption I will do in this equivalent circuit. I will pretend like transformer with the plea that r 1 x 1 is smaller compared to r naught x naught, I will bring this here R naught X m that is why, I am writing R naught not r c l cold loss, because it will take care of the mechanical loss as well. And then you say this is r 1 and this is x 1, then this is quite familiar in transformer and this is r 2 dashed by s.

See with open circuit under no load condition, I will put s equal to 0. But, mechanical loss will be there, it is taken care of by this R naught, because s you make 0, keep it open and say it is under no load transformer draws on the no load current. But, you cannot deny the fact in reality frictional loss is there, who is going to supply that. Only source of input is through this port, therefore there must be some resistance here that is why rotational loss, we say to represent this parallel branch and also I bring it here.

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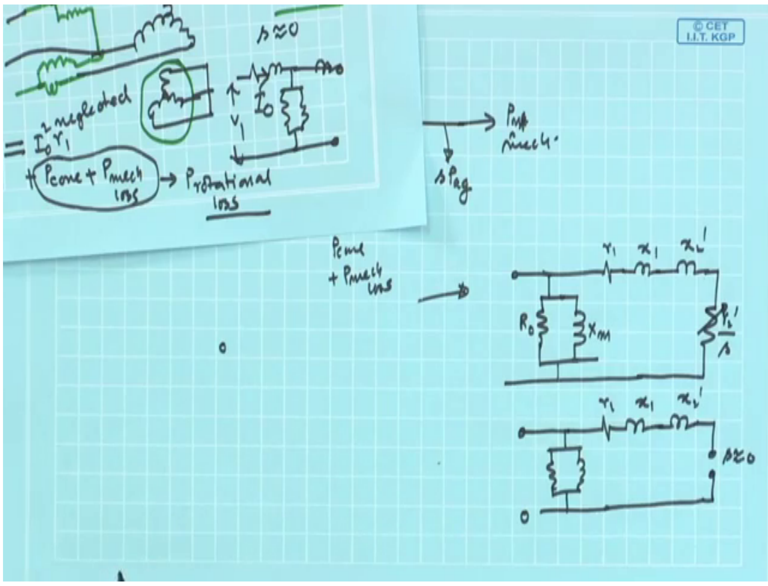

Therefore, under no load condition a circuit will be somewhat like this; this things are ok, there I am not neglecting anything x 2 dashed. And this is open s is close to 0 and that full load condition this is the circuit s equal to full load. So, with these in mind, we will as if varying r 2 dashed by s ok. And try to obtain the circle diagram of the induction motor and we will continue with this next time ok.