Electrical Machines
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Lecture - 30
3 Phase Induction Machine:
Speed Torque Characteristics

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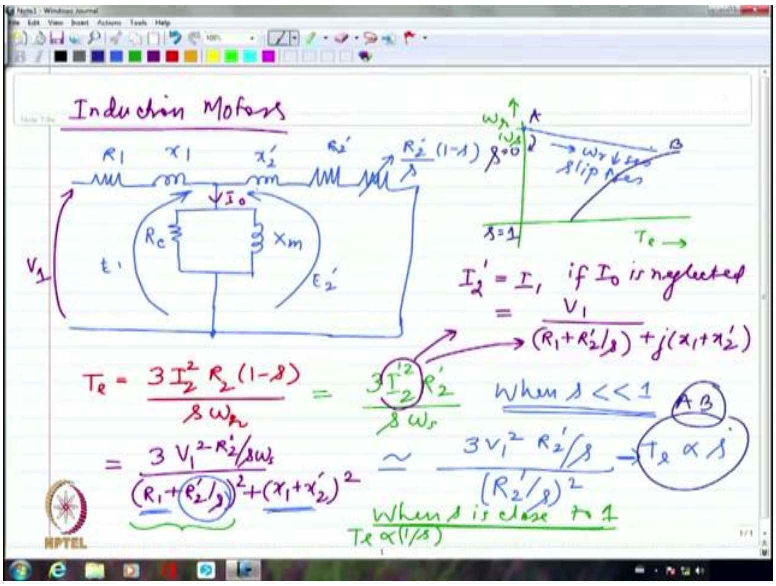

Let us, now start on the induction motors what we did; I will try to recall what we did earlier. We basically looked at the conceptual features of the induction motor. We, looked at the principle of the induction motor, before which we said what is a revolving magnetic field how it is created? Then after that we actually looked at the equivalent circuit by looking at the total power that is being passed on from the stator side to the rotor side.

And we based on that wrote the equivalent circuit, looking at a transformer equivalent circuit originally and what happens when the rotor rotates, or the secondary rotates what happens to the equivalent circuit? So, we drew the equivalent circuit on the whole somewhat like this, this is R_1, this is X_1, this is also said that we are going to have the core loss and we are going to have the magnetizing reactance which we wrote as X_m and R_c.

Then we wrote actually that there is going to be a leakage reactance which is actually X_2^l, originally, we wrote that as sX_2^l. Now, we have actually converted the rotor EMF also into stator frequency that is what we did by dividing it by S, so because of which what we got here let us say was E_1 and this become directly E_2^l, which was also equal to E_1 because of the turns ratio, that having being taken care of E_2^l will be equal to E_1.

And we wrote 2 portions of the resistance, one we wrote as R_2^l which is the inherent resistance of the rotor transformed into the stator side and we wrote one more portion of the resistance which represents the mechanical power which we showed as a variable resistance, which is $\frac{R_2^1}{s}(1-s)$. That represented the mechanical power and then we said this represents the short circuit that is there in the rotor of the cage induction motor or in the slip ring induction motor, which we create a short circuit external to the rotor.

This is the equivalent circuit we drew and then based on this we actually wrote the torque expression $T_e = \frac{3I_2^2 R_2(1-s)}{s\omega_r} = \frac{3I_2^2 R^l{}_2}{s\omega_s}$.

Whether I look at it from the primary side or the secondary side in a transformer or from the stator side or rotor side in an induction motor, so, this is going to be invariant. Then we wrote the expression for I2, so we said $I_2^l = I_1$ if I neglect whatever goes as I_0, so if I_0 is neglected. And we chose to neglect it because we wanted a simpler expression in terms of V_1 itself, whatever is the voltage that is being applied.

So, I am applying a voltage of V_1 here, so when I write the entire expression with respect to V_1 per phase, I can write, $I_2^l = \frac{V_1}{(R_1 + \frac{R_2^l}{s}) + j(X_1 + X_2^l)}$. So, from which we could get the overall expression for the torque as, $T_e = \frac{3V_1^2 R^l{}_2 / s\omega_s}{(R_1 + \frac{R_2^l}{s})^2 + (X_1 + X_2^l)^2}$.

So, this gives me the overall torque expression, from which we talked about 2 different situations one was when s is very much less than 1 or closed to 0, which is the normal operating situation of an induction motor, normally, if you look at most of the induction motors, we are going to have the rotor copper loss to be generally very-very small as compare to what is coming into the rotor.

If, I say 100 watts are coming into the rotor I may have only 4 or 5 percent being dissipated generally as the rotor resistance loss. So, I am going to have almost 95 percent being converted into mechanical output, which means I am going to have actually slip to be only about 5 percent or even less. So, that is the reason why we say slip is generally normally very much less than one corresponds to the normal operating region of the induction motor.

We are not going to have very large slip normally in an induction motor, which is fairly well design and generally, induction motors are fairly well design. So, in which case we are going to say $T_e \cong \frac{3V_1^2 R'_2 / s}{(\frac{R_2^l}{s})^2}$.

I am just doing an approximation, clearly when we do the actual calculation, we will not, but we are going to have this as R2 dash by S the whole square, so this is approximately equal to this, because of which I am going to have $T_e \; \alpha$ s .

So, I am going to have $T_e \; \alpha$ s whenever the slip is going to be really-really small. On the other hand, when we say, when the slip is close to 1 which is equivalent to the starting condition, starting condition ω_r is 0, if ω_r is 0 the slip is 1. So, when I am going to have the slip equal to 1, I am going to have rather this portion that is this entire portion is going to be negligible as compare to $X_1 + X_2^l$.

So, I can directly say that the $T_e \; \alpha \; \frac{1}{s}$, this is what is going to happen, during the slip close to 1 or slip is very close to the starting condition. So, on the whole, I should be able to draw the characteristics somewhat like this, let us say this is ω_r increasing and this is torque in the increasing direction, when ω_r is equal to synchronous speed.

So, if I take the point where it is ω_s, when $\omega_r = \omega_s$, at that point if at all ever the rotor reaches the synchronous speed which can never happen in steady state. If at all it happens, then I am going to have really no rotor current at all, no torque at all, so it is essentially no-load condition. If, I am talking about rotor having reached synchronous speed by chance, by hook or crook, I am going to see that there is no rotor current, there is rotor EMF induced because of which there is no torque.

So, if there is no torque it is as good as no load condition that means that is torque equal to 0. So, this is going to be the operating point when I am talking about synchronous speed being the operating speed and as I increase the load on the motor, may be I ask for more and more load, more and more mechanical torque, definitely I will require more and more rotor current, only if there is more rotor current there will be more torque developed.

Only if there is more torque developed, I am going to sustain the rotation of the induction motor by meeting the torque demand, otherwise there is no way the sustenance of the rotation will not take place. So, I am going to have as I increase the load further and further, I am going to have reduction in the speed. Reduction in the speed means increase in the slip, because $\omega_s - \omega_r$ that is what contributes to slip.

So, if there is a reduction in the speed, so here ω_r decreases or I should say slip increases that is what happens, when I am looking at the speed coming down and the torque increasing correspondingly. So, this is very clearly whatever we wrote earlier that is $T_e \ \alpha \ s$, so that is valid in this region, if I say from A to B this is A B, region A B corresponds to $T_e \ \alpha \ s$.

Whereas if I am going to talk about the other region which is $T_e \ \alpha \ \frac{1}{s}$ that is actually corresponding to this region, where this is actually s equal to 1 and this point is S equal to 0 that is where the slip is 0. So, obviously I will have, some kind of hyperbolic characteristics may be something which will be somewhat like this. So, I have 2 portions of the slip torque characteristics clearly, one corresponding to the slip being proportional to the torque the other being the other being the $T_e \ \alpha \ \frac{1}{s}$.

Conversation between professor and student starts.

Student: (())(12:57)

Professor: S is 0 Te is 0, yes, this is Te, S is 0 Te is 0. S is 0 synchronous speed, there is no rotor induced EMF, there is no rotor induced current, so obviously Te will be 0.

Conversation between professor and student ends.

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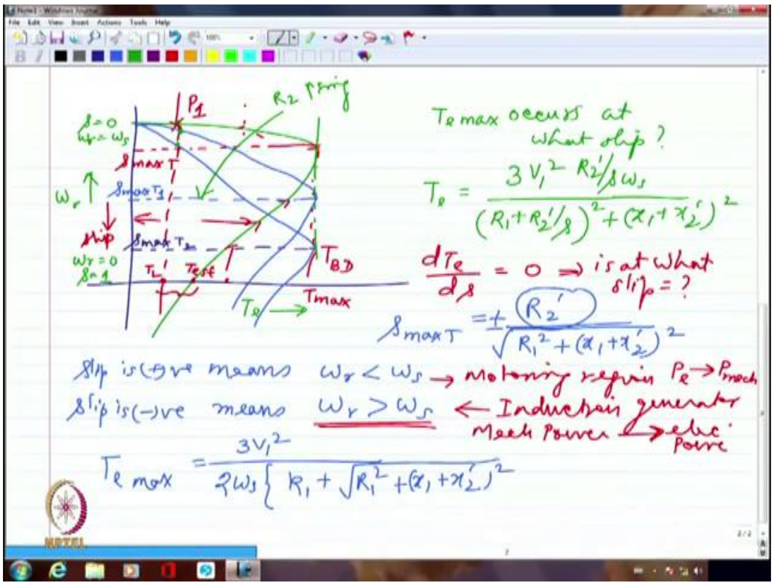

So, we are looking at now wherever it intersects. So, I can draw the entire slip torque characteristics on the whole or speed torque characteristics on whole as though this is the way it works. Actual speed torque characteristics will be somewhat like this, as per as the induction motor is concerned. This is definitely not a linear region, whereas this is the linear region and this is going to be slip equal to 1.

This is $s=0$, this is going to be $\omega_r = \omega_s$, this is $\omega_r = 0$, ω is increasing in this direction and this is T_e. So, this is the typical speed torque characteristics of a 3 phase induction motor. I asked you guys to derive where T_{emax} occurs, at what slip? So, we had an expression for

$$T_e = \frac{3V_1^2 R^l{}_2 / s\omega_s}{(R_1 + \frac{R_2^l}{s})^2 + (X_1 + X_2^l)^2}.$$

Conversation between professor and student starts.

Student: (())(14:53)

Professor: We are neglecting it just to get the ease of the entire derivation, the proof of the pudding is in eating it, so ultimately if your actual characteristics almost resembles this it is alright and it is resembles, so that is the only reason we are going along with it, otherwise we would definitely say that is the reason when I talk about the open circuit test or no-load test and short circuit test, in a transformer and induction motor there will be slight difference.

Conversation between professor and student ends.

So, when we are looking at this way, now we have to write $\frac{dT_e}{ds} = 0$. So, this is at what slip? You can find out and that will come out to be S_{maxT}, I am writing this as the torque is maximum, slip at maximum torque that is what I mean by S_{maxT}, this is a slip but maximum torque it will come out to be $\pm \frac{R_2^l}{\sqrt{R_1^2 + (X_1 + X_2^l)^2}}$.

Please, note the slip is positive at some torque T_{emax}, the slip can be negative also at some other torque T_{emax}, but that T_{emax} will be in all probability minus T_{emax}, which means there will be a mirror image kind of characteristics on either side. One thing I want you to realise is if slip is positive means $\omega_r < \omega_s$.

If slip is negative that means $\omega_r > \omega_s$, because $\omega_s - \omega_r$ that is what we said as the slip, slip speed that divided by ω_s gives me the overall slip that is what we said. So and we also said very clearly that this can never happen in an induction motor, we said that ω_r can never even reach, ω_s leave alone going beyond ω_s, for this to happen I will have to have a condition where the motor will be driven, the machine will be driven by an external prime mover.

If let us say, I have a vehicle which is fitted with induction motor and it is moving downhill, then definitely the gravity will make the speed go up unless I control it, so the gravity can make the speed go up beyond whatever is the synchronous speed also for what, in which case it can go into slip being negative. That is what I mean by having a prime mover, the prime mover can be a turbine, the prime mover can be a winter bine or IC engine or whatever does not matter, but it can also be gravitational pull.

So, the gravitational pull is actually acting like a prime mover, and if the speed goes beyond whatever is the rated speed or synchronous speed that is going to cause the slip to go into the negative region, and if the slip is going into the negative region, and if I have a prime mover in all probability, the mechanical energy will be converted into electrical energy. I am giving mechanical energy with the help of may be the gravitational pull, which is a kinetic energy that can be converted into electrical energy in which case the induction machine until now what was operating as a motor will start functioning as a generator.

So this will correspond only to induction generator operation where I am going to convert mechanical power into electrical power whereas this happens in motoring region, where I am going to have very clearly electrical power is converted into mechanical power. I am not going to elaborate further on the generator region because that will take it is own 2 hours at least. So, let me not get into generator region because we were only primarily concerned with the motoring operation.

But nevertheless at least I thought I should make a passing mention at what point a machine, which is definitely it is going to have functionality of both generator and motor, definitely any electrical machine for that matter will have the functionality of a motor as well as generator. As long as you make the situation conduce for 1 particular operation or the other particular type of operation, we are primarily concerned with the motoring operation, but incidentally when we encounter a negative slip that is the reason why I mentioned this, no more of generator, I will not talk about generator any more.

So, now this point which probably corresponds to the maximum torque, that we will again calculate by substituting this slip value into this, if I substitute this maximum slip value into the torque expression I will get what is the maximum torque this is T_{max}, we incidentally call that also as break down torque TBD. TBD is the maximum torque an induction motor is capable of generating under a particular voltage, under a particular frequency condition.

That is break down torque if you try to load the induction motor beyond this particular torque it will stop, it will stall, it will not be able to run any more. So, let us say I was working with may be 10 newton meter, 20 newton meter I kept on increasing may be it came up to 50 newton meter, may be 50 newton meter happens to be my brake down torque. If, I try to reach 51 newton meter the machine will come to a standstill situation.

It will not be able to work anymore; it will not be able to rotate anymore. So, break down torque is the maximum torque that can be delivered by the induction motor at a given voltage at a given frequency, because I am generally operating it from the grid the grid voltage is fixed normally, it will be about 400 volts 3 phase line to line and 50 hertz roughly.

So, for that voltage and for the frequency it is kind of set and stone, for a given induction motor because it depends heavily up on the parameters of the induction motor. And this is S_{maxT}, slip is increasing in this direction I hope you understand, slip is starting from 0 and going towards 1 in the opposite direction to that of the speed. So, the slip is increasing in this particular direction.

Conversation between professor and student starts.

Professor: See, if I am talking about actually a load torque like this there is only 1 point clearly and it will normally settle closer to synchronous speed, I hope you got the question, if I look at any of the load torque here if I look at some load torque like this, I will have 1 point here 1 point here, so if I am having 2 points like this, then what is going to happen, where is going to settle, that is the question?

Conversation between professor and student ends.

If, I have a constant torque load for example let us say I am talking about an elevator, elevator is driven by an induction motor let us say, so 8 of us have gotten, may be the torque corresponds to some value like this, it is starting from 0 speed clearly, so unless I have some amount of torque in excess, there is no way acceleration will take place, I hope you understand, I will have acceleration possible only if my starting torque which is T_e starting is greater than T_L.

T_L I am talking about as a particular value of load torque which is a constant torque load. So, unless I have some amount of access available the machine is not going to accelerate. So, the machine will start accelerating, as it accelerates please note that I am going to get more and more electromagnetic torque, are you getting my point this is the ordinate which represents the electromagnetic torque.

So, the electromagnetic torque available is more and more and more, so the machine will accelerate further and further, so this is the starting condition. It is accelerating and the moment it accelerates and reaches this value it will accelerate further and when it accelerates further and the torque is decreasing, so when it is not really fading into it is own self that is where stability is otherwise there will not be stability.

So, the stability happens only in the linear region, not in the hyperbolic region. So, wherever, the stability is, it will come and settle there. So, it will settle down at this point, which is probably P1 that is going to be the operating point, on the other hand instead of 18 people, 8 people, say 18 people have gotten into the elevator, the torque is very large the demand, if the torque demand happens to be somewhere here, the machine will not start at all, it will just stall, it will say overload and weight.

The elevator definitely will have an indicative button that it is overload, because the load torque is greater than whatever the machine is capable of generating at the starting condition, so it is a very good question, very valid question. So, the starting torque has to be greater than the load torque for the machine to start, otherwise it is not even going to start.

So, generally the operating point what we specify will be less than the starting torque invariably that is how it will be. So you will have only one of operating points possible which is actually coming over in the stable region rather than in the unstable region where it is just going and going increasing in terms of it speed, that is essentially the unstable operating point. So, the stable operating point will be only this.

So, P1 will be the operating point. Now, let us try to write the expression for T_{emax}. So this is going to be $R_1 + \sqrt{R_1^2 + (X_1 + X_2^l)^2}$. This will be again plus or minus only I am showing plus, minus will correspond to generator region I am not really going into generating region.

So, this will be the T_{emax}, one thing one thing I would like to point out here in T_{emax}, T_{emax} does not depend on the rotor resistance at all, all though all along when we were talking about the torque, we always said $\frac{I_2^2 R_2}{s\omega_s}$. So, R_2 was playing a very-very vital role, but T_{emax} does not depend upon R_2 it rather depends upon R_1 and X_1 + X_2 and so on and so forth.

But, the slip at which the maximum torque occurs that has R_2 in the numerator, which means as I increase R_2, if I increase R_2 like in the case of a slip ring induction motor, where I can include resistances from externally. So, if I am going to have R_2 increased than what is going to happen is this maximum torque will not get affected, but this S_{maxT} will get affected, S_{maxT} will shift towards 1. So, what is going to happen is I will have probably one more characteristic somewhat like this.

So, I am just showing how exactly the characteristic shift, please, remember this is what is S_{maxT} now, so this is S_{maxT1}, when I increase the resistance further and this is S_{maxT2}, when I again increase the resistance further, rotor resistance not the stator resistance, so I should very clearly indicate this is R_2 increasing or R_2^l increasing, either way it is fine. If I am able to increase R_2, may be like in a slip ring induction motor, which I cannot do in a squirrel cage induction motor.

I can modify the resistance characteristics of the rotor by including an external resistance only in the case of a slip ring induction motor. So, if am talking about a constant torque load I have one operating point here, one operating point here, one more operating point here, which means by changing the rotor resistance I will be able to get 3 different operating speeds then I include more and more resistances.

So, the rotor resistance control for controlling the speed of an induction motor at a given torque is possible only in the case of a slip ring induction motor which is a big plus point, because I am incurring losses, alright, but I am able to get a very simple method of speed control if I want to have speed control, no matter what, I do not mind losing out on efficiency. In that case one of the best means possible is to include rotor resistance.

Because it is very simple, just include rheostat, keep changing it that is it. So, if we can do that, that really gives me the leverage to have variable speed at a given torque that is possible only in slip ring induction motor not in squirrel cage. So, this is one of the major plus points of the slip ring induction motor all though it has no maintenance pre-operation, it is costlier, it has wear and tear, all those things are there, nevertheless, this is one of the simplest means of controlling speed of the induction motor.

So, now that we have seen the slip torque characteristics or the speed torque characteristics and we have also got what is the T_{emax} expression, please, note for all this resistances till T_{emax} is remaining the same, that has not changed TBD has not changed, I would like to emphasize that, we have not change TBD, only thing that has changed is the slip at which the maximum torque occurs and the speed also can be varied, so much for the slip torque characteristics and for the speed torque characteristics of the induction motor.

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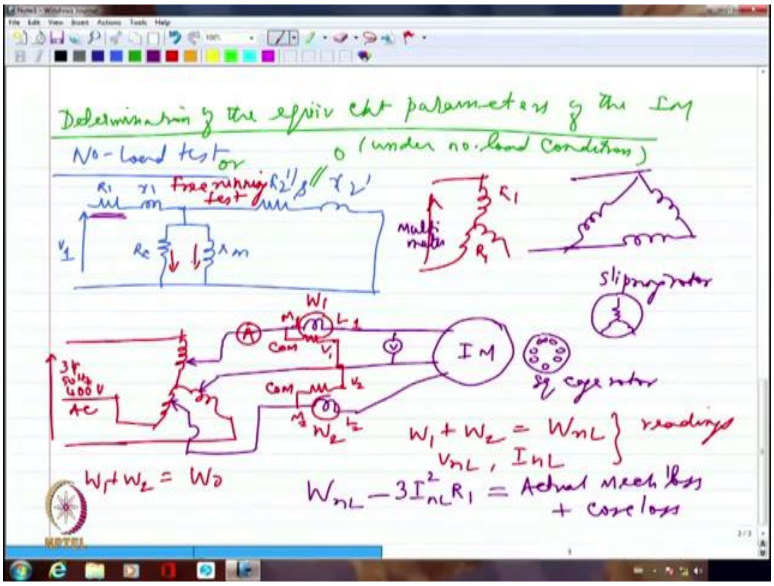

We talk so much about R_1, R_2^l, X_1, X_2^l but we did not talk so far as to how to determent them. So, let us try to go and see how to determent the equivalent circuit parameters of the induction motor. We all are already familiar with transformer, how to determine the equivalent circuit parameters, we had seen open circuit test and short circuit test, as induction motor is very similar to a transformer.

Similar tests are going to be able to determine the parameters for this machine as well, no doubt. But how will I open circuit the induction motor? If I open circuit the induction motor it is not going to rotate and the secondary side is any way short circuited in a cage motor, I cannot get in and then break the end ring connection and say it is open circuited I do not want to do that, so how I am going to really do the open circuit test? Rather than doing open circuit test what we do is no load test of the induction motor.

We are just going to allow the motor to run freely, free running test, we call it as free running it is running freely without being loaded, I am not going to load it at all. So, you are going to have essentially no load test being done when the motor is running freely without being connected to any other or coupled to any other mechanical load, when I am going to have no load test you thing about the induction motor characteristics.

I am going to have rather equivalent circuit this R_2^l/s, this is X_2^l and this is V_1 this is R_1 this is X_1, of course, I do have R_c and X_m, then it is running freely it is as good as no load the torque is 0, when the torque is 0, the slip will also be close to 0, if not exactly 0, slip will be close to 0 because I am asking for literally 0 torque, I do not want any torque that means the rotor current will be almost closed to 0.

The rotor current will not literally flow it may have very-very miniscule value, so the no load condition is as good as having the rotor circuit impedance to be infinity or the rotor circuit being open circuit completely, it will equivalent to that, slip is almost close to 0 under no-load condition, if slip is almost close to 0 under no-load condition R_2/s happens to be infinity, if R_2/s is infinity it is as good as open circuiting the rotor.

So, no load condition almost mimics the situation of open circuit condition of a transformer in the case of an induction motor. So, that is the reason why we conduct normally no load test or we also called it as free running test. So, under free running test condition we normally apply no load on the shaft and try to measure what is the power. So, what we are going to have is the circuit diagram is somewhat like this I am going to have 3 phase supply, I will have a 3 phase variac or an auto transformer.

So, I am connecting the full supply to the variac and I am going to have 3 jockey points coming out like this which will go to the 3 phase induction motor. I cannot do it per phase, obviously I have done it for 3 phases and then calculate per phase parameters. Now, here is my induction motor, so induction motor let me show it like this, this is my stator, the rotor I can show internally, but I have written IM so I do not want to show it there otherwise this is the way I will show the squirrel cage rotor.

If it is slip ring rotor I will show it like this as though 3 windings come out that is it. So, this is slip ring or wound rotor, whereas this is squirrel cage rotor. I am just showing the representation, so this squirrel cage rotor, now please note I will not show any brushes in DC machine I will always show brushes in the armature, here I should not show a brush.

Now, this will be connected through wattmeter and ammeter and voltmeter, of course, we can connect or multi meter can do the job of measuring, so I am going to show 1 wattmeter 1 more wattmeter and I am going to show the pressure coil two wattmeter method we are using, so I am going to have 1 more pressure coil here, potential coil and current coil, we call this, we were talking about this, when we are, we were initially talking about 3 phase circuits also, so this is M, L, mains load and this is going to be the common point and this is the voltage point this is common this is voltage. So, may be M_1 L_1 M_2 L_2 this is V_2 this is V_1.

Now, I will connect this directly to the induction motor, so I am going to show as though this is connected here, this is connected here this is connected here I can connect a voltmeter if I want here, of course, I should have connected an ammeter which I missed, of course, ammeter should come definitely. Assuming the 3 phase induction meter to be balanced it will be balanced normally, so 1 phase current if I measure it is good enough, it can be star connected, it can be delta connected it does not matter, I am going to get 1 W_1 and W_2, 2 wattmeter readings.

So, W_1 + W_2 is going to be W_0 this is, of course, 3 phase 50 hertz 400 volts AC what is available in the lab normally. So, you will apply rated voltage to the induction motor by using a variac, slowly increase the voltage so you will not see a jerk of current suddenly flowing into the motor, so you will slowly increase the voltage and the motor will start rotating, you will bring it up to the rated voltage you will measure what is the value of ammeter reading, and you will also get the voltmeter reading and you will also get the wattmeter readings.

Under no load condition the major current drawn is by the magnetizing reactance core loss component of resistance, generally, core losses should be as minimum as possible in an induction motor because I would have laminated the core hopefully the hysteresis losses will also be not to high, but there is one loss which we cannot account for that is rotational losses, definitely there will be some amount of rotational loss, there will be friction, whether I like it or not, there will be some amount of windage whether I like it or not.

So, there is going to be some amount of mechanical losses which I cannot account for. Most of the times in induction motor equivalent circuit RC would also take care of this mechanical losses very often we might club everything together and say let R_C represented, because it is very difficult to bifurcate or partition all the losses independently, very often it will become very difficult for us to partition the losses, so we might take the complete mechanical losses during no load test plus whatever is the core losses everything put together we might call that as R_C.

So, the current drawn is primarily due to the magnetizing current, if I say R_C is not having much of losses, if magnetizing current is the primary current that is being drawn during no load condition, the power factor is going to be bad, because magnetizing current is always inductive in nature. But if it is inductive, I am going to have 90 degree lagging current and if it is 90 degree lagging current and R_C current is a small current then overall current is going to be extremely lagging.

If it is extremely lagging I will have into wattmeter if you may recall $\cos(30+\phi)$ in one of the cases, $\cos(30-\phi)$ as the other case, wattmeter readings correspond to $V_L I_L \cos(30+\phi)$, $V_L I_L \cos(30-\phi)$, if Φ is greater than 60 degrees lagging then in all probability 1 of the 2 wattmeter definitely will kickback, you would see that the needle goes below 0. So, you will not be able to read the wattmeter at all, 3 phase wattmeter will automatically add and give you the overall power.

So, generally I insist on using to wattmeter so that you guys are able to see these kicking back phenomena, it is important to see that only then you are going to realize that when the power factor is really bad I am going to get very clearly a kicking back in 1 of the wattmeter. If 1 of the wattmeter kickback, then what we will do is to reverse the current coil, that means you have to disconnect and reconnect the current coil that is what we will do normally.

So, M toward the load side L will come towards the supply side, if I just reverse 180 degree out of phase will automatically make 1 of the 5 whatever we have $30+\phi$ or $30-\phi$ come out to be may be 180 minus or something like that because of which you will automatically see that the reading becomes positive. So, you would not this difficultly if we are talking about reversing the current coil, but whatever you got as may be after reversing you will get a positive reading but note it down as minus so and so watt.

So, let us say W_1 was 100 watts, W_2 was minus 50 watts, originally, so it was actually showing kicking back but after reversing it has shown 50 watts, so you will show W_1 as plus 100 watts W_2 as minus 50 watts is that clear. So, this kicking back would normally happen in most of the induction motors, if it so happens that it is a well design induction motor with very minimal requirement of magnetizing current.

So, this is the no load test, so I am going to have $\omega_1+\omega_2=\omega_{NL}$, and I am going to have V_{NL} and I_{NL}, these are the readings that I get, R_1 I would be able to measure just with a multi-meter, R_1 is the resistance of the stator winding, I can always connect may be between 2 terminal of the induction motor stator, I can connect a multi meter. If it is star connected it will come out to be $R_1 + R_1$, I hope you understand because 2 of them will come in series.

If my stator winding is in star and I put a multi meter between these 2 it will come out to be $R_1 + R_1$, so whatever I get as the multi meter resistance I have to divide that by 2 if it is a star connected induction motor, but if it is delta connected induction motor I will have R_1 in parallel with 2 R_1 that is how it will be, I hope you understand. I am going to have R_1 in parallel with 2 R_1, so it is going to be 2/3 R_1 because of which I should be able to calculate again back words what is the value of R_1 from here.

So, I can simply use a multi meter and measure the resistance. I have measure the resistance; I have done the no load test. Now, in the transformer, we conveniently neglect whatever was dissipated in this R_1 because the current was less than 5 percent under open circuit condition of the secondary, we could neglect it completely, whereas here I cannot afford to neglect it completely because of the fact that the current drawn under no load condition happen to be anywhere between 25 to 30 35 percent this is true in the case of a large induction motor about 20 percent or something.

But is a small induction motor again what we have in the laboratory an all we could not careless, so if you look at actually the value of the no load it can be as high as 50 percent even in many cases, so it is very large normally the no load current is very large because of which we will say $\omega_{NL} - 3I_{NL}^2 R_1$, this will be the actual mechanical loss plus the core loss, which will help us to calculate R_C.

Please remember all the readings are for 3 phase, so I it a delta connected motor $V_{NL} = V_0$ per phase, but if it is a star connected motor $V_{NL} / \sqrt{3}$, I have to do the conversion everything on a per phase bases, similarly what I have calculated now as the actual core loss plus the mechanical loss I have to divide by 3 per phase ultimately than I have whenever I do the per phase calculation I better not forget converting everything on a per phase bases, I have to do that, unless I am bound to make mistakes. So, we will continue with the no load test and the second test which is equivalent to short circuit test.