Energy Resources and Technology
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Lecture - 24
Wind Energy – IV

In the last class, we were, we finished with the understanding about how big wind turbines are for a specific amount of power output, the diameter of the wind turbine. Now the question is, the next question we have to face how many blades should be there? I suppose in one of the classes I have talked about the concept of solidity, right. Solidity is the rotor area.

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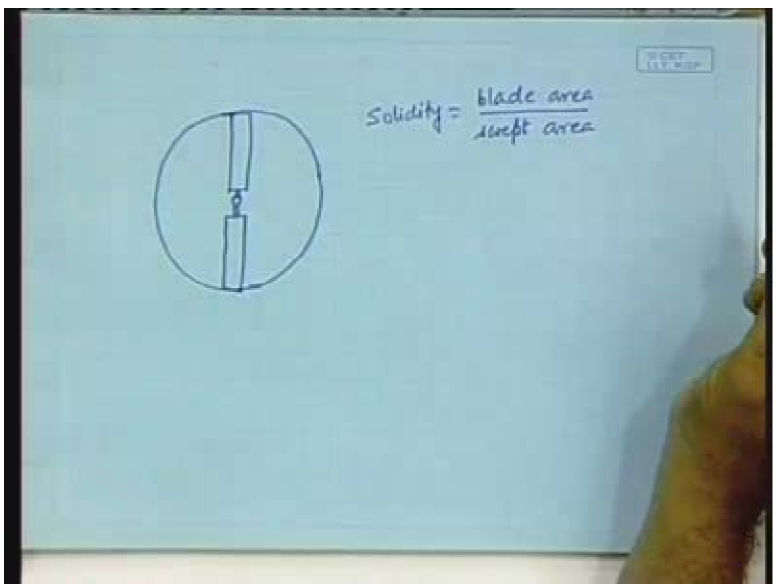

Suppose this is the area swept by the rotor and suppose this is the actual blades then, a part of the swept area is shadowed by the blade, right. Imagine that you have put a light here and you see the shadow. Shadow will only take the area of the blade, actual blade that is seen by the light divided by the whole swept area that is known as the solidity. So, solidity is … It is easy to understand that for low, small number of blades, the solidity will be low; for high number of blades, the solidity will be high.

In general, when you demand, when you require more torque and low speed, you use a high solidity rotor. For example, for the water pumping windmills, these are high solidity rotors, while the electricity production windmills is that of low solidity. So, normally for electricity production that is what we are considering, we are putting emphasis on right now there you would expect the solidity to be low and as a result, there is another reason why the solidity should be low, because the lower the solidity, the higher will be the rotational speed. Why? Because, the inertia of the whole thing is small, so it can rotate faster. So, if you want to achieve a high rotational speed, you need to have a low solidity. So, naturally the number of blades should be small. How small?

Now, that how small question is actually addressed by another consideration.

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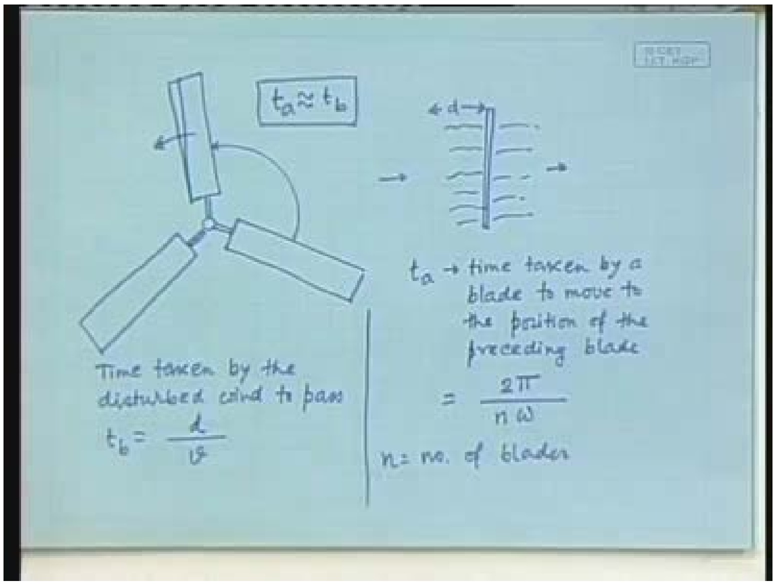

That is suppose, suppose you have a blade here, a blade here and another blade here, then as this blade passes, there will be some disturbed wind, because as it passes the wind will not remain as it was without the hindrance of the blade. So, there will be disturbed wind and if you look at it from the, from the angle in the plane, then you would see something like this that this is the blade and wind is passing like this, then there would be a distance in front, where there will be some disturbed wind and there will be distance in the rear, there will be some disturbed wind. So, the blade is rotating. As a result, it is disturbing the wind both up wind as well as down wind.

Now, if it so happens that the next blade comes into the position taken up by this blade before the disturbance passes away, then obviously it will run into a disturbed wind. So, naturally it will be seeing turbulent wind and naturally the whole efficiency will go down and if this one is so sparse that the disturbed wind passes, after that it comes much later, then obviously there would be lot of wind that is passing through without being, without taking part in the energy transfer. So, the it is clear that the optimal choice of the blade should be dictated by the consideration that the time taken by the disturbed wind to pass through and the time taken for one blade to come in the position of the other blade, they should be almost the same, clear; slightly larger, but almost the same.

So, suppose, suppose t a is time taken by a blade to move to the position of preceding blade, then this will be equal to 2 pi by n omega, right, where n is the number of blades. So, the t a is the time taken for this blade to move into this position. 2 pi by omega is the time taken for a whole rotation, 2 pi by n omega is the time taken to move to this position, n is the number of blades. So, this is one thing. The other thing is suppose the distance, the length of the disturbed wind is d and the speed of wind through the blade is small v, so how much time is taken so that the disturbed wind passes through? d by v; so, the time taken by … that we will call it t b, that would be d by small v and naturally, the consideration that we should have in mind is that t a should be approximately proportional, approximately equal to t b, right.

Now obviously, that depends on the structure, the construction and stuff like that of the blades. Why? Because, the length of the disturbed wind will depend on that and naturally, the number of blades, the consideration of the number of blades and the consideration of the blade construction are not two independent things. Depending on how you are constructing blades, what kind of smoothness you are able to build into it, depending on that, we will have to choose the number of blades. But, there are other considerations also. For example, if you have 2 blades, normally 2 or 3 you will find actually, so it is a question of a choice. Different companies choose 2 blades, different companies choose 2 blades; the choice is dictated by the fact that if you have 2 blades, obviously you will produce some less energy, because as you have seen while we were calculating, we multiply by the number of blades, but not much.

When we are calculating, we were doing some kind of, kind of a very rough estimation, but actually from going from two blade to three blade, the power goes up by say, something like 20%, but the cost goes up by more, right. So, in terms of economics, it will work out better to use a two bladed turbine. There is also the fact that the two bladed turbines are easier to erect. That means you have to, you have to spend in erection also and in that two bladed turbines are easier.

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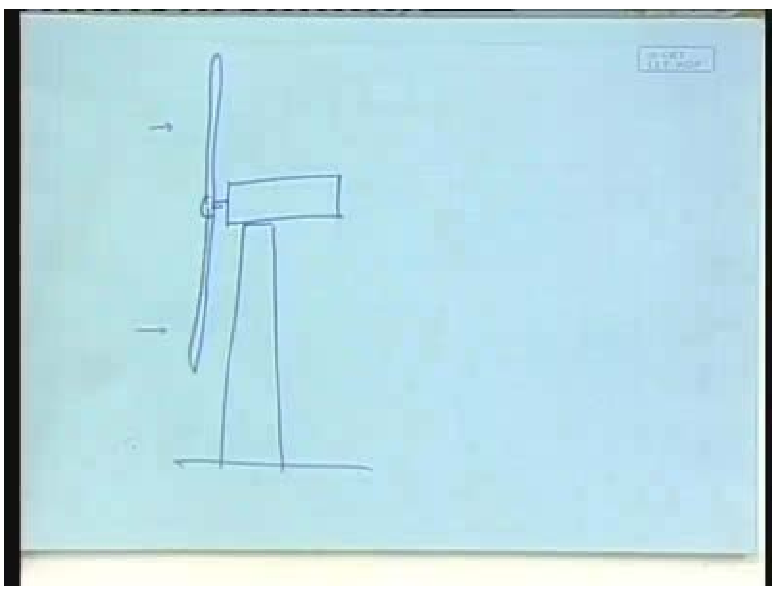

But, just imagine this particular issue that you have a tower and on top of that you have this structure and then the blade. Obviously, it could be, well, there are some rotors that work up wind like this, so that the wind comes from the front side. There are also rotors, where the wind comes, you design so that the wind comes from the other side. But in both cases, you will find that where the tower stands, when the blade passes in front of that just behind it there is a tower, so in front of the tower there will be disturbed wind that is something like a tower shadow. If the wind is coming from this side you can easily see that it will be the tower shadow, right. So, in terms of wind, not in terms of light, wind will see, wind will be obstructed by the tower which will not reach the blade that is down there. So, as the blade passes by, as the blade passes, when it comes here it will suddenly run into some disturbed wind and that happens both for down wind and up wind, because if it is up wind, then also there is disturbed wind this side.

As a result, the torque will pulsate as it goes through the whole cycle and that torque pulsation obviously will be less if you have three bladed turbine. Why? Because, there are two blades that are not undergoing that reduction in the torque, only one blade is undergoing the reduction in torque. So, the total reduction or the fluctuation, the pulsation will be less felt by a three bladed turbine than a two bladed turbine. As a result, this torque pulsation, what does it do? The torque pulsation is felt somewhere here. The torque is felt here. The torque pulsation essentially sometimes leads to blade failures. So, it is generally known that the three bladed turbines are structurally stronger, less prone to failure than the two bladed turbines. That is why even though economics works against it, many companies choose three bladed turbines.

We will later see that there are advantages of going for even higher speeds, very high speed rotors. In that case, you might argue then why not one blade? Well, there have been rotors constructed with one blade.

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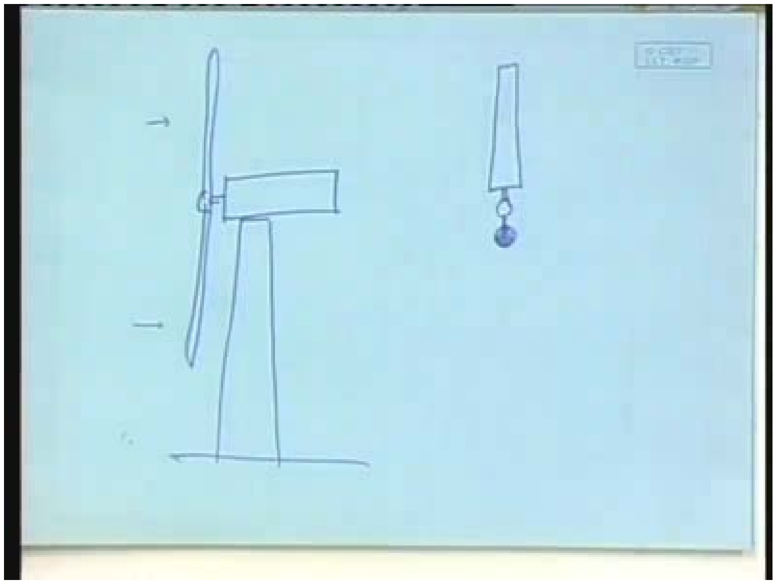

That means it is just, I am showing the frontal view, it is just one blade and the other side has to be, you know, balanced. So, there is a counter weight that is all. Now, imagine this fellow rotating up there. It is not a nice sight, it is not a nice sight; it looks somewhat odd. So, even though these things are simple, cheap, makes economic sense, these are not actually put in place, because they are not really nice sight, because when you look at it, you always feel that something is wrong with it. That is why these are not constructed. But, it is easy to see that when this one, n is 1, then it is the same blade and it has to go through the whole cycle to come to the same position and if it rotates fast, then it can do the same thing. So, from this consideration t a is equal t b, sometimes you might construct a blade that will require there to be just one blade. But, the problem is that, problem is that, there are people in the vicinity and they say they have headache looking at it, but this kind of rotors have been constructed.

So, I have more or less clarified how the number of blades is chosen. Now, let us come to the other issue. What makes this blade? How do you make these blades, you were discussing, right? The blades for very small wind turbines of the order of say, half a kilowatt or 1 kilowatt, these are often constructed out of wood. That means you simply make, take wood and shape it and nowadays there are methods of actually shaping the wood in any particular, in a given formation. So, for small wind turbines that works. For large wind turbines, no, you cannot have wood. You do not have that big size of wood anyway.

So, these are always constructed out of fibre glass, these are always constructed out of fibre glass, where there is a resinous material, there is a plastic material and there would be glass fibers giving this the structural strength and in that case one has to form the dye. That means the dye in which the fibre glass will have to be poured, then cooled, so that the whole thing is made out of, made into a single structure. So, the whole construction of the wind turbine blade is a, is a rather complicated affair, because you need facilities that big.

As I told you, the size of the blade of a 1 megawatt wind turbine will be of the order of a football field. So, you have to have the facility of constructing one single piece of fibre glass material in that size. So, it is essentially, it is essentially constructed of fibre glass.

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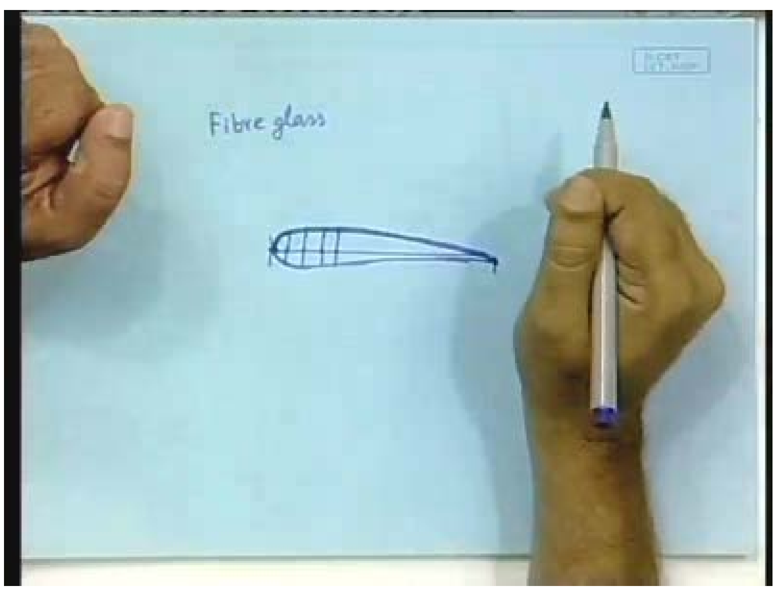

What will be the section? That means you have seen that it requires a certain section, as I told you that these sections are similar to those of the aeroplane wings and various specific geometry, geometry means from here to here, what will be the geometry, exact equation or coordinate of each point in the upper layer and the lower layer. So these are given in terms of, let this be the chord line with the distances and these distances. So, in the data sheets that you will find on the net, you will find these coordinates given, from which you can also construct this kind of blades. Again, as I told you, in the data sheets you will find these, the C L C D, etc., calculated or measured for different values of Reynolds numbers and out of that you have to choose the one that has the least Reynolds number, because that is what is more pertinent to wind turbines, clear, fine.

How will you determine the chord? This is the chord from here to here, the length.

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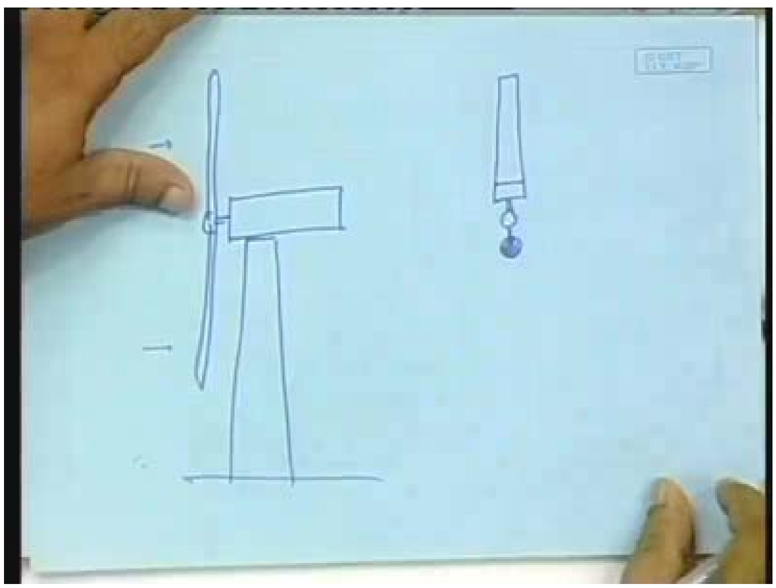

From here to here, the chord, so how big should it be? Obviously, since the chord length appears in the equation for the lift force produced, you have seen that lift force has the D AB term, which is essentially dependent of the chord length, the chord length plays a role in the design. But obviously, if say, let me draw separately.

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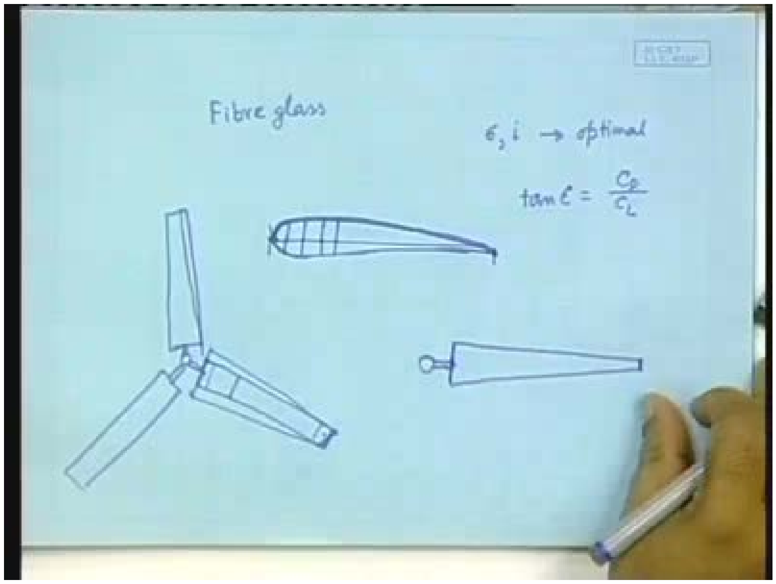

Suppose you have got a wind turbine something like this, then this chord length, as I told you, should be different from inside to the outside due to the basic fact that unless you do so, the torque produced and the thrust produced in the outer edge will be far different from that in the inner edge. As a result, the blade will experience a bending force, it might break. So, normally you have to put a larger, larger cross section, larger chord in the inner edge and a smaller cross section in the outer edge and otherwise, it should have a taper. So, normally a blade should look like this. It should have a taper. Now, the taper calculation, how to calculate this taper? How much should be the taper? That is dictated by the structural strength of the blade. How much bending stress can it withstand, because you really cannot design the blade, so that the stress produced or the torque and the thrust produced by this point and that point would be the same, you cannot do that. If you do that, it will be awkwardly shaped, as I told you in the last class.

So, you essentially make a prior design, a priori make the assumption that I will be using this much of taper and then from there you calculate how much will be the bending stress and then find out whether your blade can withstand that bending stress for the highest possible wind speed that this particular wind turbine can experience. So, that is how this taper is calculated. We have also seen that the blade should have a twist. Why should we have a twist? Because, the optimal performance is obtained at a certain value of epsilon and a certain value of i. The capital I, so these are optimal at a certain value of epsilon and certain value of i.

What value of epsilon? The least value of epsilon and what value of i? The i corresponding to that least value of epsilon. So, epsilon is, tan epsilon is C D by C L, so you want to have a least value of this for which you choose the value of epsilon and for that you will choose the value of i.

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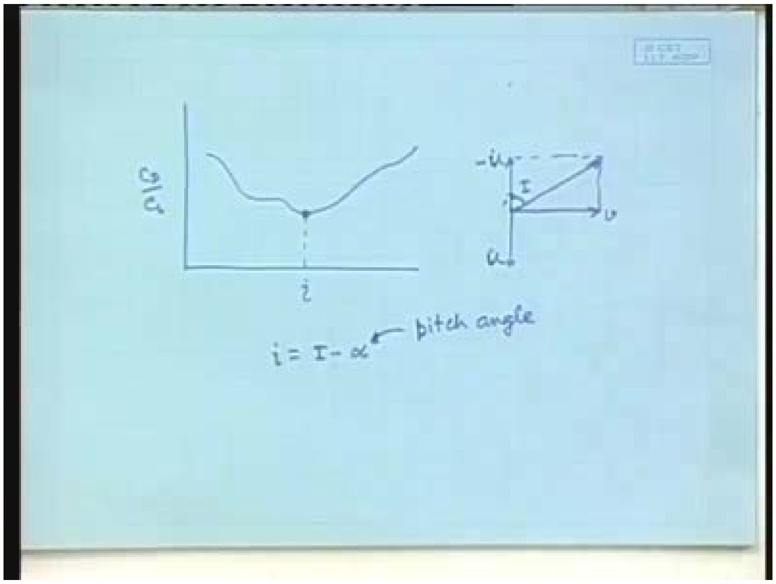

That means against i you will choose the C D by C L, you will plot the C D by C L, you will get a graph something like this and the minimum point is where your optimum value of i is. i is the angle of attack. But, as you have seen that if you construct the velocity parallelogram, here is your v, here is your minus i, here is your i and here is the w and this is your capital I. Obviously, as the speed of rotation, linear speed of the blade changes from the inner edge, it would be only this much; in the outer edge it will be that much. So, obviously this parallelogram will change from the inner edge to the outer edge and the relative wind will move from this side to that side, as you go from the inner edge to outer edge.

As a result, if the, if the, no, this is u, sorry; u means the linear speed of the … So, you have the capital I which will be different from the inner edge to the outer edge. But, the small i which is the angle of attack, should, it should at least make an attempt to keep this i constant at the optimal i. What does it mean? Since and this is the pitch angle, this angle should be clear. Pitch angle is the angle of a blade section with the plane of rotation, with the plane of rotation. Here the plane of rotation is this. Here it is the angle of the relative wind with the plane of rotation, capital I and naturally the angle of attack is I minus alpha. This is the angle of attack and this, this is what you are trying to keep fixed as the optimal value.

So, what will you have to do? You have to vary alpha from the inner edge to the outer edge. Now, again the modern large sized wind turbines, where the, where the attempt is to operate it optimally, there it is actually given. But, for this relatively smaller sized wind turbines, depending on the construction method it may or may not be possible to give the amount of twist that is dictated by these considerations. If you do not then what will happen? Again, in certain parts the blade section will operate sub-optimally. It will operate somewhere here or here and then depending on that you have to calculate how much would be the power produced. But, you should attempt, your knowledge should tell that yes, I want to keep the i constant at the optimum value.

You would notice that that v, the wind speed also varies from time to time. It varies from inner edge to the outer edge, but this varies from time to time, because it is dependent on the wind speed that is coming; that is not in your hand. So, this fellow also varies. If this fellow also varies, how can you still try to keep the i constant? By changing the pitch angle; that means the pitch angle is also not just you give a twist which is from the inner edge to the outer edge, but depending on the wind speed you have to keep on changing that. That means there is a constant twist between the inner edge and outer edge that is constant, the difference in the angle is constant. But then, the whole thing is moved, so that is the pitch angle control. Is it understood? How it is done and things like that, I will come sometimes a little later. So, you have the concept of the design of the blades. How is it done? How does it look? That is more or less clear to you now, right. Is there any question? No, fine.

Then comes the question of the tower. One of the important things that you have to keep in mind in imagining a wind turbine is the big tower.

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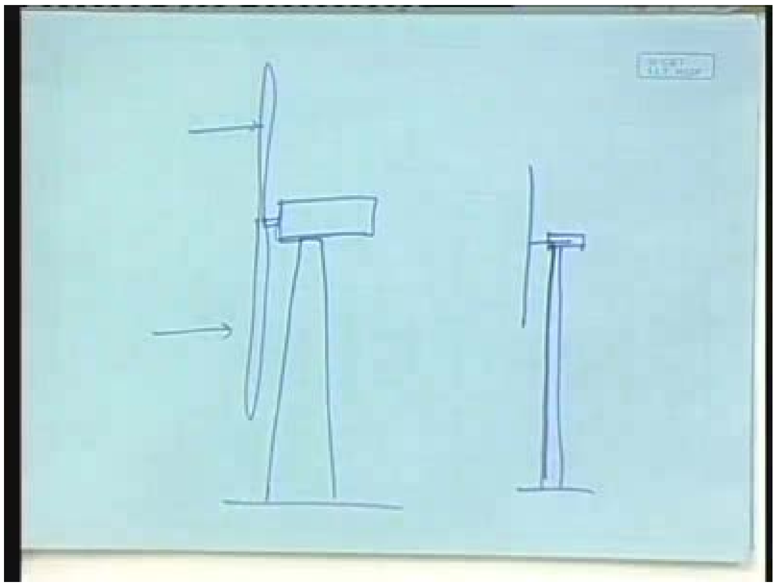

So, it has to have big tower. So, here is the tower. Now, the tower obviously has to carry the whole weight of the blades, of this whole thing in which you will have to house the gear box, the transmission system, the brake, the electrical generator, everything on top of the tower. It is a huge tower, on top of it all these weight has to be housed and you have already seen that this wind also gives a thrust that tries to topple the tower, which can be calculated. So, it is not that it is something nebulous; it can be very accurately calculated for every possible wind speed. So, you will know how much it is; how much is trying to topple the tower and how much is actually acting in this direction. So, depending on that you have to make a very strong tower that will be able to withstand these two issues.

The other thing is that as this fellow rotates there is a rotation and naturally a rotational frequency is generated. The gear box rotates at a different speed. Because there is gear box, so there is one side rotating in one speed, the other side rotating at different speed and the generator is also rotating at a different speed. So, these are naturally occurring, naturally occurring frequencies in the system and this tower will also have a natural frequency of oscillation and there is always a possibility of resonance. If that happens, the vibrations are amplified and the whole thing may collapse because of that. So, while designing the tower and designing the whole thing these have to be very properly understood and taken into account, clear. So, it has to be a very strong tower. How tall? Normally, the height of the tower is approximately twice the diameter of the blade. This is actually not drawn to scale. Normally it would be, say if this is the tower rotor, this will be the size of the wind turbine, approximately twice the diameter of the wind turbine. So, this is about the tower.

You have already seen that there is, there are constructions, vertical axis wind turbine constructions, which do not need a tower. There the whole cost in the tower is less and therefore, they are far easier and far cheaper to construct. But, they have the problem that if you have the tower that reaches higher altitudes and at higher altitudes you have got higher wind speeds, while if something is constructed close to the ground it does not have access to the high wind speeds. But, that is one advantage of having a tower. There is also the disadvantage that there is a large expenditure in the tower itself.

What is inside this box? What is inside this box?

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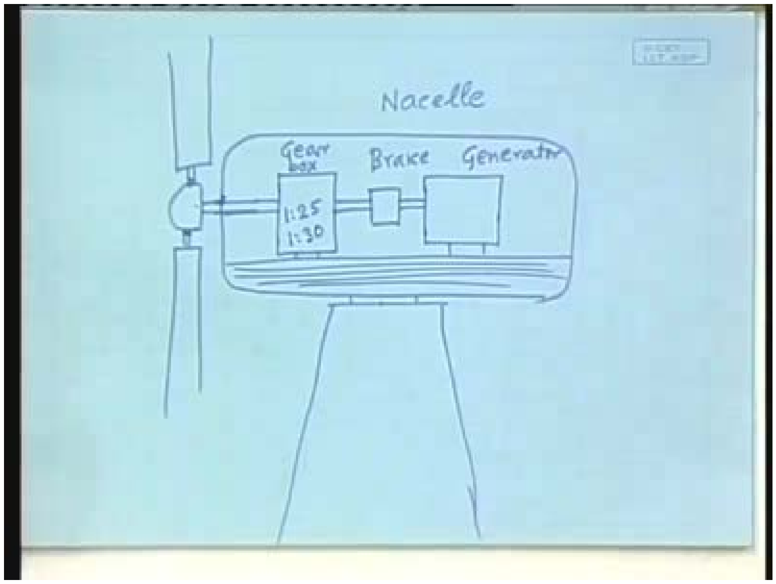

Well, inside this box, I will blow it up, so you will have … and say here you have … and here you have the tower going down. Now, what is inside? Inside firstly there has to be, the shaft is to be connected and the shaft is to be connected first to a gear box. So, that together is a transmission system. Power is transmitted through the gear box to the generator. So, after the gear box you have the braking mechanism, because at very high speeds, very high wind speeds, storms and stuff like that you need to brake it. You cannot allow the wind turbine to rotate, because then it will obviously fail. Then the shaft goes into a generator, electrical generator.

What this generator is and other things, I will talk about it later. So, here there is a platform on which these are standing. So, this is the generator. In addition to that there will have to be a few mechanisms. For example, this whole is called nacelle, this whole nacelle should be able to rotate like this, because it has to face the wind. So, this whole head is actually movable. The whole head is actually movable like this. So, there is a sort of turn table here that allows you to move and there is a motor that makes it move. So, this is not actually standing pretty on top of the tower, the whole thing is moveable, because it has to face the wind.

Not only that; at these points you should have again servo motors that turns these blades like this. Why, because the pitch has to be controlled, right. So, at these points you will have to have motors that will rotate. It is not a continuous rotation. It is just turning in order to turn the whole blade, so that the pitch can be changed. So, in addition to all this that you, that you can see in this picture there will be a motor here, there will be another motor here. These are servo motors essentially meant for orienting this whole thing. This is called a control and this is for the pitch control.

Why do you need the gear box? You need the gear box because, the generator cannot work efficiently at the rather small speed, something like 70 to 80 RPM of the blades. Normally the generators that you have seen in our laboratories would be working something like 1500, 1000, that kind of RPM. So, there has to be a gear box. This gear box would normally operate in 1 to 25 or 1 to 30 that kind of ratio. So, you need a gear box and then you need a brake and then there is a generator. What this generator is I will come to that separately, later.

So, is the, what goes inside the tower, understood? It is a really very tall thing. If you go up there, you will find as if you are standing on top of a skyscraper and then on top of the whole thing this has to be there and people have to climb up and do the servicing inside. It is a big deal. I mean this is like a big room inside the turbine housing, clear. Well, in any place where you talk about any electrical power generation or use of electrical power – motor, generators, in all these, one always tries to understand what will be the dependence on the power with the speed, dependence on the torque with the speed, things like that; power speed characteristics, the torque speed characteristics. The amount of electrical machine that you have learnt in the first year, there also you had heard about the torque speed characteristics. It is very important.

Now, in the case of the wind turbines also we will need to understand what the power speed characteristics look like. Now, in this case, the power speed characteristic will have a property, so we are trying to find out.

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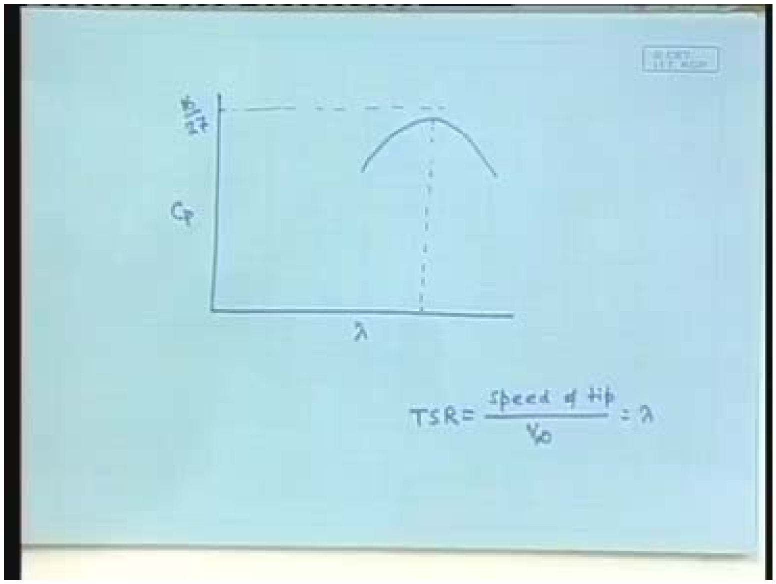

Let us start our understanding from the, you have learnt of the tip speed ratio, right. Just to recall, TSR is speed of the tip to infinity. So, this is, this is denoted as lambda. So, lambda versus power coefficient you have seen that that has the characteristic something like this, while the peak is, the maximum possible value is 16 by 27. This means that the maximum power coefficient operates at, only at a specific tip speed ratio. That we have seen already, but this is the power coefficient. So, how much will be the actual power generated?

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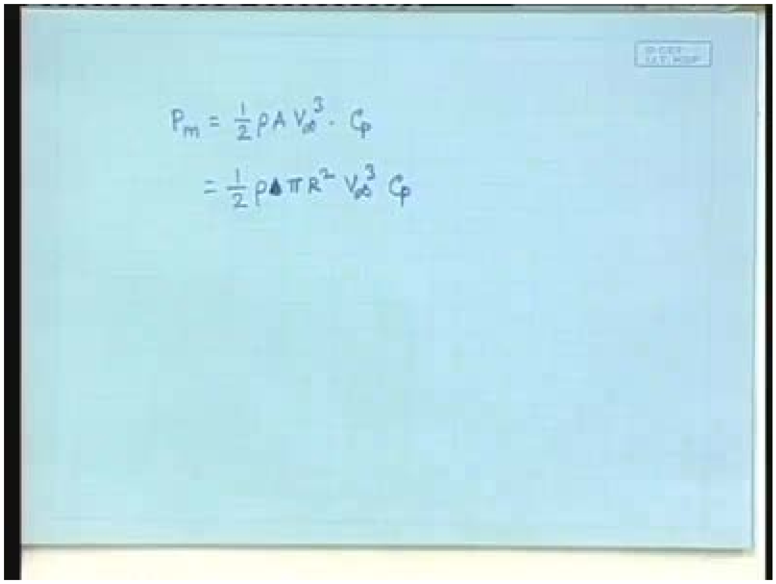

The power generated P or let us say mechanical power P m is the power contained in the wind times the power coefficient. The power contained in the wind is half rho A V infinity cube times C p and the A is half rho A, half rho pi R square V infinity cube C p, fine. We are trying to find a relation. I will, I will come to this one little later, let us see.

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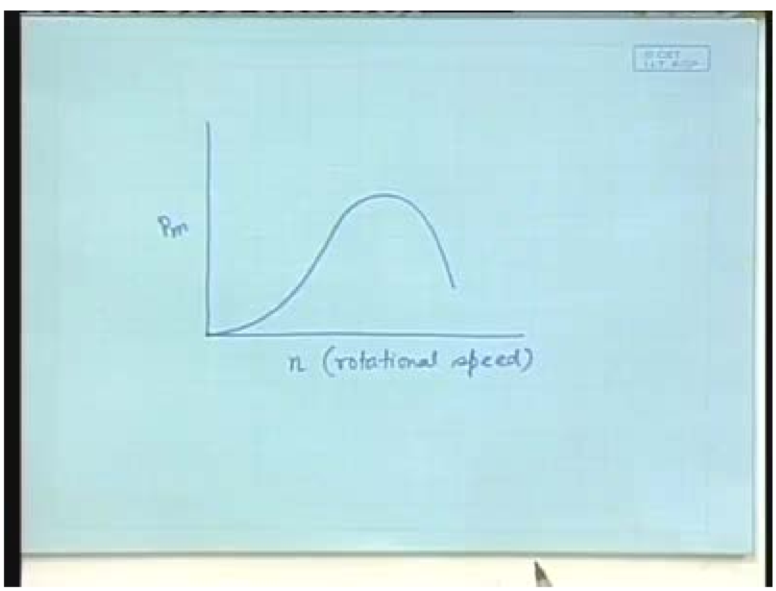

So, now we are we are trying to construct a characteristic, where your P m is here and here is the n, rotational speed. Let us see, let us go by logic. What will be the power produced at zero speed? Zero, so it must start from here. It must rise then. If it starts from here it is must rise. But, can it rise indefinitely? No, because as the rotational speed increases, say since the TSR the power is dependent on C p and C p depends on lambda, so if the speed of rotation goes very high, this will remain constant. Then what will happen? The TSR will be very high. As a result, the C p will go down, power coefficient will go down. Power will be less, so it will again fall. So, the characteristic would be something like this.

For a given wind speed, for a given wind speed the characteristic, power versus speed characteristic should be something like this. So, after this start at zero, it should rise up, reach a maximum and then as you increase the speed further, it should go down. Now, how should it vary with the wind speed? In order to understand that let us do this. We are trying to relate it with the, with the wind speed which is here and we are trying to find out the relation with the rotational speed.

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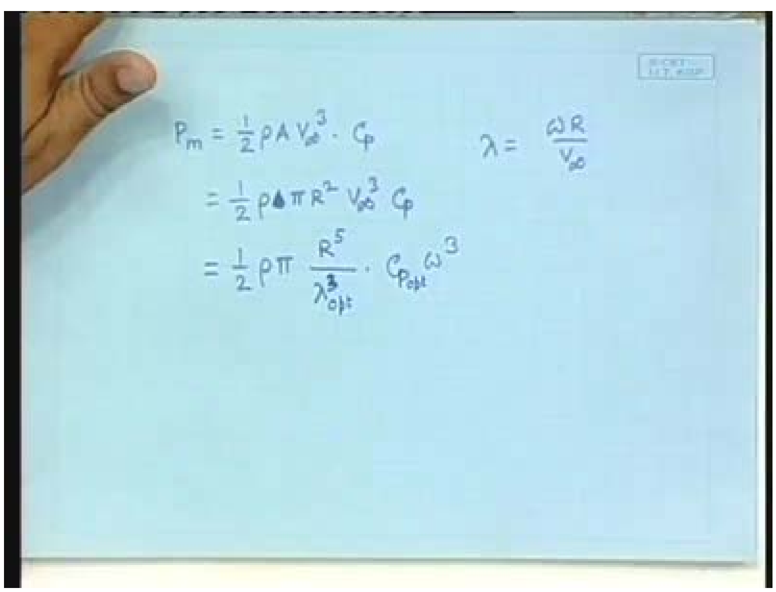

In order to do that, we will substitute, we know that the lambda is omega R by V infinity. So, let us substitute V infinity here. So, what do you get? You get V infinity is omega R by lambda. So, half rho pi, this will be R to the power 5, R square and from here R cube comes and here it would be lambda square, na, cube times C p omega cube. Now, as I told you that it operates at an optimal C p, at an optimal value of lambda, so if you are operating at that, then you can say here C p is optimal, lambda is optimal. Suppose you are operating at that point, supposing you are operating at this point, so these two are optimal. Then, what is the relationship between the P m and the speed of rotation? It should be cubically proportional, right.

How? How should this character manifest itself?

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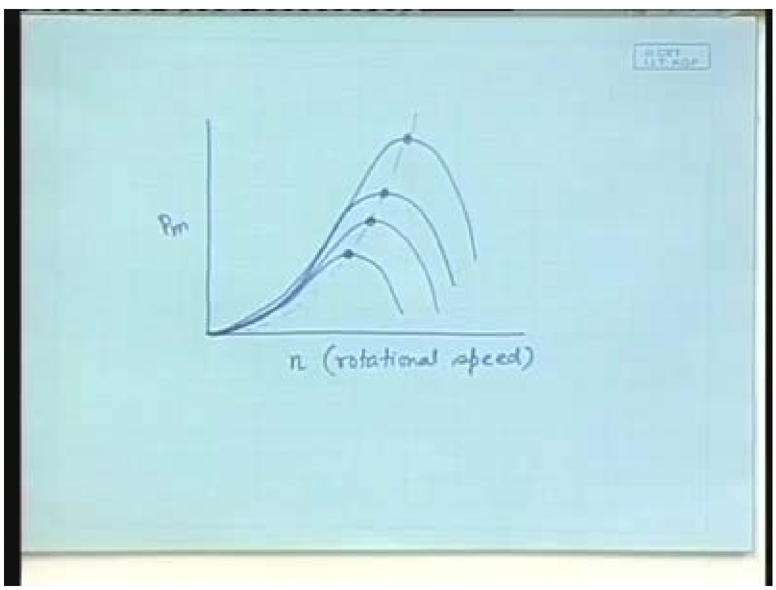

For different value of wind speeds you will have, let me draw the cubic characteristics; for different value of wind speeds you will have the characteristic going like this, so that the peak powers should follow the cubic characteristics and because the maximum power depends on omega cube, speed of rotation people try to reach as high as possible speed of rotation. It is cubically proportional to the speed of rotation. So, is that clear? So this, the peaks which actually are related to, peaks means that is related to the maximum C p, optimal C p, if you are looking at optimal C p, they should relate this way. From here we can also understand the torque speed characteristics. This is the power speed characteristic. The torque speed characteristic is simple, because the torque is power versus, power by this speed.

So, the torque speed characteristic you know, power and speed; for every value of the power you can divide by the speed, this particular speed, to get the torque here and you can plot.

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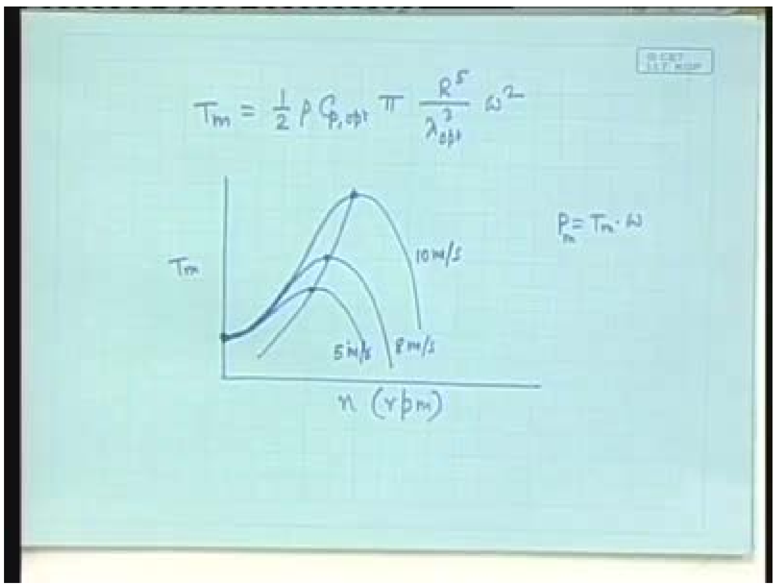

So, the mechanical torque will then be given by, from the equation that I have just written, it will be given by half rho C p, again optimal I am taking, opt, pi R to the power 5 by lambda optimal cube times omega square. So, power by omega is torque; so, here it was omega cube, it will just become omega square. So, here also you will have characteristics, somewhat similar characteristics of the torque, mechanical torque versus speed n in rpm. At zero rpm what will be the torque? No, might not be, might not be. At that point power is zero. Power is the, sorry, so you have the, power is the product of the torque and the speed and at speed is equal to zero, it does not need the torque to be zero in order for the power to be zero, because speed is zero. So, it could start from somewhere here. Is that clear? So, …

Student: …

No, it does not say, wait. Notice that the power P is, P m is T m times omega. So, at n is zero, omega is zero. That is why this does not need to be zero. It is zero for the Darrieus rotor, where there is no starting torque. But for the horizontal axis wind turbine, there is no reason to assume that it will actually be zero, though it is really small, very small. So, it will start from here and it will follow a similar characteristic, something like this. Again at different wind speed it will be, so this is say at 5 meters per second, this is say at 8 meters per second, this is say at 10 meters per second, that kind of. As the speed increases, it will have characteristics like this and again the peaks should follow the square characteristics. So, what is line? Square, it is a, it is like a parabola.

Now, why do we need to understand this? Because this is the aerodynamic torque produced that means the wind is producing this torque. But when it rotates, when you are extracting power from it, there is a back torque, right. When you are extracting power by means of electrical, you are converting to electrical energy that conversion to electrical energy gives a back torque to it. So, ultimately when the forward torque and the back torque are the same, then that will be the equilibrium condition. So, at different speeds you will have particular torque. This is the generated torque and there will be a load torque. In this case, the load torque is the torque given by the electrical generator. So, I do not know if you have this concept clear?

Supposing you have, you are supplying electrical generator with some kind of a power that means you are rotating it; you are giving a torque, it is rotating. If you are not loading it, it will not give any back torque, but the moment you start loading it that means power goes. Power goes means the voltage time current goes, the power goes and in the mechanical side what will happen? Speed times the torque, but now this will be the back torque. So, whoever is giving that prime over, whoever is rotating it will feel, the moment you are loading it you will feel that now somebody is trying to slow me down and it may have to work against it. So, that is the back torque that comes whenever you generate and actually use the electrical energy. Here also the same thing will happen. So, there is, this is the character of the generated torque and there will be a corresponding character of the load torque.

Now, if this wind turbine is supplying for example, a pump, water pump, then the water pump will have its own characteristic feature of the speed versus the torque and these two will have to be matched. Why because, we want to operate on this line all the time; this is related to the optimal value of the C p. Similarly, when you are using it as an electrical source, as an electrical source, that means it is being converted to electrical energy and that is supplying some kind of a load, then it will also have its own torque versus speed characteristics; yes.

Nowadays, all these actually are, mostly are not directly connected rather they go through some kind of a power electronic interface through which it is possible to control the power and hence the torque. If you do so, you might argue that then it is possible to have exactly the load torque also proportional to the square of the speed, so that it goes there.

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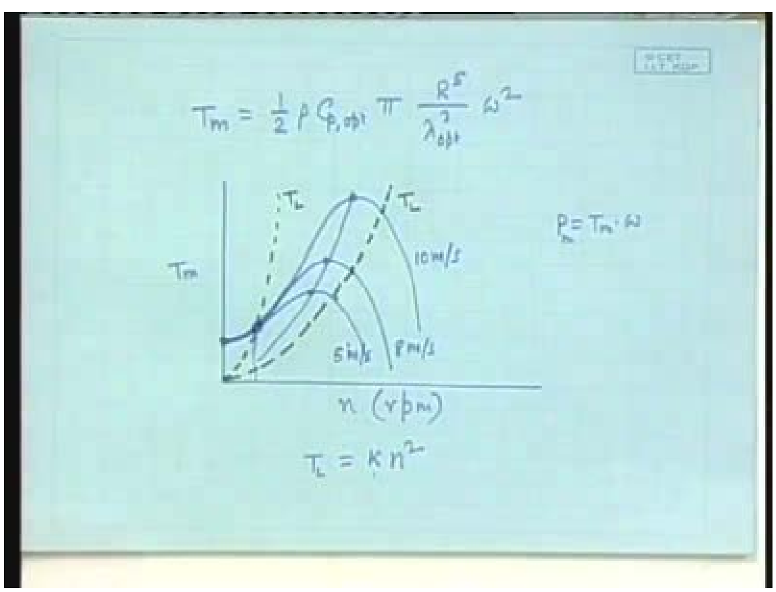

So, you would like to have, you would like to have the T L is equal to some kind of constant of proportionality times n square, right. Because the generated torque was having this same characteristic, the load torque should also have the same characteristic, so that it operates exactly here. But, notice what happens if you wrongly choose k? If you wrongly choose the constant of proportionality, see I will draw in a different color, this characteristic will be something like this and this will depend on the k. This is also a parabolic relationship. This is also a parabolic relationship, but it does not go through the peak, because the k has been chosen wrongly. So, the k should be chosen correctly. If it is further wrong choice, say to the higher side, then what happens? It goes like this.

What is the result of that? Notice, this is the characteristic of the load torque T L, T L and this is the characteristic of the generated torque. It will always operate where the load torque equals the generated torque. So, normally the operating point would be here at this wind speed, here at this wind speed, here at that wind speed. But, if you have the high value of k, so the character is like this. What will happen? It will operate here, which means the wind turbine will not speed up at all. It will operate at very low speed. So, you can easily see that how important is the choice of the load characteristics. The load should be such that it has a characteristic where the load torque is squarely proportional to the speed, rotational speed. Not only that the constant of proportionality should be so chosen that it operates along this line. This line is corresponding to the optimal value of the C p. Is that clear?

So, anything that works, wherever there is a motor generator set, the motor gives one torque, generator gives a back torque and what will be the speed of, ultimately speed of rotation? It will be exactly that value where these two torques are equal and opposite to each other. This torque depends on the speed, this torque also depends on the speed. So, it will operate at that speed which is corresponding to the equalization of the two torques. …… thing will happen here. There is a torque given by the wind generator, there is a back torque given by the motor and these two should be tuned in such a way, these two should be tuned in such a way, so that you can operate on this line and if the tuning fails, this is what happens. In this case, it will operate sub optimally and in this case it will operate hopelessly badly. The machine will be very slow, slow rotating. Why? Because of this …. problem.

So, you will see, it is not only the pitch angle that needs to be controlled. It is also the characteristic of the generator that needs to be controlled and the torque ultimately depends on, if you can control the power that goes out, if you can control the power that goes out from the generator to the load, then there is a speed of rotation. The power is nothing but the speed of rotation times the torque, you are essentially controlling the torque. So, by controlling the amount of power that is fed from the generator to the load, you can actually tune it to operate on this line and that is what is done and that is what should be understood by the energy engineers, clear. Fine, we will, we will continue with this in the next class. Is there any question on this, whatever I have taught today? Okay, let us call it a day today.