Energy Resources and Technology
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Lecture - 22
Wind Energy - II

In the last class we have seen that the main force that drives a wind turbine is the lift force and we had drawn this diagram.

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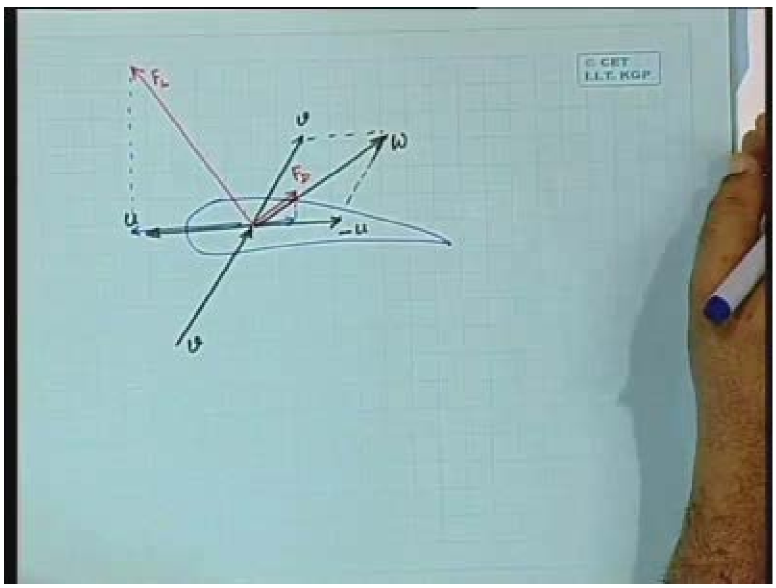

You had the airfoil and at some point we drew the direction of the motion, u and the direction of the incoming airflow, v and so we obtained the parallelogram, minus u and v, add them together we have the vector for the relative wind, w and based on this relative wind, we have a force that is created in the direction of the relative wind, which is the drag force F D and a force that is created perpendicular to the relative wind which is larger than the drag force, which is F L. So, you have a projection of the lift force in the direction of motion and a projection of the drag force in the direction opposite to the motion and since this force overwhelms this force, you have a net force that tries to push it further in the direction it is moving.

So, essentially this is the basic principle. But, engineers are often intent on obtaining some numerical predictions. We should be able to predict how much will a wind turbine produce. How much power wind turbines will produce? How much torque it will produce? Not only that, a wind turbine if it is rotating like this and wind is coming, they will also be a force that tries to topple it, a thrust force, right. That means the wind is making it rotate, but it rotates in a direction perpendicular to the, to the direction in which wind is coming and that tries to topple the tower. I will, I will illustrate it by this means.

So, you have the wind coming and the wind turbine, it is rotating like this. Therefore, the direction of u, direction of v, wind is coming and the direction of u will be perpendicular to each other, right. So, we can draw this like this.

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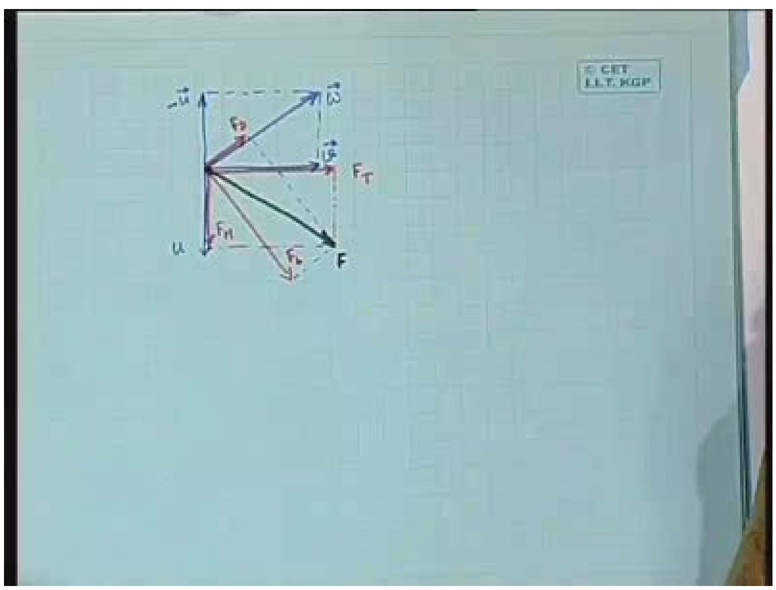

You have the v force here and you have the u force here, the wind direction is like this and the direction of the rotation like this. As a result, we will construct the parallelogram like this, minus u and in the last picture we drew a general picture, but now we are referring specifically to wind turbine in which these two vectors are orthogonal. You have the w here, so this vector, this vector added together gives the w or the relative wind vector. Now, you have the drag force in this direction, F D and the lift force in this direction, F L. They added together give you the total force. This will be the total force. Let us call it F, the total force.

Now, this will have a component in the direction and this direction. So, there will be a component like this and there will be a component like this. Now, what does this component do? Notice that it is in the direction of v. That means this is the force, this is the force that tries to topple the tower and there is another force that acts in the same direction in which the blade is moving and therefore, that produces the moment, so this force is called the F T, the thrust force and this force is called F M, the moment producing force. So, this is a force. When we calculate all these, it is not difficult to see that we cannot do this calculation for this whole blade in just one go. Why? Just imagine that the blade is like this.

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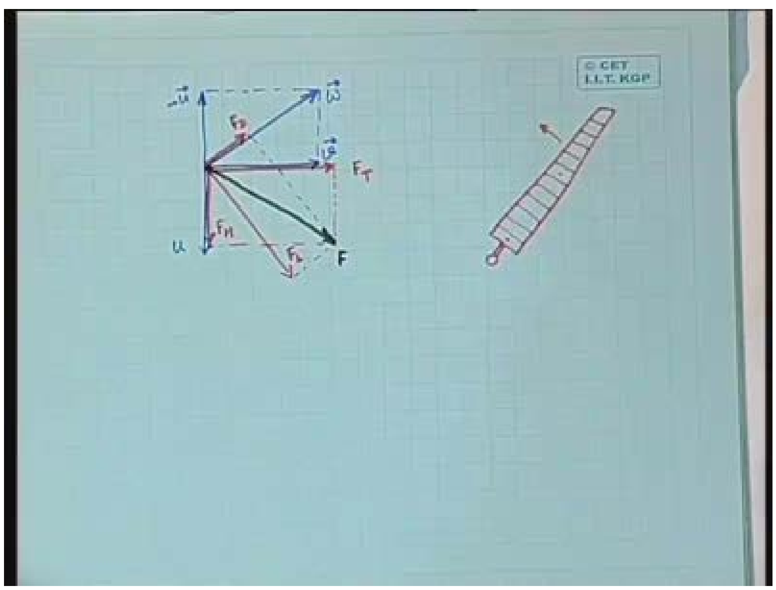

I am drawing one, one blade and it is rotating like this. What will be the u here? u means the velocity of the blade, linear velocity of the blade. If it rotates at a certain angular velocity, it is not difficult to see that the linear velocity here will be different from the linear velocity here. So, the linear velocity along the blade will change and therefore, these vectors will be different, both in magnitude as well as direction as you go along the blade, right. So, in order to do this calculation, what we do is we make the blade divided into small sections, then take one of them and for that you can draw this kind of a force diagram. As you go to another, the magnitudes will change. The v magnitude will remain the same, but the u magnitude will change. Naturally, the direction of the w will change, direction of all these forces will change. So, we need to do this calculation for each section.

While doing the calculation by hand, we often divide the blade into a small number of sections say, 3 or 4 and we can do the calculation by hand. But often, the actual calculations are designed, done by computers, where you define these into many small sections and for each section the calculation is carried out and then you can add up. For example, if this one produces a certain amount of thrust, this force, this one produce another certain amount, the whole thrust experienced by the blade will be simply the summation of them. Similarly, the moment; the moment produced by this one, moment produced by this one, moments produced by this one, all these will have to be added together to obtain the final moment.

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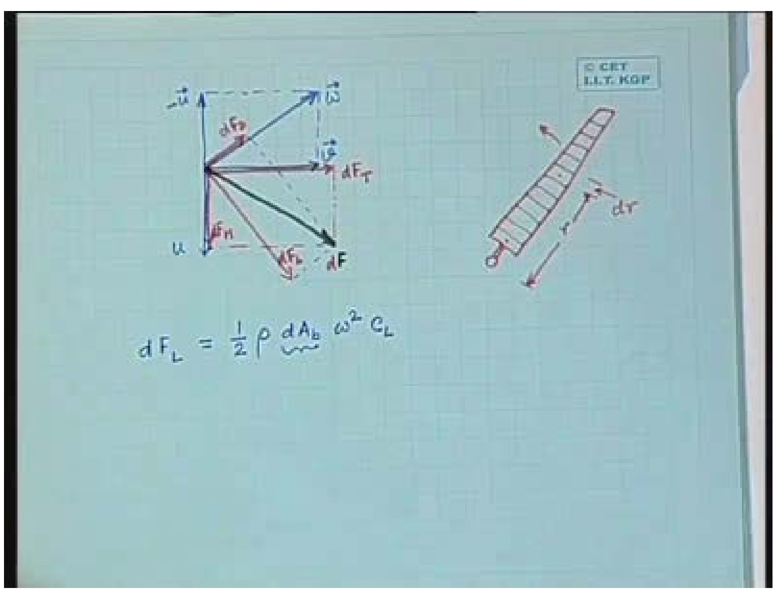

So, we say that here is a particular element that is at a distance say r and having the width of dr and for that we can do the calculations. Now, what calculations? Now, the calculations essentially start from the expression for the F L and F T. What is F L here and F D here? Normally, since these are all elements, therefore these are denoted as dF D, dF M, dF T, dF L, dF and all that. Why? To signify that these are related to the blade elements, not the whole blade. Now, what will be the lift force produced? The lift force produced, dF L, its expression is half rho dA b, dA b is the area of the blade, then w square times a very important factor that is called the lift coefficient, C L. This lift coefficient depends on the shape of the blade, the roughness of the blade and things like that.

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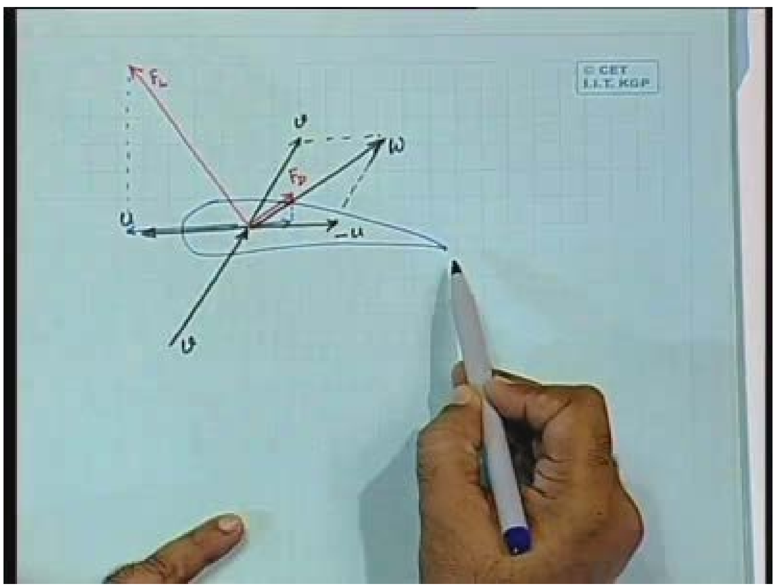

So, essentially that depends on, when I drew this particular shape, you might ask what is the, what is the geometry of this, what is equation for that? Now, in practice, various geometries exist. People have experimented on various geometries. You see the aeroplane wings, you can see the curve, all right, but in each aeroplane, each design this curve is different which means that these equations are different. What actually happens is that people have experimented with various designs. The experiment is normally carried out in wind tunnels. They have constructed large wind tunnels in which this particular shape of the airfoil is put, wind is blown and they make accurate measurements on the amount of drag produced and amount of lift produced and from there, this lift coefficient and drag coefficient can be calculated.

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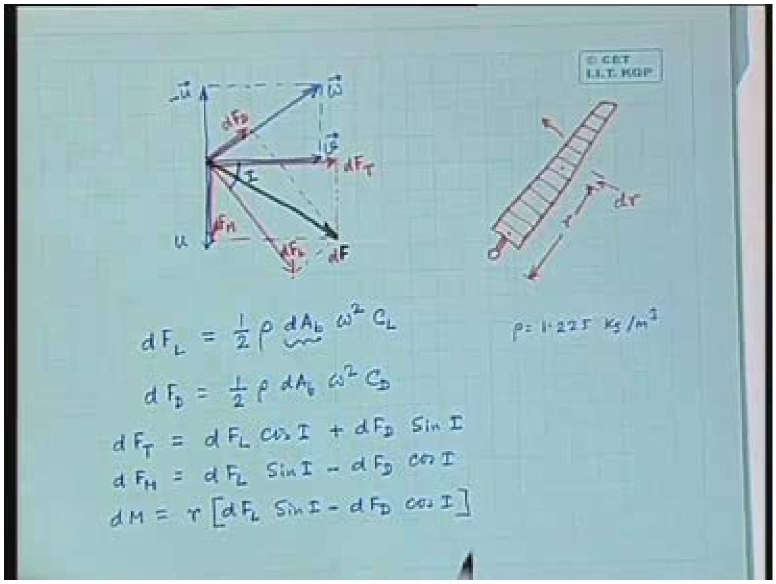

So, this is the expression for the lift produced, F L, dF L and the expression for the dF D is exactly similar, another coefficient here, another coefficient that is a drag coefficient. Now, if these two are known, so what is known? This is known and this is known and if, we need an angle in order to refer to that, this angle is said to be I, you see, this angle, then we can resolve this into the proper directions in terms of the I. So, we can write, we are interested in actually the thrust force, because the tower has to withstand that amount of force. We are interested in the moment producing force, because the power produced is dependent on that. So, we can resolve this and that in this direction and in this direction to obtain this. You can easily see that, then the dF T, the thrust force will be dF L cos I plus …, so that is the thrust, fine.

Now, dF M will be this force, yes, dF L sin I minus, yeah, dF L sin I minus dF D cos I, right. Now, dF M is the moment producing force. How much will be the moment? Moment will be the moment producing force times r. So, dM is r times that, so r into this.

We can simply calculate from here, we can simply do the calculations from here, clear, because the dF L and dF D, if we know all these terms, rho is the density of air, it varies all right, because the air pressure varies. But often we take it as rho is 1 point say 225 or something like that. Area we can, we can measure, w square is obtained from these two, u is obtained depending on the distance and C L, C D, these things are obtained from the air foil characteristics that are available. That means for every airfoil people have measured that.

Now, these are often available, these days available on the net. Earlier they were not available on the net, but these days if you find, if you search for the airfoil characteristics, there are a few places, few universities, for example the University of Stuttgart has a large wind turbine, wind tunnel and their data are available on the net. University of Wisconsin, they have a large wind tunnel, their data are available on the net. So, these things you can easily calculate. Now, in what form are they available? I will, I will show you the representative graphs of this. For example, for certain air foil, the air foils are sometimes named after NACA, National Aeronautical Council of America, there, they have a series of airfoils, they have numbers. There is a few airfoils that are designed in Germany by Votman, so they have separate numbers.

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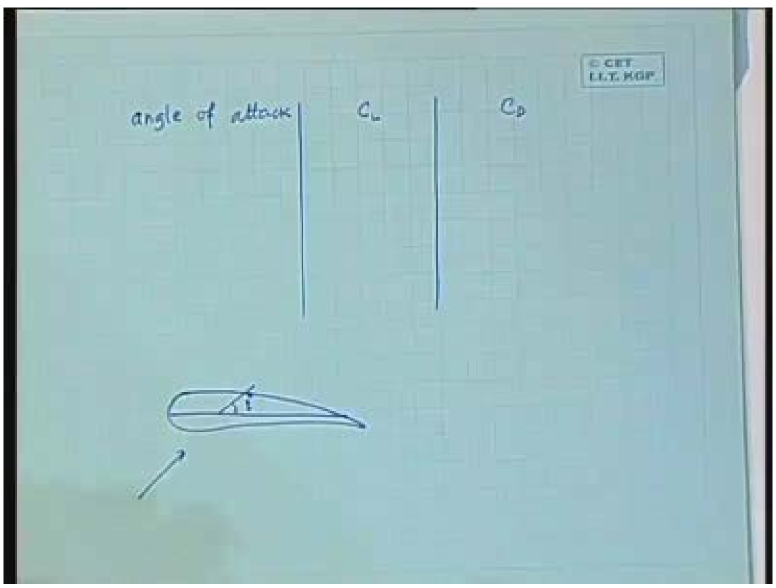

So, each airfoil has a number and the graphs are often available, data are often, often available in the form of a, the angle of attack versus C L C D. Now, what is this angle of attack? You can keep the airfoil, if the air is blowing you can keep the airfoil like this, you can also keep the airfoil like that, so that is the angle of attack, the angle at which the …, for example, here (Refer Slide Time: 17:16) this is the let me, let me draw it then it will be clearer. If you have this, then you can draw a line of chord and if the relative wind is coming from this angle, then this is the angle of attack and this angle is denoted by small i. So, for every angle of attack you have the C L and C D listed. They have calculated found and they have made it available on the net. So, you have the graph something like this.

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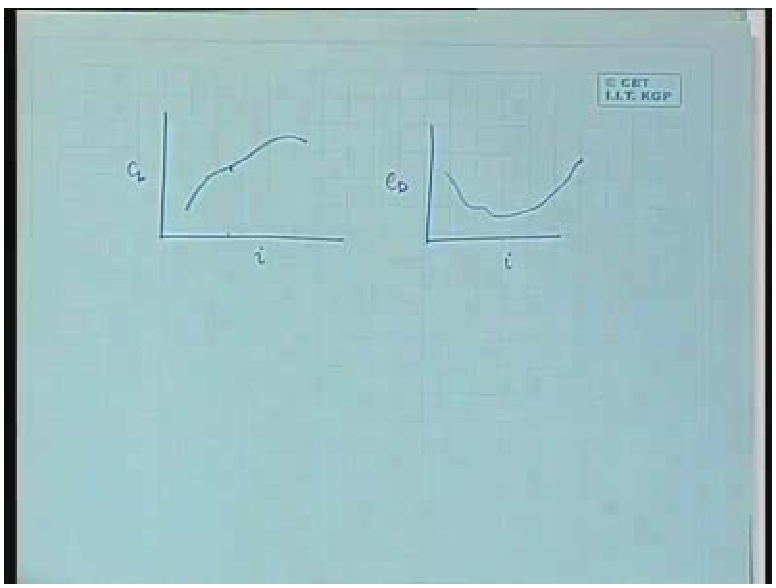

If you draw the graph they will look something like this that small i verses C L will have some kind of a characteristic, small i verses C D will have some kind of a characteristic. These are very specific to that particular airfoil, there is no general characteristic. So, from here depending on the angle of attack for that particular blade element, you have to read the value of C D, you have to read the value of C L and that you have to substitute here.

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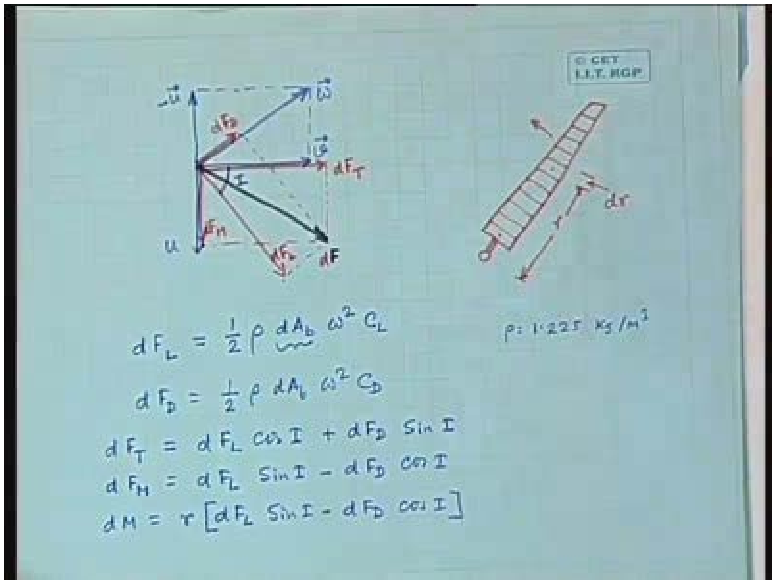

It is clear that for each blade element the angle of attack will be different. In what sense? The capital I that you have drawn here, this is the angle between the lift force and the wind velocity, this is not the angle of attack though. Why? Because, this blade, the blade is not aligned; its chord, its chord is not exactly aligned with the direction of motion. It has an angle called a pitch angle and therefore, you have to subtract that from the I, in order to find the angle of attack. From there you have to read the values of C L and C D and then everything follows. So, from there you calculate the moment. The moment times the rotation is the power, the moment times omega, rotational speed is the power. So, you can calculate the power also. Under any given condition, you can calculate the power also. So, this gives a very simple way of calculating the power as well as the thrust that will be produced by the wind turbine, clear.

So, you see that because along the blade, the u, the linear velocity changes there would be a few implications. One, the implication will be that at this point and at this point the moments will be different, clear. Why because, at this point u is large. As u is large, w is large and therefore, the lift, lift force is large and therefore, this component will overwhelm this component further. As a result, this part will try to fly off faster than this part, clear. Therefore, there will be a sort of a shear force produced that tries to break the blade and this is one of the major reasons of blade failures. Blades do fail because of this reason. There will be another force that is here is a blade and there is a thrust force produced. There will be larger thrust force to the tip and there will be smaller thrust force to the inside of the blade. As a result, there will be a bending kind of force produced and that bending force will also, might be a cause of the failure.

Generally, people try to avert this problem by two means. One, by using a taper, so that the area inside is bigger than the area outside; to the tip it sort of tapers. As a result, this point, this number, this particular dA b becomes smaller at the tip and so, we can adjust to keep it within the, keep the breaking force, bending force within the limit that can be withstood by that material. The other thing is that v generally produces a twist. Twist means this pitch angle at which it is inclined that need not be the same. In fact, that should not be the same. Why? Because, you see, inside the u will be small, outside the u will be large and therefore, this w will be more inclined to this side, toward the inside, more towards that, towards the outside.

Now, normally you would like to have as little drag produced as possible. So, just, just look at this.

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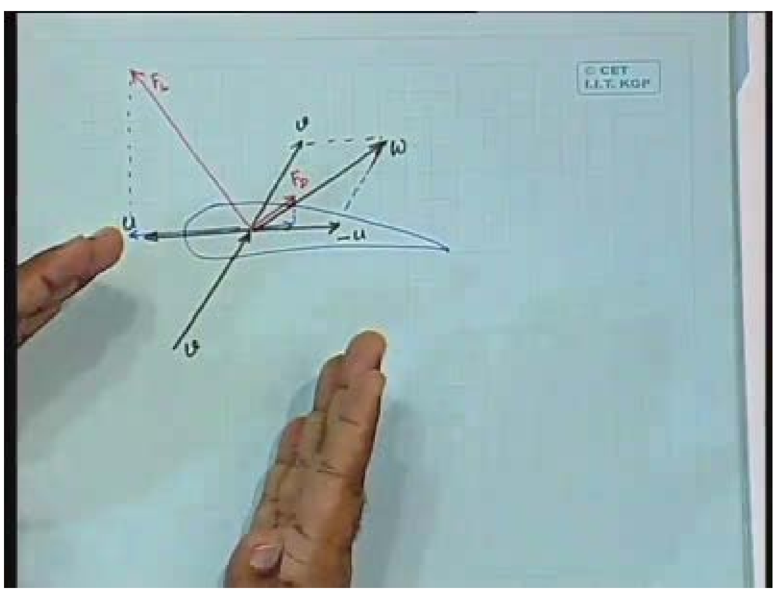

How much is the drag produced that is the amount of area that is seen by the wind because, notice that it is, it is like this. This is the area, this is the w. So, this is the area that is seen by the relative wind and that is the area which it tries to push back and therefore, the F D that is why is proportional to this, the area that it sees, w sees. So, in order to reduce that drag what you have to do? You have to orient it along the direction of the relative wind. That is the most natural thing to do. Now, the relative wind changes from the inside to the tip of the blade, the direction changes and so, you will need to change the angle from the inside to the tip of the blade. It means that it will have a twist.

So, most of the modern wind turbines have a twist. That means the pitch angle is not the same, inside the blade and the outside. So, by these two means we try to have sort of a balance between the power produced this side and that side. So, this is how we often adjust it, clear.

So, now there are a few very important numbers associated with any wind turbine.

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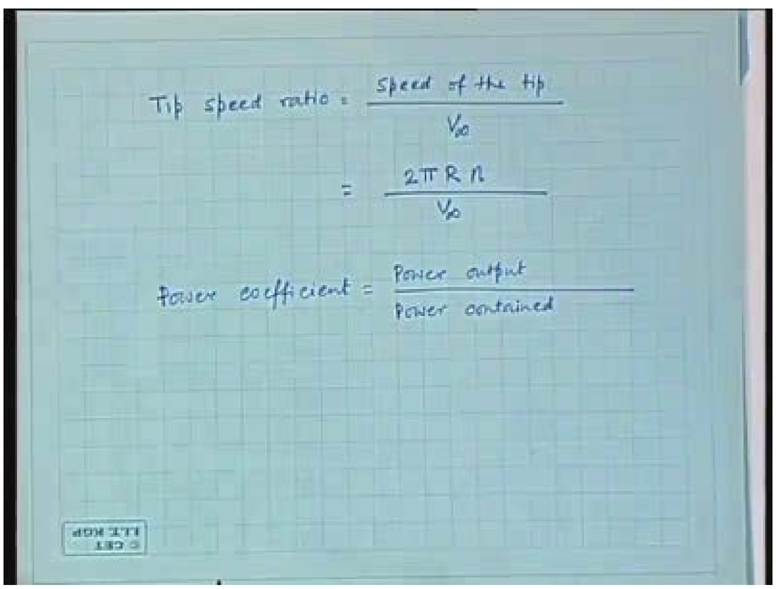

One of the important numbers is the tip speed ratio. Tip speed ratio is the speed of the tip divided by the unaffected wind velocity. So, what will it be? That will be 2 pi R, the radius into the n, the speed in rpm divided by V infinity. Now, notice that as the wind speed changes if the speed of rotation remains constant, then the tip speed ratio changes. There is another important identifier. One thing is that there are very slow turbines. The turbines that are mainly used for say water pumping, they are slowly rotating, those will have a low tip speed ratio and the ones that are used for electricity production, they are fast rotating turbines, they will have a high tip speed ratio. You might ask how much? Well, the tip speed ratio of a slow water pumping wind turbine is often of the order of 1.5 to 2, while that of an electricity production wind turbine will be of the order of 6 to 9. So it, that rotates very fast, the blades rotate very fast in comparison to the wind speed.

There is another important factor, important number that is associated with wind turbine. That is the power coefficient that is essentially the efficiency, the aerodynamic efficiency. So, that is power output of the wind turbine divided by a power contained. The only distinction is that this power output is not the actual electrical power output of the whole wind turbine generator system. This is the power output of the aerodynamic power that means the power that has been converted from wind into the mechanical domain. So, this is the power coefficient. Now, it so happens that for every wind turbine there is a distinct relationship between the power coefficient and the tip speed ratio and the graph would be something like this.

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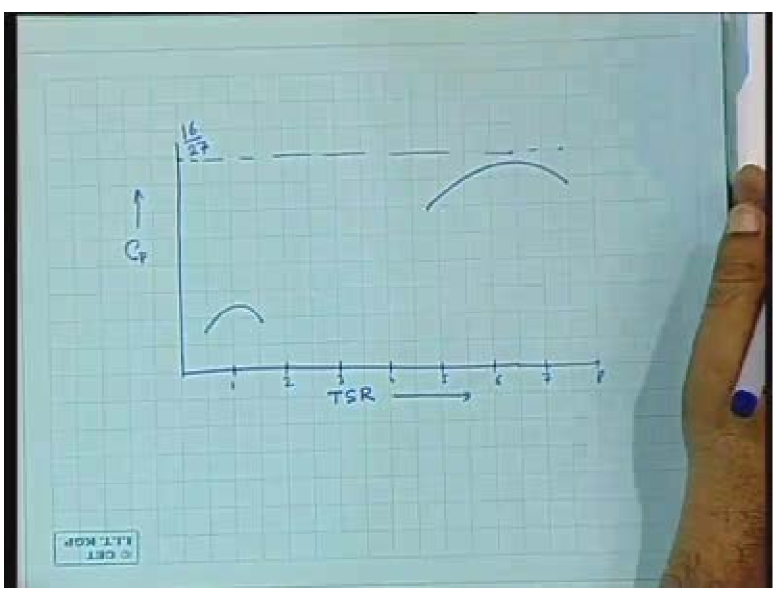

So, this is the tip speed ratio TSR in the x-axis and the power coefficient C P in the y-axis. What is the maximum C P? No, we have derived in the last class that the maximum C P possible is 16 by 27; that we have derived in the last class. So, that is the maximum C P possible. So, that is what we tried to achieve. Now, we can say 1, 2 3, 4, 5, 6, 7, 8. Now, the modern horizontal axis electricity production wind turbines will have the curve something like this. That means the peak goes very close to the Betz limit. The Savonius rotors that we have talked about will have somewhere here. The one Savonius rotors which is a vertical axis wind turbine with two cylinders cut and put together, so that will have it here.

So, every wind turbine will have this kind of a characteristic and this kind of a characteristic means that the maximum power coefficient occurs at a specific TSR, at a specific tip speed ratio, which means that as the wind speed changes you would like to keep the TSR constant and since the tip speed ratio is the speed of the tip divided by the wind speed, wind speed is varying, therefore the speed of the tip has to vary proportionally which means that the speed of rotation, rotational speed has to be, has to vary in proportional to the wind velocity.

Now, that does not happen automatically. We need to do something in order to make that happen and the lever in our hand is often, in case of large wind turbines, the pitch angle. So, we vary the pitch angle as the wind speed changes. Why would we need to vary the pitch angle?

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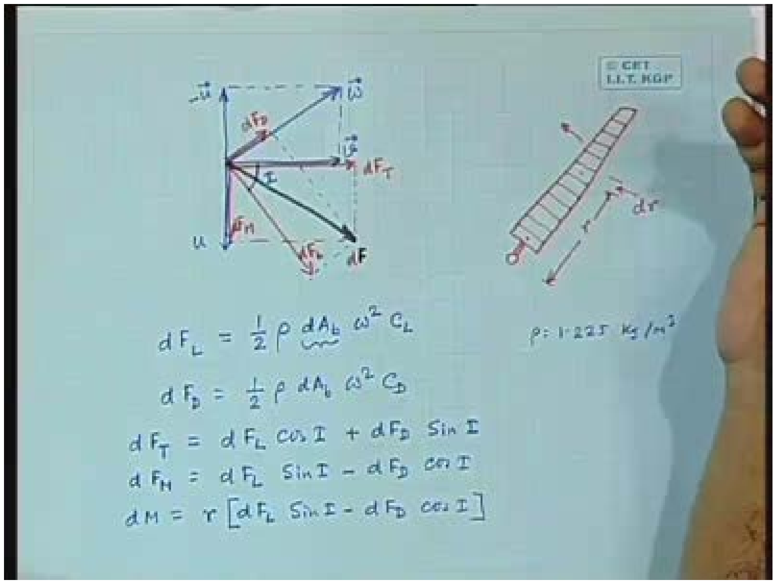

Because, all the time we would like to be aligned with the relative wind and as the v changes, as the v changes, then the w's direction also changes, so we would like to rotate the blade, so that it is always aligned and that is how it produces the maximum amount of energy. This is called the pitch control. That is why most modern wind turbines, the ones that are used for electrical power generation, now there are electrical power generation wind turbines of the size 1 megawatt, huge wind turbines and they have this pitch control mechanism.

There is another type of wind turbine which is called, rather peculiar looking wind turbine, they are called the Darrieus rotor.

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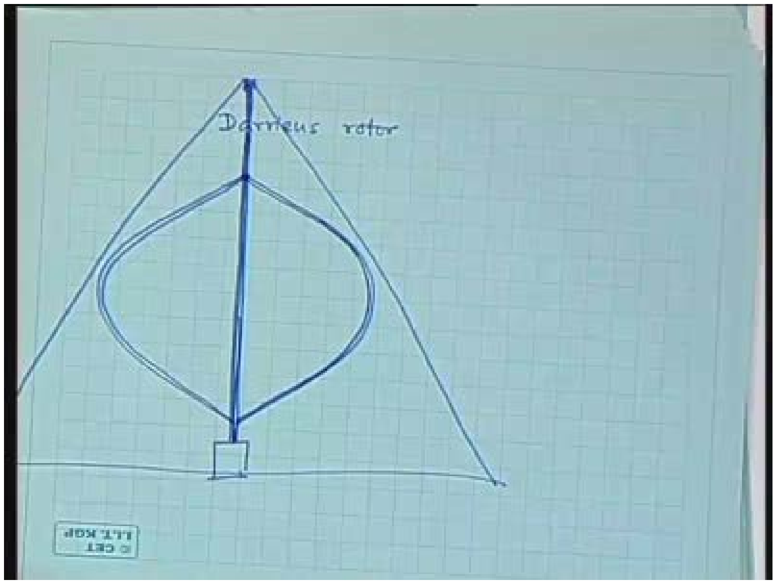

The Darrieus rotors are peculiar in the sense that just by looking at it you will never understand how it rotates. They look something like this. So, this is the shaft. It is a vertical axis wind turbine and here you have the generator system and the shaft actually goes up some length and then, you have the …. connected that is tied down, to the down. So, this is the shape and these are, these blades are thin and air foil shaped. Now, you might say that when wind comes and hits it, it will of course try to push this one as well as this one and therefore, there will be no force produced, no torque produced. Yes, that is true, but the point is that your argument is coming from the, from the point of view of thrust.

How much it pushes? No modern wind turbine works on the push principle. So, this works on, again the lift principal of a, of an airfoil. How it actually works? In order to understand, let us draw in this way.

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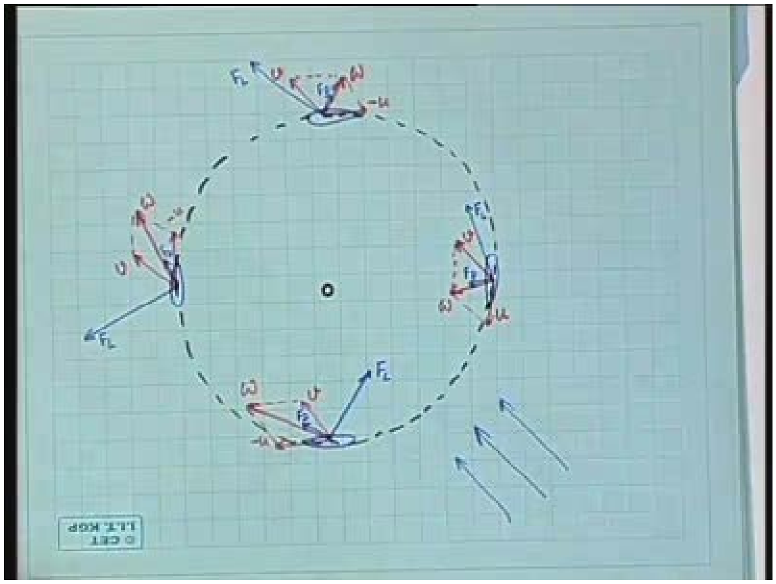

Suppose this is the shaft at the center and suppose this is the, not a bad circle, so this is how it rotates. So, at every point we will draw the airfoil structure and imagine that the wind is coming from this direction, fine. So, now when it is here, then your v is like this, u is like that and therefore, minus u is like this. So, this is your v, this is your u, minus u and therefore, you will construct the parallelogram like this and we will say that this is my w. If this is the w, then this is the drag force produced and this is the lift force produced, right. This is the w.

You would notice that the lift force has a component in the direction of motion. So, if it rotates, then this lift force aids the rotation and therefore it produces a positive torque. When it comes here, then your v is in this direction, u is in this direction, therefore minus u is in that direction and therefore, you will complete the parallelogram and say that here is my w. So, your drag force will be like this and the lift force will be like that. I am always drawing the lift force larger than the drag force, because that is the characteristic of the most airfoils. Now, here also there is a component of the lift force that aids the motion.

Come here, this is the direction of the v and this is the direction of minus u and therefore, this is the direction of w. In this position also this is the direction of F D and this is the direction of F L. Still F L has a, has a component in the positive torque direction. Come here; here you have the direction of the velocity, wind velocity here, v and here is minus u and therefore, this is the direction of w. Again, you have the F D like this and F L like that. Do you notice that everywhere, well almost everywhere there is a component of the lift force in the direction of the motion and as a result there will be a positive torque produced and it will keep rotating.

So, do you now notice how it looks?

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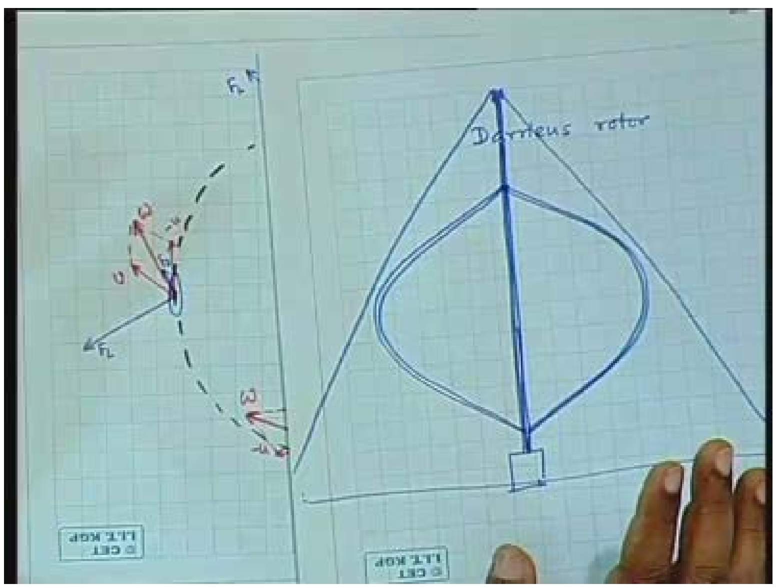

This is the airfoil that is actually here. All this is the airfoil structure. So, as you look at the cross section it would be this airfoil, fine. Can you see the structure and as it rotates, well one thing is clear that if there is no u, sorry, yes, if there is no u, then you might again draw these parallelograms and you will find that no net torque is produced, which means that this particular wind turbine, the Darrieus rotor has no starting torque. It has to be started somehow by some means and then the moment it has a starting torque, it starts rotating on its own, because there is a positive torque.

Student: Sir, I could not understand the structure of the …

You could not understand the structure of the Darrieus rotor, right. So, the Darrieus rotor structure is the axis is vertical. At the, at the ground level there is the generator and gear box. At the top there is a, there is a hinge and which is connected to a …. that means these …. keep the shaft vertical and does not allow it to move. Now, on the shaft you have these structures, the airfoils are bent like this and like this. Now, you might ask why is it this shape, why could not it be anything else? The reason is that, okay what is the shape? This is the geometry. Is it parabola?

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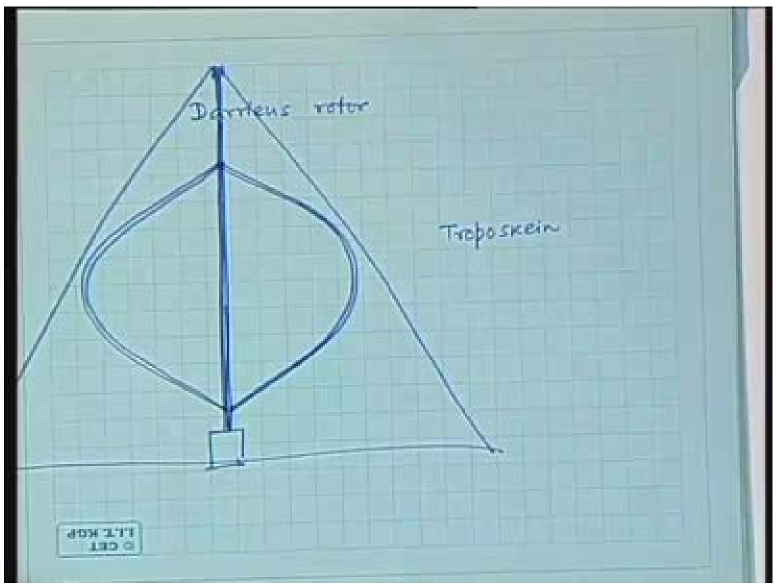

No, not exactly parabola, its geometry is called Troposkein, it is exactly that shape. You see, if you hold a flexible wire and rotate it like this, it takes a shape, right and that shape is called Troposkein. That means it is exactly the shape that a flexible wire would take if it is rotated like this which means that as it rotates, the only force that can be, only stress that can be produced in these blades could be just a tensile stress. Do you understand? There can be, cannot be any bending stress, because if it were flexible and if it were rotated, then you have to take the same shape and if you make it in that shape, then the only force that can be produced is the tensile stress that stretches, that is all.

So, if you have, if you build into it strength along the direction of the length of the blade, then obviously it becomes more stable. It is very difficult to, for such a blade to break, which is not true for horizontal axis wind turbines. There can be this kind of forces which can make it break, but here nothing will happen. So, the structure is that you have the vertical axis and you have the blades that are shaped like this and this cross section is the airfoil cross section, clear, this cross section is the airfoil cross section. So, as it rotates, so the airfoil goes around like this and that is what I have drawn here, the airfoil goes around.

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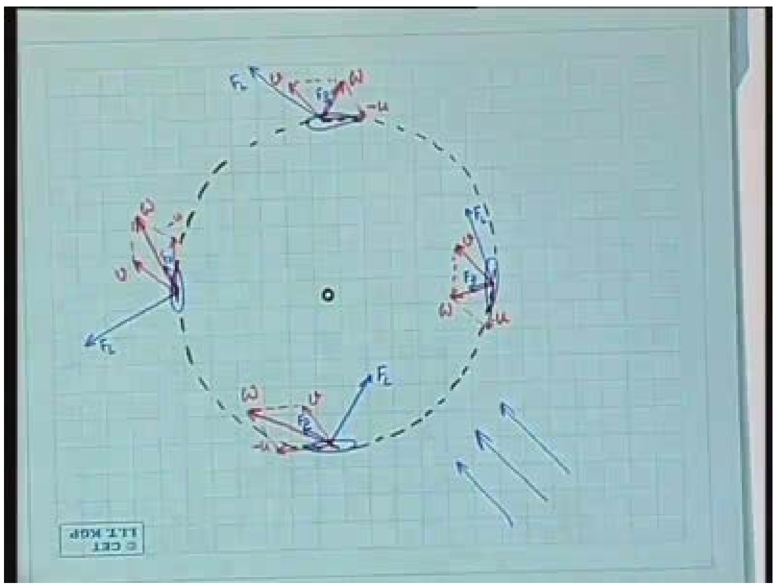

So, once it is here, after sometimes goes there, after sometimes it goes there and it rotates. As it rotates, you would notice from this diagram that everywhere it experiences a positive torque. This, this particular shape, this particular design was invented by Darrieus that is why is called the Darrieus rotor.

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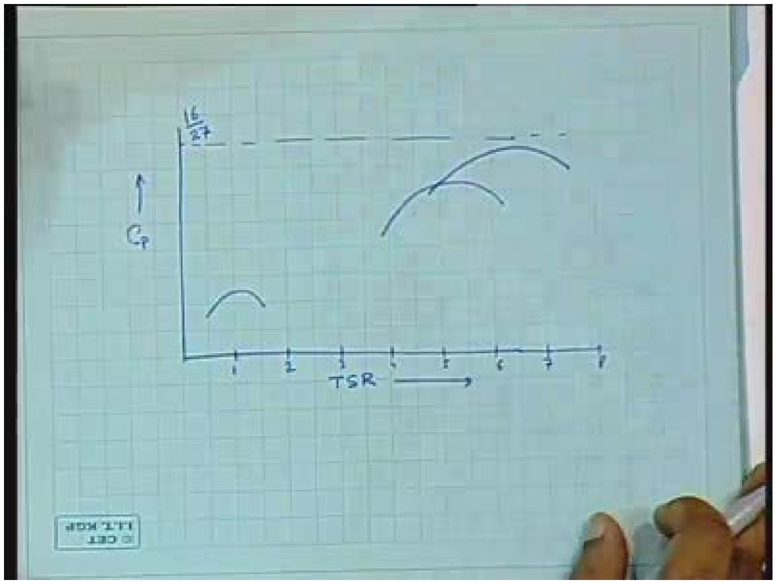

Now, this Darrieus rotors, if you draw it on this diagram, their position would be somewhere here slightly lower than the efficiency of the horizontal axis wind turbines, slightly into the lesser TSR side. But, as far as efficiency is concerned, since it also works on the principle of the lift force, therefore it does not really is very much off. Its maximum efficiency is also very large. So, the question is how do they compare?

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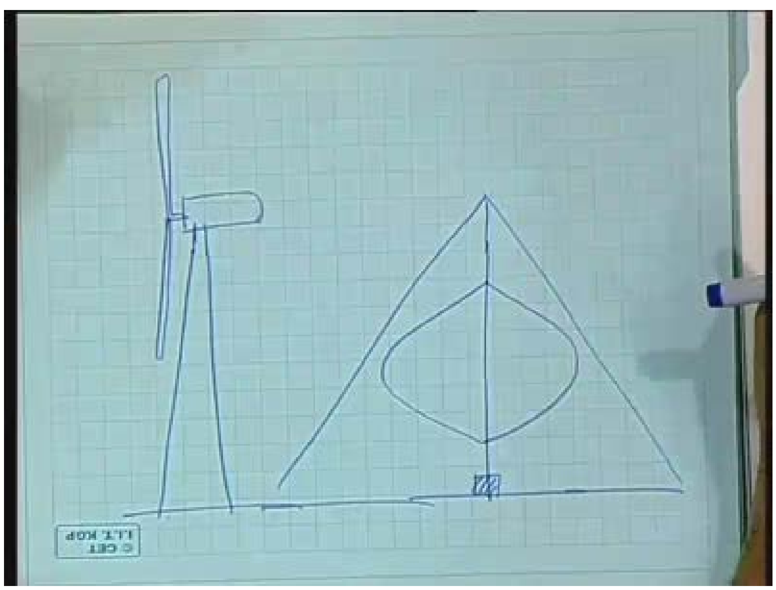

The one is the horizontal axis wind turbine which have a structure like this and the vertical axis wind turbine which has structure like this. How do they compare? Now, you will notice that by virtue of being the, blade being up at a height, by virtue of being at a height the horizontal axis wind turbine is able to access higher wind velocities, but this vertical axis wind turbine has to be close to the ground and therefore, the wind speed it can experience is not as high. But at the same time, there is a very large expenditure in constructing this tower and since the whole gear box generator assembly has to be here, the whole turbine and its weight has to be here, therefore the tower has to be strong and naturally that incurs a lot of expenditure.

Here there is no tower; the generator is on the ground, easily accessible, so naturally the cost of production of this kind of turbine is far lower. So, this can access higher wind speeds and as a result, as I told you, the amount of power contained in the wind is cubically proportional to the wind speed, so it has higher amount of energy available to it. This has a lower amount of energy available to it, but its production cost, the cost of installation, these things are far smaller.

Now, the places where you can expect a reasonably high amount of wind velocity close to the ground, where are they? Very close to the sea, because the sea surface is more or less flat and therefore, there is no obstacle, up and down, high and low obstacle and therefore, there the wind speed close to the ground is also very high and there the Darrieus, Darrieus axis wind turbines, Darrieus, Darrieus rotors are economically competent. But, the ones that are produced, that are installed in land there the wind has to cross a lot of obstacles to reach the position of the wind turbines. There it is definitely more meaningful to have the wind turbines at an elevation, so there the horizontal axis wind turbines are more meaningful. So, in terms of axis, this is the horizontal axis wind turbine and this is the vertical axis wind turbine.

Notice that the horizontal axis wind turbine has to be oriented in the direction of the wind, while the vertical axis wind turbine it does not matter. So, another complication and another control system can be avoided in case of the vertical axis wind turbine.

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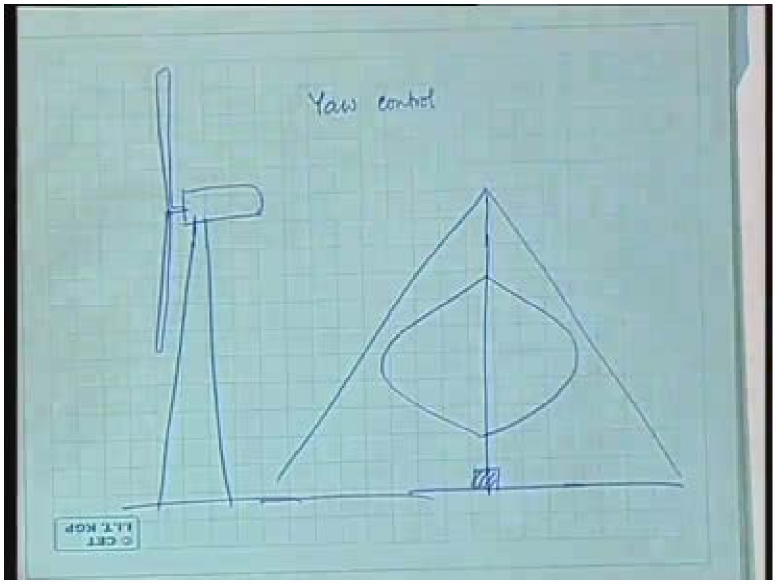

This control, the controlling to face the wind is called Yaw, Yaw control. I will come to the details a little later. So, Yaw control is necessary for horizontal axis wind turbines and Yaw control is not necessary for vertical axis wind turbines. So, there are essentially two types of wind turbines, nowadays used for bulk electricity production - the horizontal axis wind turbine and the vertical axis wind turbine, though right now in India all the wind turbines that have been installed, India has now a very large wind turbine install capacity, mainly in the states of Gujarat and Tamilnadu, these two places have really gone ahead with installing wind farms. That means large tracks of land that are otherwise barren, now covered with wind turbines and that produces in totality very large amount of power. So, that can be compared with the power production capacity of a standard thermal power plant. So, India has this kind of and all these are at present horizontal axis wind turbines, though you can easily see that under certain conditions, certain circumstances, the vertical axis wind turbines will be also very meaningful. It is just that the companies which have started operating here they specialize in the horizontal axis wind turbines.

So, you have learnt about three different types of wind turbines. The ones that are used mainly for water pumping, they are the vertical axis Savonius rotor types. There are also another type of horizontal axis wind turbines that are used for water pumping. Their structure would be something like this.

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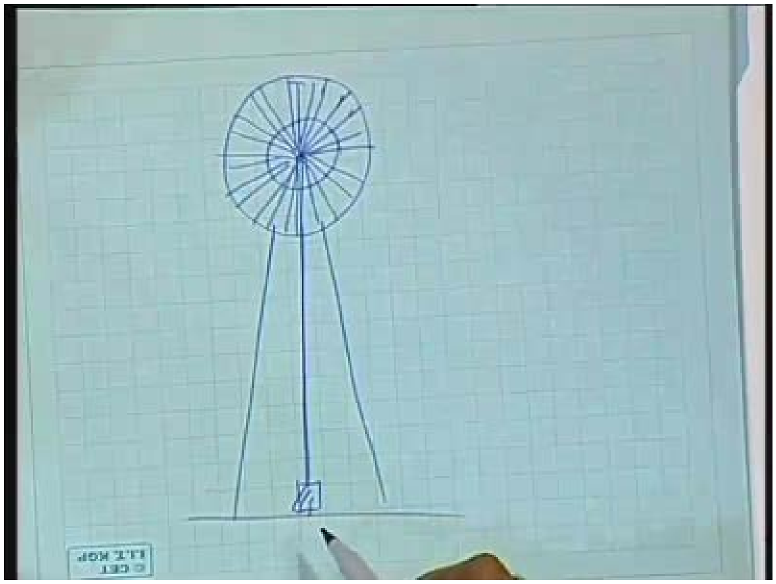

There would be a tower, obviously any horizontal axis wind turbine will have to have a tower and here there would be a large number of blades, a large number of blades and there will be another ring to give it the strength and the whole thing will be, why do you need a large number of blades? Because, you need to produce a large torque in water pumping wind turbines and naturally from here there would be a shaft coming down and down here would be the pump. This water pumping wind turbines were very popular in USA, early part of this century, of the last century. But nowadays, with the availability of electricity even in very remote locations, these have gone out of favour.

But in India, this makes sense because, there are large areas in which there is a, there is a large availability of high wind speeds, places where you need irrigation and the places where you can install these. These are horizontal axis wind turbines, relatively more expensive than the Savonius rotor. Generally, these are industrial products, while the Savonius rotors can be constructed on site. These have some inherent mechanism. For example, how would it orient itself to the direction of the wind that means Yaw control?

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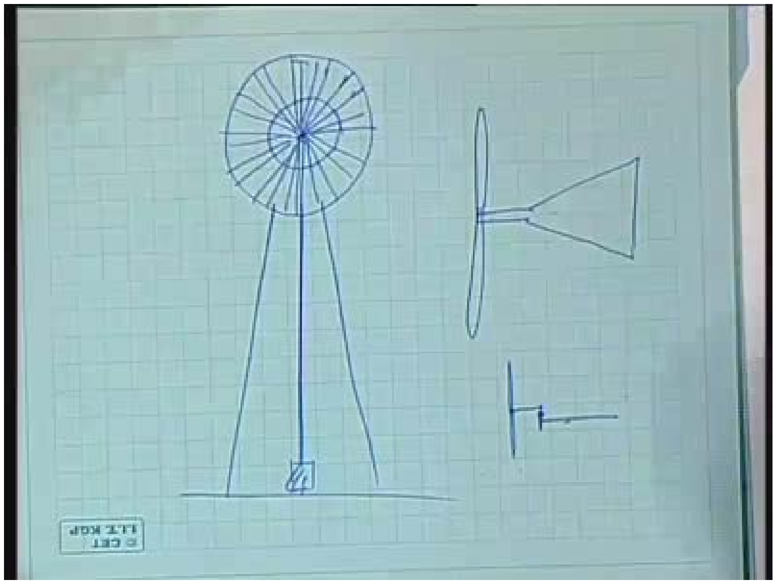

Simply by means of, suppose this is the blade, by means of a tail vane like this, a vane, so that if the wind comes from wrong direction, it pushes and makes it orient itself to the direction of the wind, simple. Not only that, some of them have a built in protection against high winds. When very high winds or cyclonic winds come, then most of the wind turbines have to be shut down. I will come to those things little later, but for the water pumping wind turbines you cannot have the sophisticated mechanism of disorienting it. So, there has to be a very simple mechanism. What is done is something like this.

Suppose this is the blade and here is the axis of the blade, of the turbine and there is the axis of the tail vane, which is slightly made off and in between the shaft is here. Earlier you would, you would think that this is in the same direction, right. If you look from the plane view, then it is not really in the same direction, slightly off. As a result, when the wind speed is less, then the force on this one dominates and it orients it around the direction of the weight. But, when the winds are large, then the thrust on the, on the blade will dominate and it will disorient it away from the direction of the wind. So, this kind of simple mechanisms of, automatic safety mechanisms are sometimes built into the water pumping wind turbines.

So, you have, now, now let us concentrate on electricity production wind turbines. As I told you, there are two types - the Darrieus rotor and the horizontal axis and the most popular at present are the horizontal axis wind turbines. In horizontal axis wind turbines you have, you need a few types of control mechanisms.

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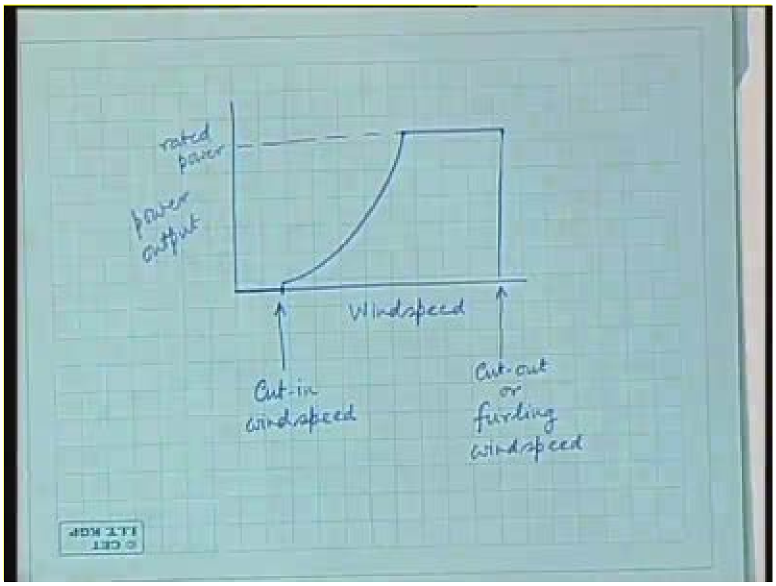

One, suppose the wind is starting to blow at a certain point of time, obviously it cannot start below a certain wind speed, so if you draw the power output versus wind speed characteristics, then it will start only after certain time, not time, only beyond a certain wind speed. This wind speed is called the cut-in wind speed. It is called the cut-in wind speed. Beyond the cut-in wind speed, it will start producing power. Now, if all the things that I just mentioned like properly controlling the direction of the pitch, so that it, the blades always face the relative wind and this kind of mechanisms are followed, then the power output will be proportional to the power contained and the power contained in the wind is cubically proportional to the speed. So, the power output will grow like this as the wind speed increases.

But, after sometimes you reach the power generation capacity, the rated power of the generator. Even if the wind speed increases, you cannot allow the generator power output to increase, because then it will over heat and burn. So, there has to be some mechanism then of keeping the power output constant as the rated power. So, it will be kept constant at the rated power till a certain wind speed, beyond which it is dangerous to operate the wind turbine. So, at that point it will be closed down. This is called cut-out or furling wind speed. So, normally the power output versus wind speed characteristic of a generator would be something like this. I will come to more details about how this is maintained, how this is obtained in the next class. Fine, that is all about it today.

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This is a small model wind turbine. As you can see, it is a very small diameter thing and it is being blown with artificial wind from the front and so you can see it is rotating. Now, we will stop the wind and see the actual structure and construction of the blades.

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What you can see now is the airfoil profile, which is as you can see, as it is zooming back you can see that it is inclined at an angle to the plane of rotation and actually this is the plane of rotation. As you can see, it is the plane of rotation and these airfoils are inclined at an angle, so the chord is inclined at an angle to the plane of rotation which is the pitch angle. So, as you can see, the wind is blowing from this side and it is rotating this way. So, the relative wind is along this direction and this pitch angle has to be so aligned, so that the blade is, blade chord is aligned to the direction of the relative wind.

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So, this is the front view of the wind turbine, model wind turbine and normally this is not rotating now, because wind is not blowing and normally it will rotate in that direction and here you can see the tail vane which is used to orient to the turbine in the direction of the wind. So, as the wind blows, this will feel a force and that will automatically orient it to the direction of the wind. Since it is a very small wind turbine one can use a tail vane for this purpose. For larger wind turbines, you will need an automatic motor control mechanism for this orientation.