Physics of Renewable Energy Systems
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Lecture 13
Wind turbines and their operation

Hello, so, let us continue with our discussion on wind power. And in today's lecture, we will be talking about the real designing of wind turbines and once we have the wind turbine system that is installed, how do they are operating.

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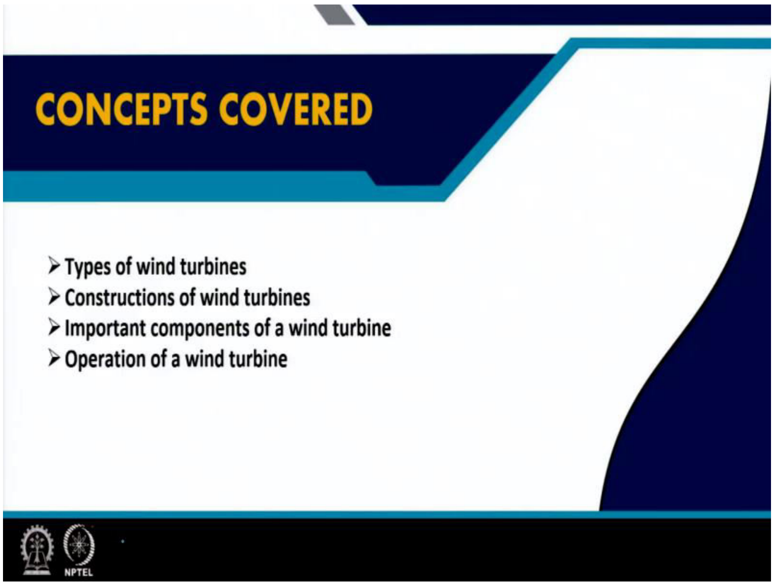

So, in today's lecture, we will consider the various types of wind turbines that you can have, how do we construct these types of wind turbines, what are the components that actually must be considered while you design or install these wind turbines. And finally, after we have understood all these aspects, how do we control the operation of a wind turbine such that we can extract the maximum power.

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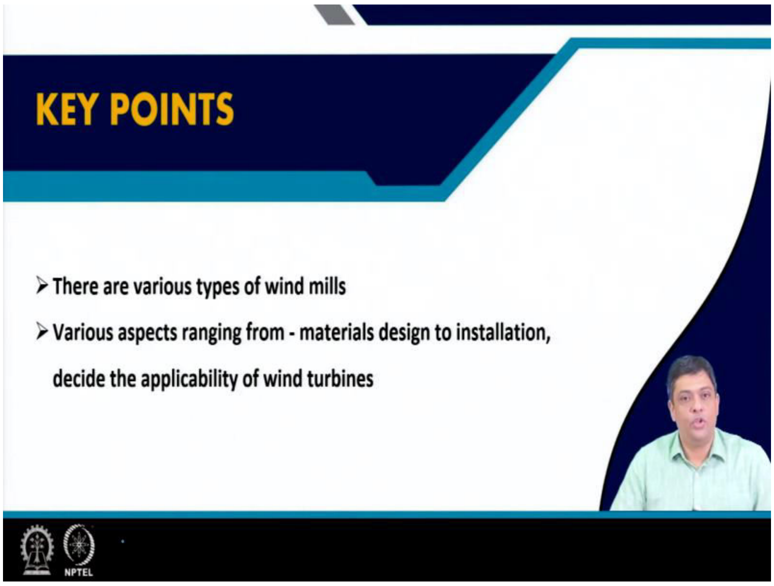

So, obviously, the key points which I want that you should be able to understand and take back with you after listening to today's lecture are that there are various types of wind turbines and along with that, you have factors like material design or the elements, the components which are used in designing or installing the wind turbines that must be considered because those aspects decide the applicability of wind turbines.

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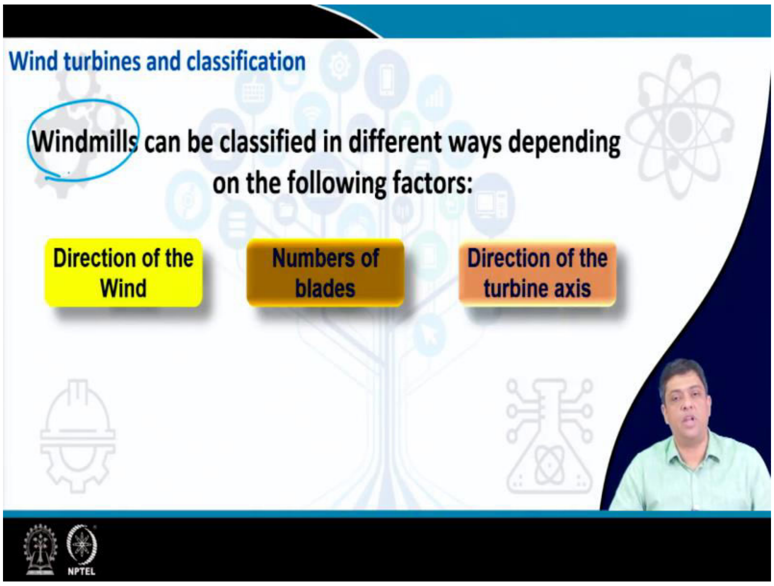

So, the wind turbines can be classified under different sub headings as I indicated in the previous slides. Sometimes people use these terms wind turbines and windmills interchangeably. Please remember, what are we doing windmills for the systems which will convert your wind energy to mechanical work and here you are talking about wind turbines, using wind turbines you will be converting it directly to electrical power.

But, therefore, you have two words which I have mentioned here. And there, you will see that there is some mismatch, but I am using it typically, because, you will, you can many people use it interchangeably. So, if you want to replace windmills by wind turbines that will be more consistent, but just to indicate clearly I am using this that you should remember. So, they can be classified under different headings depending upon the direction of wind or the number of blades which you use or the direction of the turbine axis.

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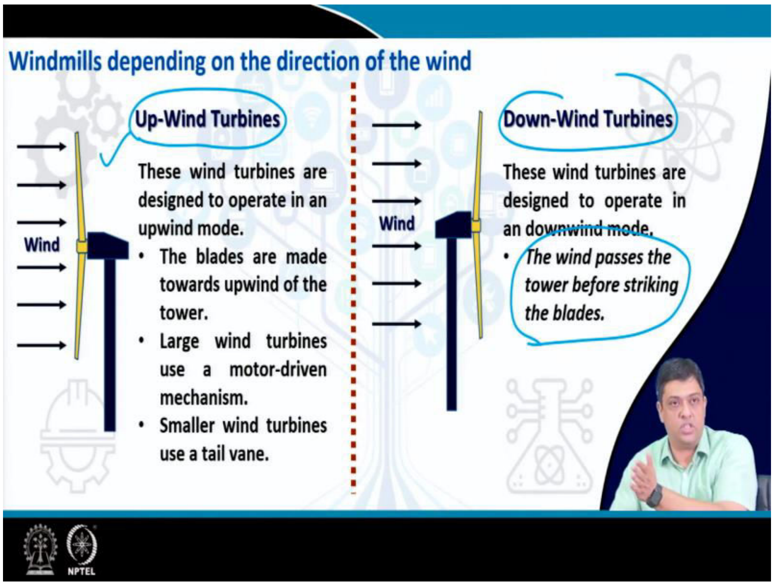

So, depending upon the direction of the wind, you can have up-wind turbines or down-wind turbines you can see that for the up-wind turbines, the blades are receiving it, but the down-wind turbines the blades are actually being hit by the winds coming from the backside. So, the wind in down-wind turbines actually passes the tower before striking the blades, which I just said that the blades are hit from the backside. Whereas, in the other case, that is the up-wind turbines, the waves actually interact with the blades first before crossing the tower.

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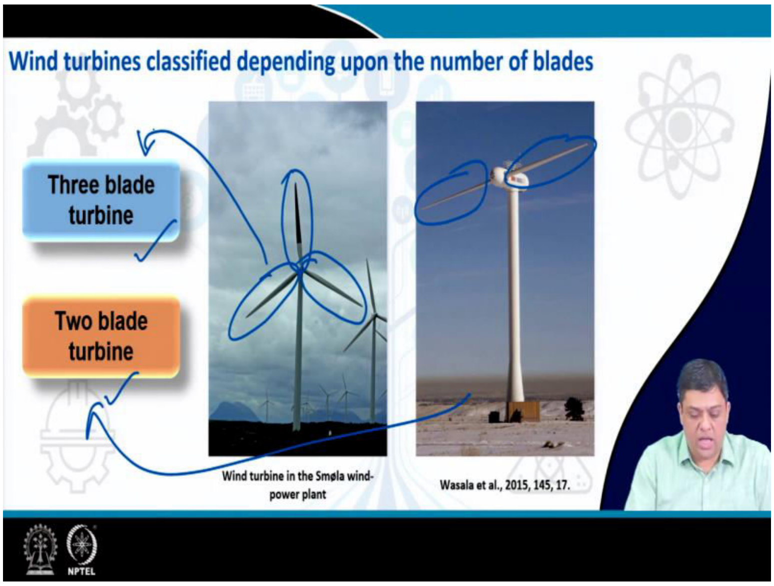

So, the wind turbines can be classified depending upon the number of blades as I mentioned. So, depending upon the number of blades, which are used, you can have three blade turbines or two blade turbines and typically, you can see how do they differ. So, you have one blade and two blade. That becomes your two blade turbine, if you have one, two and three blades, then they become the three blade turbines. And you will see that three blade turbines are more commonly seen in India and the reference from where these pictures are taken are mentioned here.

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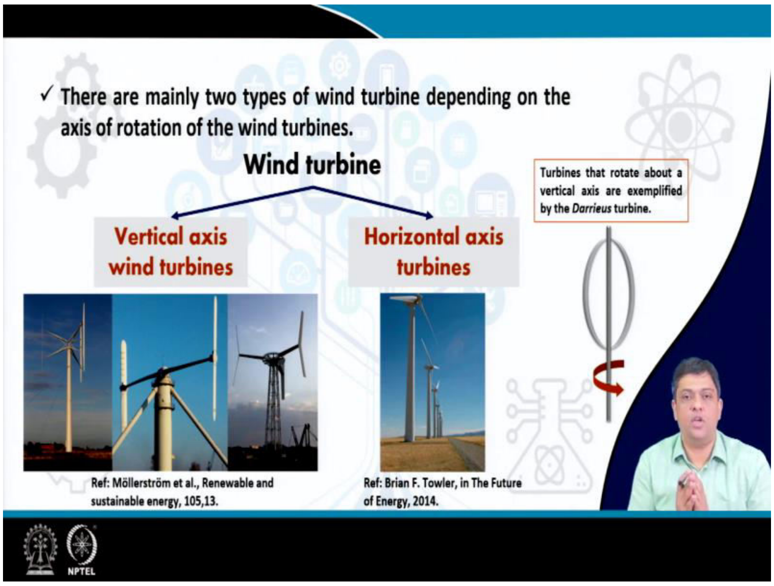

So, depending upon the axis of rotation, we have two types of wind turbines, the vertical axis turbines or the horizontal axis turbines. You can see in vertical axis turbines what is happening that you have the turbine tower and the tower on which the turbine is and rotation is along the vertical axis.

Whereas, in horizontal axis turbines you have the tower and the rotation is around the horizontal axis and that is the difference between a vertical axis turbine or the horizontal axis turbines. And turbines that rotate about vertical axes are of various types and you will see about them as we go along in the lecture.

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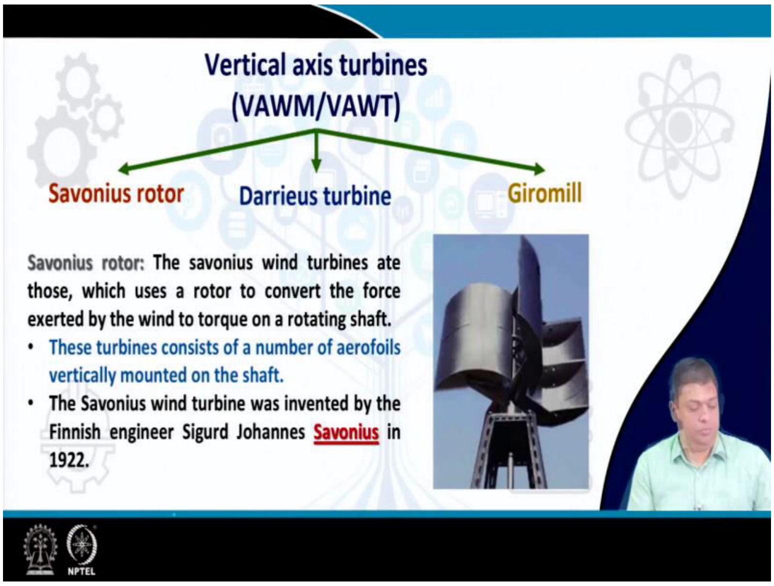

So, the vertical axis turbines are of different types you have Savonius rotor, the Darrieus turbines or Giromills. For example, the Savonius type turbine which was discovered by the Finnish engineer Sigurd Johannes Savonius is the turbine where the rotor is used to convert the force exerted on the by the wind to the torque on the rotating shaft.

So, what do you have, you have these rotors, the wind is hitting and the force drives these rotors and then you extract the power. So, these turbines consist of a number of aerofoils which are vertically mounted on the shaft, so that they can rotate vertically around the axis.

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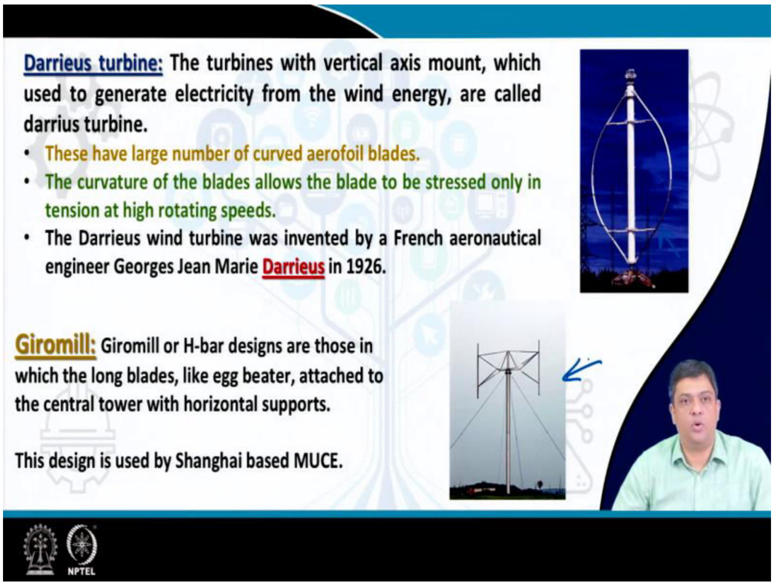

So, the next one is the Darrieus turbine, in these turbines which are also vertical axis turbines, you have a large number of aerofoil blades which rotate around the vertical axis and this was discovered by a French aeronautical engineer George Jean Marie Darrieus. And in comparison, you have Giromills, which are used along the vertical axis and they look like egg beaters. So, if you have seen the blades of an egg beaters, then the shape of the Giromills blades are similar to the ones which are used in egg beaters.

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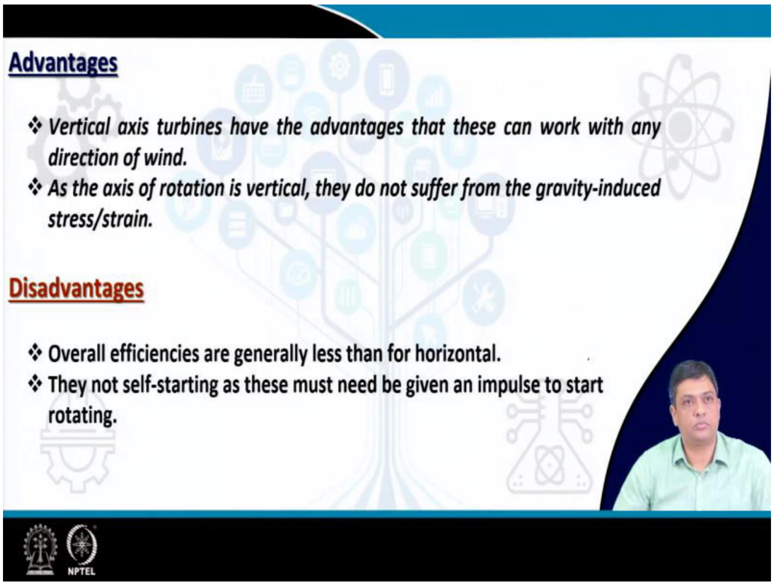

The advantages are that they can work with any direction of wind. As the axis of rotation is vertical, they do not suffer from gravity induced strain or stress. So, if they are rotating, so, they do not suffer from gravity induced stress or strain. The disadvantages associated with these kinds of turbines are that the overall efficiencies are generally less than that which can be obtained using horizontal type turbines. They are not self-starting and they need an impulse to start the rotation.

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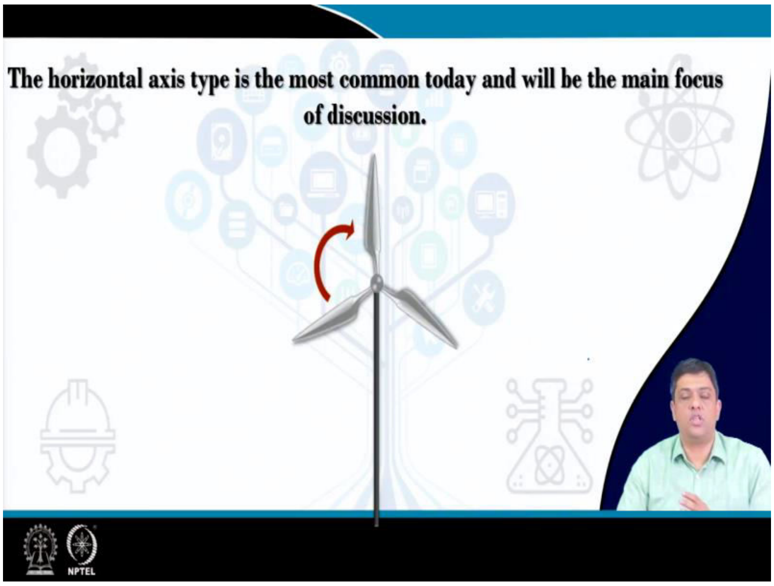

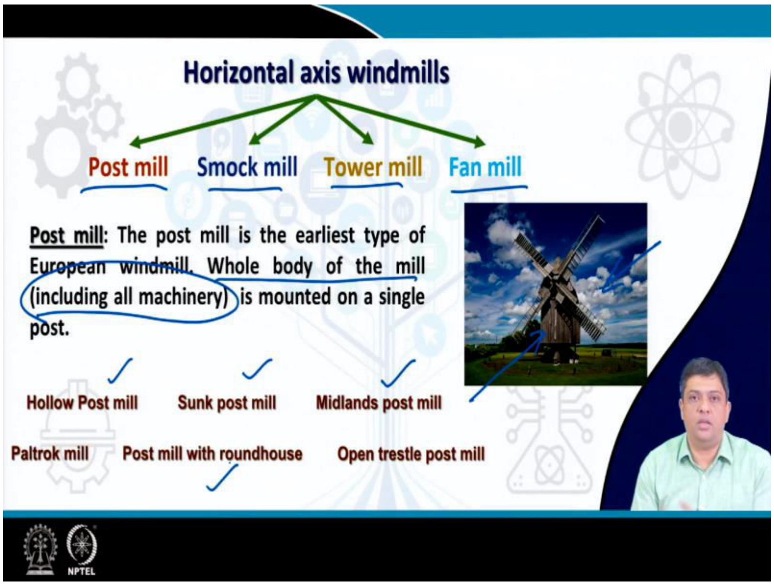

As of today for us that is in our country. The horizontal axis type is most common and therefore, will form the main focus of discussion. These horizontal axis windmills can be seen from many centuries now, and they are now classified as post mills, smock mill, tower mill or fan mill.

And you have seen these kinds of pictures in various places. The earliest type of horizontal axis wind mills which were used are the post mills. And here the whole body of the mill including all the machinery is installed on a single post and these post mills can themselves be of different types, they can be hollow post mills, they can be sunk post mills, the midland type post mills or post mill with roundhouse. So, depending upon the whole body and the shape of the fans or the blades, you can sub classify the post mills.

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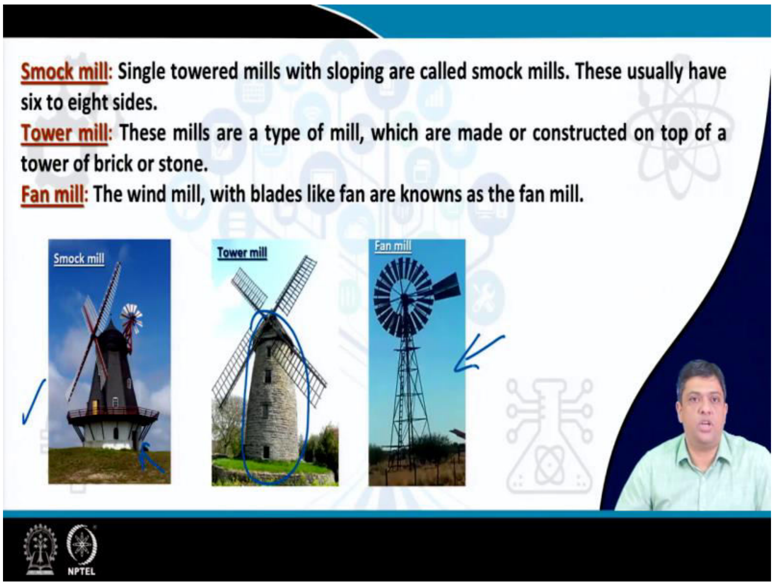

Now, you have similarly, you have smock mills, what are these smock mills, these are single towered mills with sloping which are called as smock mills. These are usually six to eight sided mills and you can have the operation of the blade along with that you can see you have the construction below it where people can stand.

You have tower mills; these mills are the type of mill which are constructed on top of a tower or a brick or stone. So, earlier designs, you and now you see that there are, these towers are actually of various shapes. And you can also have the fan mills which are used in various places and the shape of the blades are like the ones which are used in the fans.

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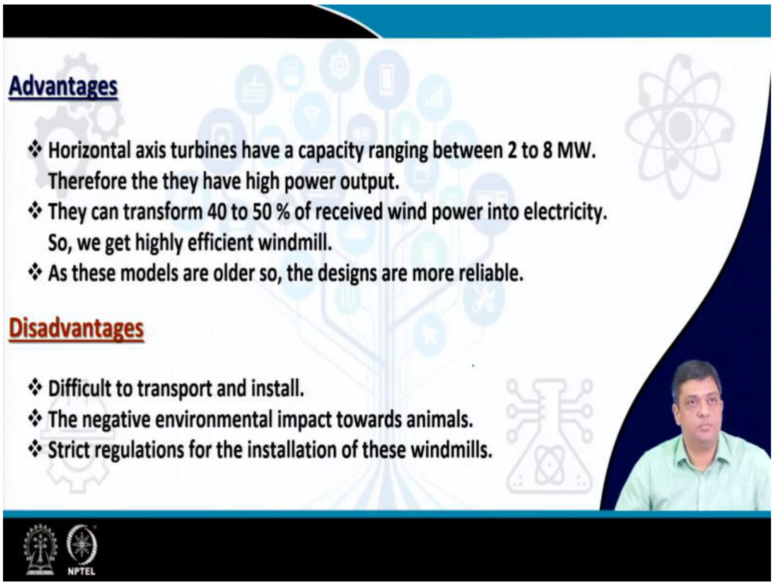

The advantages of these kinds of mills were or horizontal axis based turbines are that they have large capacities ranging to 2 to 8 megawatt. So, they have high power output along with that they can transform 40 to 50 percent of the received wind power into electricity. So, they are highly efficient. And if although they are older, their designs are also reliable and more stable to many of the designs proposed much later. So, there are certain advantages like the stability and reliability which are extremely important for such windmills which we have discussed till now, for the horizontal type.

The difficulties are that they are difficult to transport and install. So, if you want to fabricate the whole setup somewhere else, and then transport and install in let us say city 2, while they were being fabricated in city 1, then the transportation is difficult. And as we discussed they also have this negative environmental impact and to ensure that they do not lead to other types of pollutions strict regulations are required.

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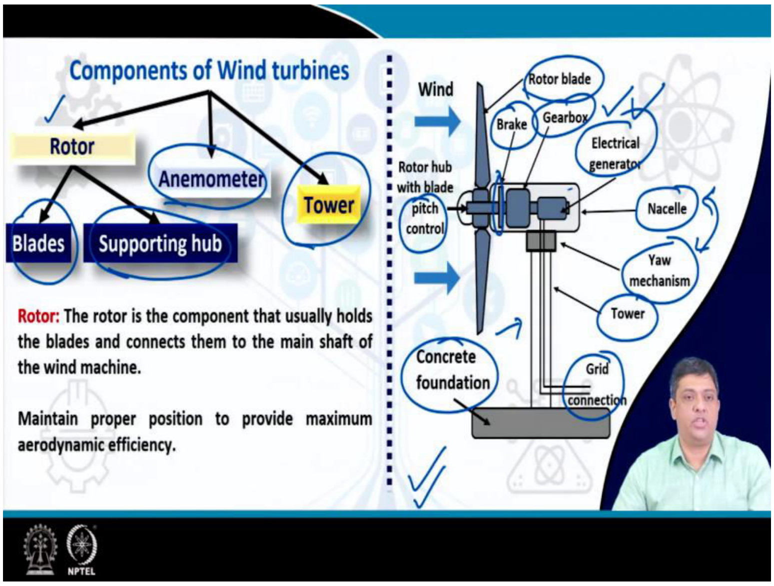

So, let us now talk about the wind turbines which are more common and you will see that this is a typical design of a wind turbine. You have the rotor blade and you have the tower which you see from far when you are crossing a wind turbine farm or a windmill farm. But there are many other components those are as critical as these two if we have to ensure that the turbine works optimally.

And those include the wires which connect your electrical generator to the grid. You have the gearbox which is installed inside the casing which is called nacelle. It actually allows you to control the speed of the rotor blades and also if you want to have a condition or control or the capacity to reduce the blade speed or increase the blade speed.

Now, suddenly if you have conditions where the wind speeds increase tremendously and you have the condition of turbulence, then what would you expect? I would say that the first thing which will cross your mind is that please stop the wind blade and if you have to stop the rotation of the wind blade, then you should have a break and that is also installed.

So, these are many more components which are used. In addition to these so called electrical components, you see you have installed the whole tower on a concrete foundation, this concrete foundation first of all ensures the stability of your tower and the blade combination; it also reduces the vibration transferred to the ground and it also ensures that you do not lead to the mechanical failures which can lead to the tower itself collapsing.

So, there are various factors which come in while we design the concrete foundation and a lot of civil engineering comes into picture. You see there are two terms the Yaw mechanism and nacelle which are slightly new. Nacelle is basically the compartment where you are in installing the electrical generator, the gearbox and the brake are actually being installed this under inside this compartment that is nacelle.

And Yaw mechanism is a large number of ball bearings, which system are at the top of the tower, on top of it using this interlocking or ball mill or ball bearing based interlocking systems, you can install the nacelle on top of the tower. So, this is being done by the Yaw mechanism it also protects your nacelle and allows its stability on the top of the tower.

And finally, you have the pitch control, you can also have the pitch control mechanisms while the turbine is operated. So, the main components of the turbines are the rotor which are basically blades and the supporting hub, anemometer which measures the wind speeds and then you know what is the wind speed that is going to hit your blade. And finally, if you want to have a stable wind turbine, then the tower construction cannot be neglected.

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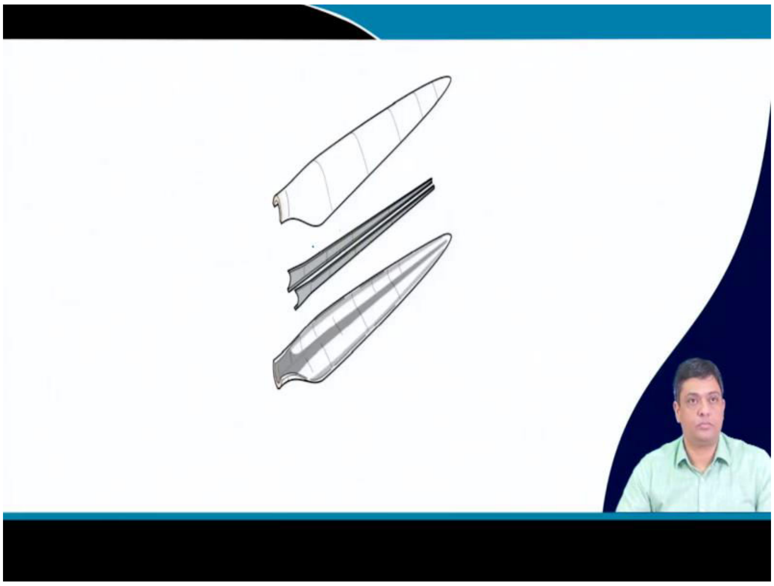

And these are basically what you do you have the two aero dynamical shells under which your, these networks of arrow wings are encompassed.

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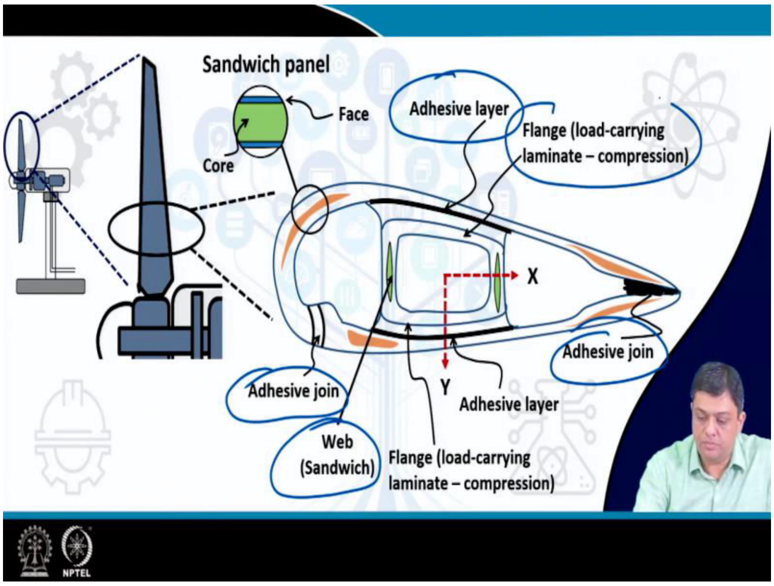

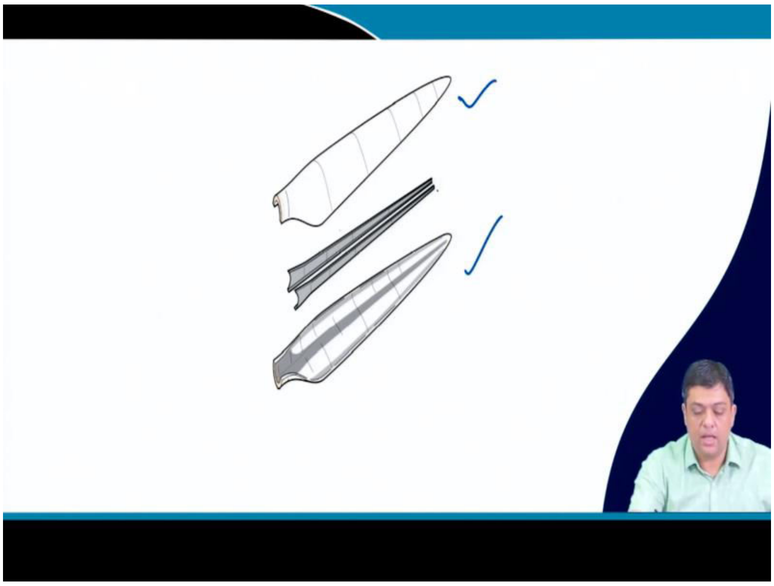

So, this is what a typical cross sectional area or a wind turbine blade looks like. You have two regions which are adhesively joined together and there are various factors. So, you have the core and the face, the top two layers and the internal layer these are joined together using an adhesive. So, you have the adhesive joints.

Operation of this whole blade will become clear as we go along but this is typically an indication of various factors which should be considered while designing the wind blades. So, you have the adhesive joints between the various sections, you have the two blades, if you see these are the two blades I am talking about and then they have to be brought together with the laminate flange which is in the middle of the two aero dynamical systems. So, you have the sandwich, the web sandwich between the laminates and then you have the flange.

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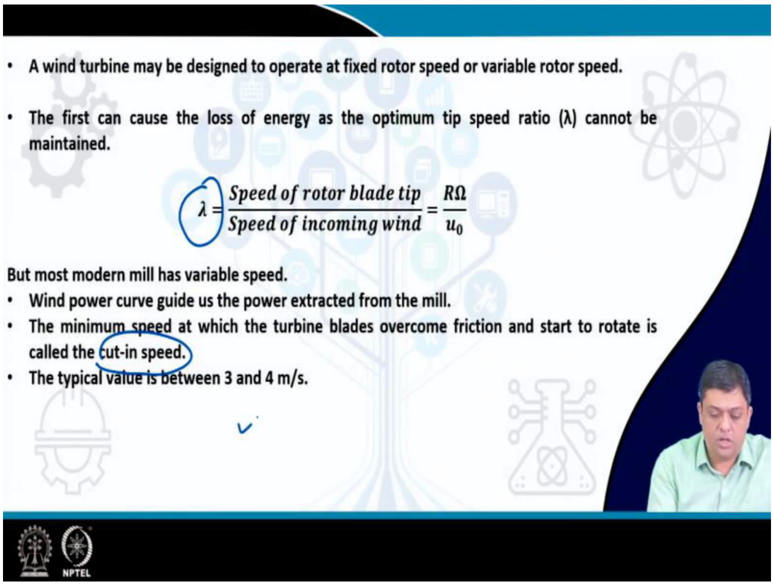

And a wind turbine which looks to be very simple is now clearly a much more complex system. So, to design and operate a turbine, let us say with fixed rotor speed or variable rotor speed, you will have additional factors which will be considered. What did we discuss earlier? We have seen that the loss of energy at an optimum tip speed lambda cannot be maintained then what will happen? It means there you will end up losing some energy.

So, if lambda is not maintained, you will end up losing energy. But most modern mills are so designed that they can operate with variable speeds. And wind power curve which we had seen in the earlier lecture guides us to the maximum power that can be extracted from the mills.

And as we said earlier, that you cannot have very low wind speeds or very high wind speeds, because, if you have very low wind speeds, then you will have certain wind passing through the blade without interacting with the blade and blade will not be able to extract energy and if you have very high speeds then that will lead to turbulence condition and the subsequent damage can be observed.

So, you have to have an optimum operating condition. So, the minimum speed at which the turbine blades can overcome the friction and start to rotate is called the cut-in speed and the typical value of this is 3 to 4 meters per second.

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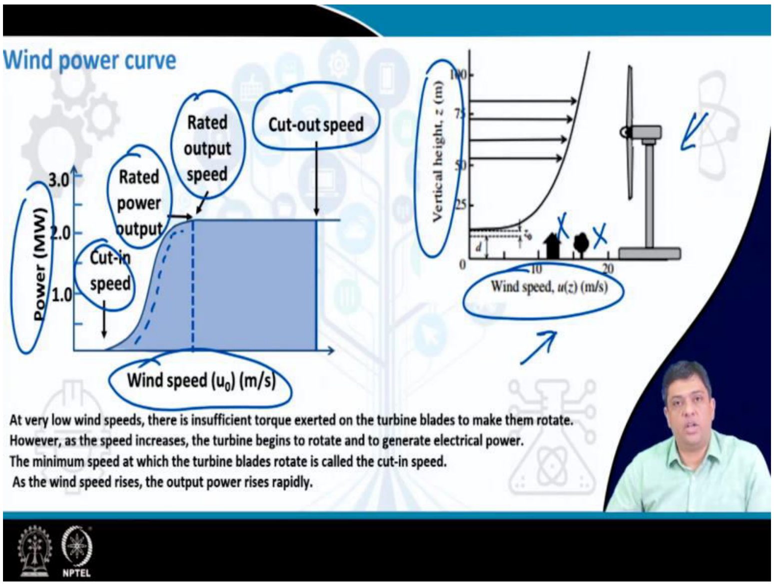

And if you draw a wind power curve that then what if you draw power on the y axis and the wind speed on the x axis, you will see that there is a cut-in speed, you have the increase and then after some point you will see saturation and this is the point which gives you the rated power output and rated output speed. And if you just go on increasing, then you will obtain a cut-out speed because beyond this speed you can see the damage. As I had discussed while installing the wind turbines, you cannot just install it randomly you have to choose it very carefully.

And so, if you draw a vertical height versus wind speed and the height of the blades, which will be chosen, you have to see that the turbines should be such that they do, while they operate they do not hit the trees below or the houses below; while they cannot be very high otherwise its tower height becomes very large and then you have the other effects coming into picture. So, there is an optimum height and speed calculations which are there, so as to ensure that maximum power can be extracted.

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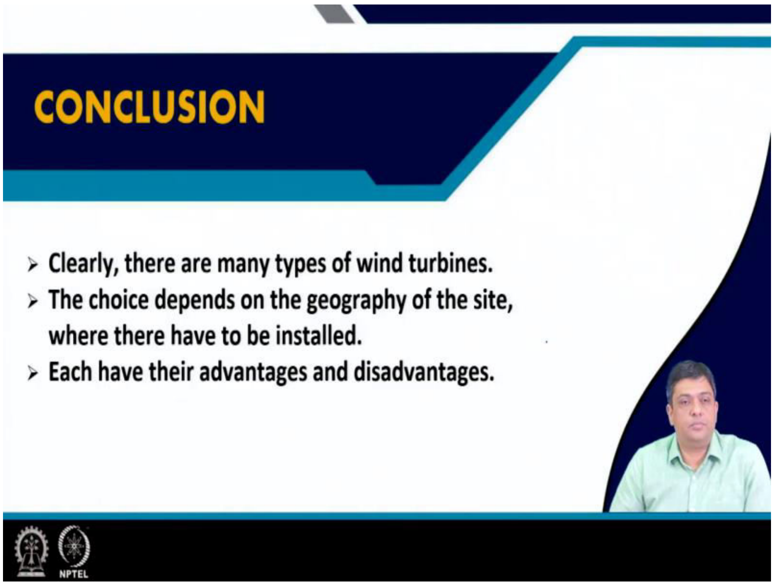

So, hopefully in today's lecture, I have clearly shown to you that there are many types of wind turbines. And the choice of these turbines and their installation sites depends upon the geography of the site, along with the climatic or weather condition of that site and each of these turbines have their own advantages or disadvantages.

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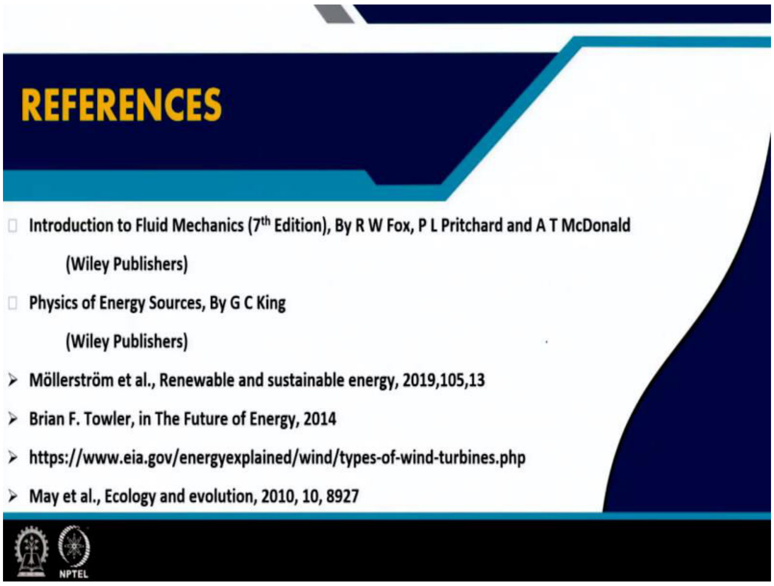

These are the references which were used to prepare the lecture slides today or to obtain the data which were presented in today's lecture. And I thank you for attending today's lecture. And in the next lecture, we will start talking to you about the materials aspect of designing the wind turbine blades and why the physics of these materials become so critical if we want to have turbines which are optimally performing. So, I thank you once again for attending today's lecture and have a nice day.