Introduction to Smart Grid
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Lecture – 09
Distributed Generation Resources – III

Good morning to all of you, today in this class we will discuss about another distributed energy resource that is the wind energy system. If you could see that now a days the power demand is increasing exponentially. And to meet such power demand; so, we have to construct either new corridors or new power structures.

So, in that case the; if we talk about the transmission structures, it demands more cost and also it demands areas and some other issues are also there. If you see the like we have coal based generations so, there the carbon dioxide emission is also one issue.

So, to meet the power demand, we have many other alternatives so, one alternative energy source is the wind energy system, which is the largest renewable energy source to provide the power to our demand structures, to our customers.

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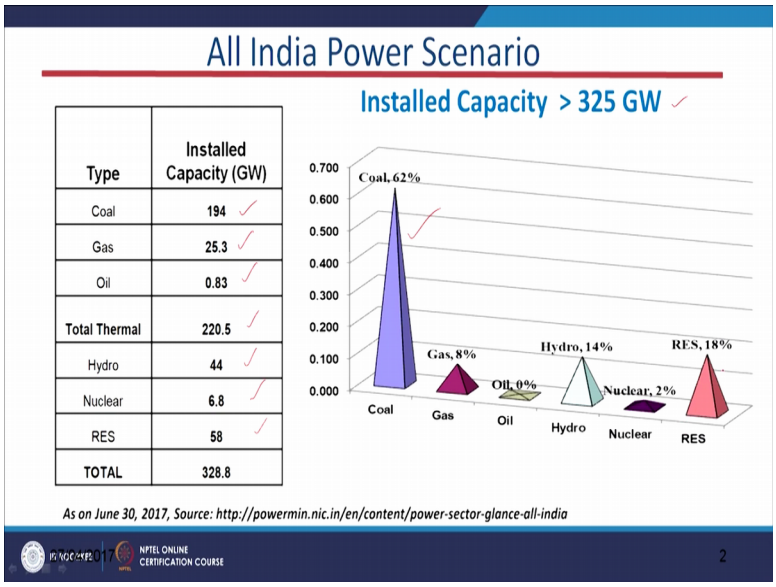

The installed capacity is more or less greater than 325 gigawatt and, if we could see here, the coal is about 195 gigawatt, gas is 25.3 gigawatt, oil. And we have thermal, hydro,

nuclear and RES means the Renewable Energy Sources. If we could see this particular figure here, the coal is around 62 percent and this renewable source 18 percent.

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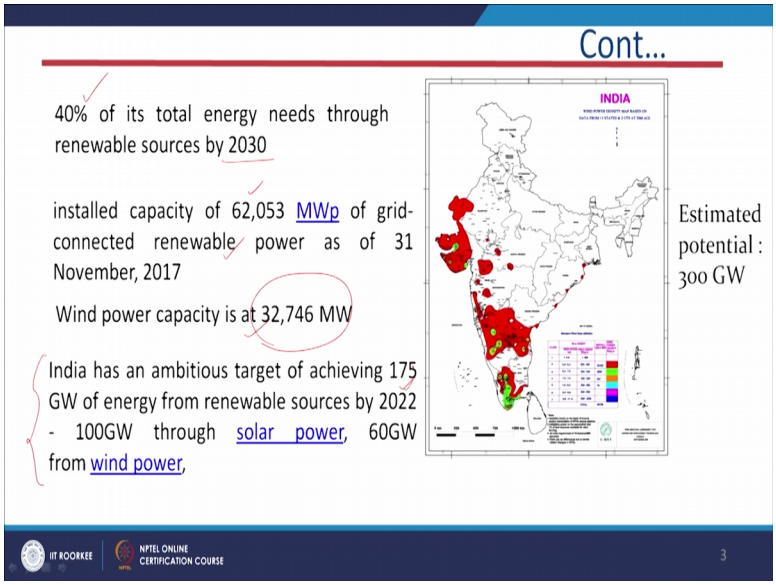

So, our target is to basically to increase the power generation from renewable energy sources; not from the coal generation based system. By 2030 the target is to have 40 percent total energy should be from renewable sources.

And in fact, this is the capacities 62053 megawatt, or 62 gigawatt of grid connected renewable power installed capacity, we have by 30 first November 2017. And wind power out of it the wind power is 32746 megawatt and another part this is a very important point here I just want to mention.

So, our target by 2020 is to have 175 gigawatt of energy from renewable sources and, that is too 100 gigawatt from the solar power and 70, almost it is written here 60 say 60 to 70 gigawatt from wind power generation. And this figure is not impossible it is quite possible, if we will see this energy map of the India the solar map.

So, this red colors basically show the sites where the wind potential is present; it will try to harness the wind energy on this particular sides. So, it is possible to have 300 giga watt; ao, it is quite possible to meet this 60 gigawatt by 2022.

This is from the website we have Ministry of New Renewable Energy, that is the wing of our Government of India Ministry.

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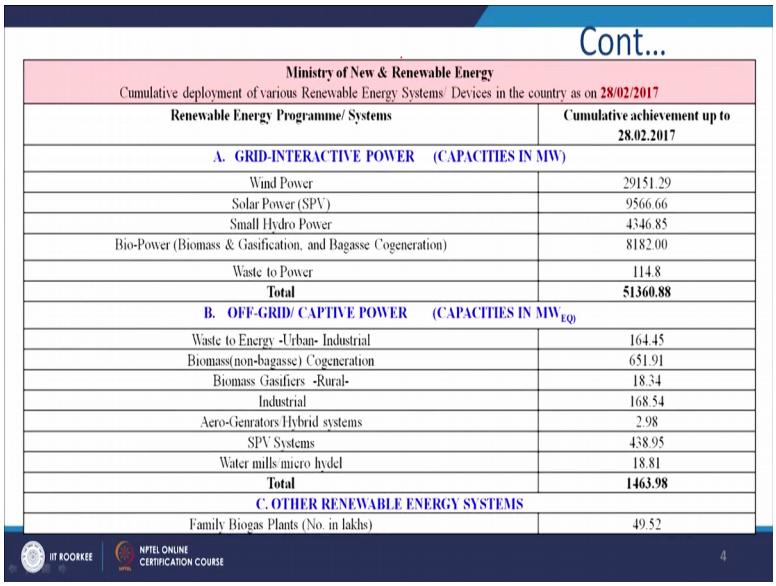

And this wing is basically dedicated for renewable energy sources, and here some of the figures I have collected by 28th to 2017; February 28th 2017, and you see the first one is the grid interactive power capacities is in megawatt and, the second one the B part is off grid capacity power and capacities is also in megawatt.

And some of other renewable energy sources are also this figures are provided from the renewable ministry of renewable energy system sites and, if you could the wind is the largest power generation.

As far as the India is concerned the wind is the major power renewable power source and, second is the solar and third is the small hydro power plants. And if you will see the off grid, or capacity power captive power here, this waste to energy urban industrial we have 165.45 and also we have biomass 651.91 and biomass rural industrial we have 18.34 and so on.

The point here in this particular part we want to discuss that in India the wind plays a major role as far the renewable energy sources are concerned.

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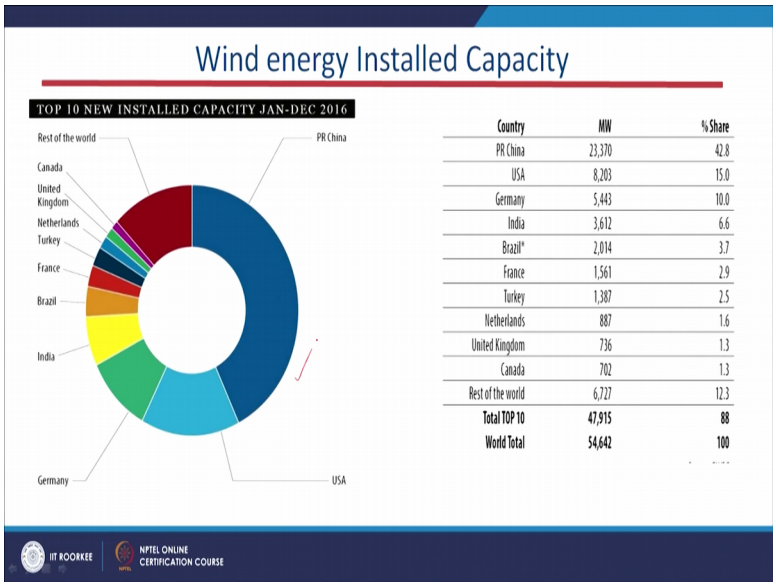

And if you could see this pi chart the India stands as the forth position globally, this china first 42.8 percent share and, the second one is US 15 percent Germany third 10 percent, and India is 6.6 percent globally.

The position is fourth largest wind generation country and as far as the India is concerned, we have the largest wind farm which is located in Muppandal wind farm.

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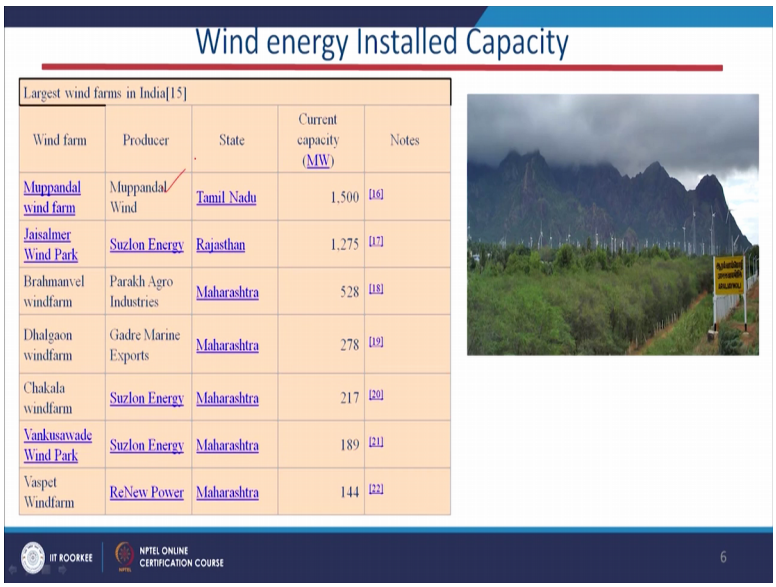

And it is located in Tamil Nadu state and, the capacity is 1500 megawatt and, other states like Rajasthan, Maharashtra, they are also following and these are the figures, which are

noted down here and overally if we will see that wind is a very I mean the largest source of renewable energy sources for us.

So, we have that potential that the forecasting figure, which is given basically 300 gigawatt power, we can harness from the wind system that is quite possible, if we will increase the technology and the controls, or monitoring systems better so, we can always do it by our smart grid technology.

The question now comes that why wind energy is very important and, why it is very advantages for us?

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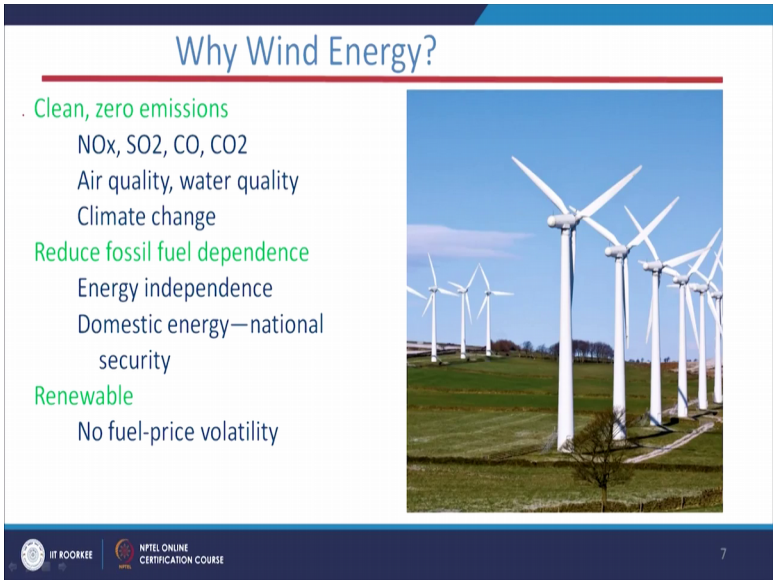

The first point is it is clean and zero emissions, which is required for us. If we will see the coal based generation there we have carbon di oxide emission process is present like the very dangerous gases like NOx, SO 2, CO, CO 2, but this gases are not present where the wind energy system is present.

That means we have a quality air and quality water and of course, if the poisonous gases are not present. So, the climate change is also not difficult I mean it is in healthy condition and second point is it is fossil fuel depends.

So, it will have more and more power generation from wind system so, of course, to meet the demand we have to basically reduce the dependency, from the fuel cell like a fossil fuel cell based generation that is our coal based generation plants.

And yes of course, it is renewable in nature the wind is basically from heating of the sun the unequal heating of the earth surface. So, it is renewable in nature that is no end to the wind.

So, these are few key points, where we can see that wind system is more advantages than the coal based generation system. And this is the potential impacts and issues.

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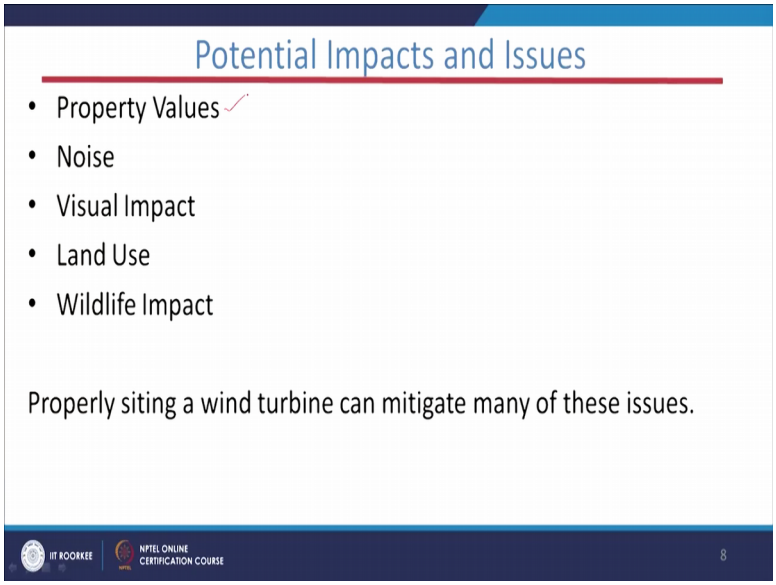

The first one is the property values and the second one is noise, and the visual impact land use and wild life impact. So, if you just see overally what are the draw backs, what are the disadvantages of the wind system?

So, the first point is the property values, if we could see that while just planting I am just citing this wind farms it needs large lands. And second is that while this wind generator runs so, the sound will be produced and that sound that noise is also not desirable that if with proper citing the wind farms, we can reduce it of course, or using proper technology advanced technology we can reduce, but the noise is present.

And the visual impact yes aesthetic look is essential so, that is why the wind farm like the wind turbine blades, or towers we have to take care so, that the visual look will be better. And land use and the wild life impact.

The wild life is very important, if we are using the wind farm for our power purpose using the power, or harnessing the electricity, then we have to also careful towards the

wild animals. Basically the wind farms are located far away from the cities, or localities where the wind is available. But; however, we have to take care the wild animals that should not any risky factor, that should not be risky factor as per the wild animals are concerned.

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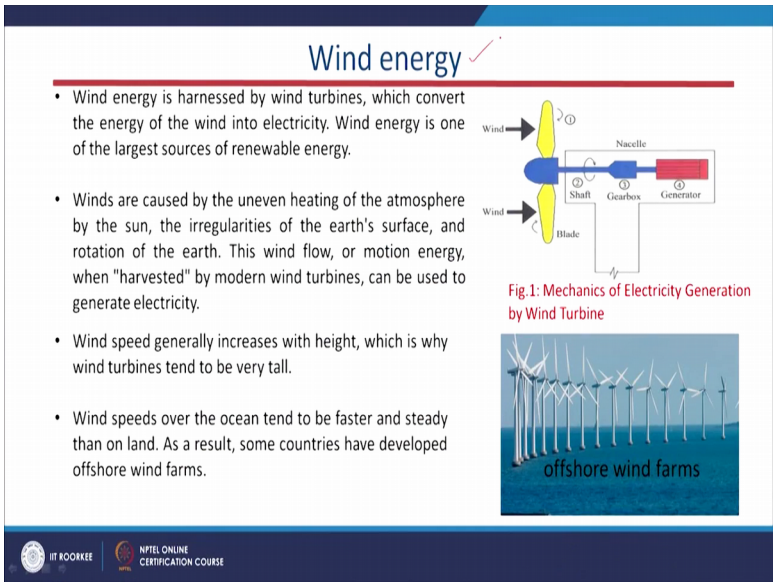

Now, I will just discuss here what is this wind energy; if you could see here this figure so, it is schematic figure of this wind energy system, where I have shown this two arrows basically the wind flow, flow of the wind system wind and this is our blades these are the blades and, we have shaft and gear box and the generator.

Now, in general in wind system the kinetic energy which is present in wind is converted to the mechanical energy with help of this, mechanical system gear box we have shaft and, we have this rotor. So, this rotor basically converts.

The kinetic energy which is present in the wind to the mechanical energy and, next stage the mechanical energy is converted to electrical energy using this generator. So, we will discuss more about this principle of operation of the wind system and also we will learn different parts of the wind system.

Now, if you see here the second picture we have here the off shore wind farms, first of all this we have on shore means, on the land we have wind farms also on the off shore on the top of our ocean on the label. So, we have also wind farms two things.

If will see on the land the speed of the wind is basically not steady and also not so, high and in that that is why we just put the height of the wind power is very tall, if you could see in the lands so, to access the to harness the more wind to get the more wind. So, we have to make it very taller. But here in case of ocean the flow of the wind is steady and, also it is little, but i mean faster also this two things faster and steady.

So, due to this many countries also they are planning off shore wind plants and, that is also helping that is also coming in a very bigger farm and it will also off course, it will mitigate our power requirement, coming to the constructional feature of the wind system.

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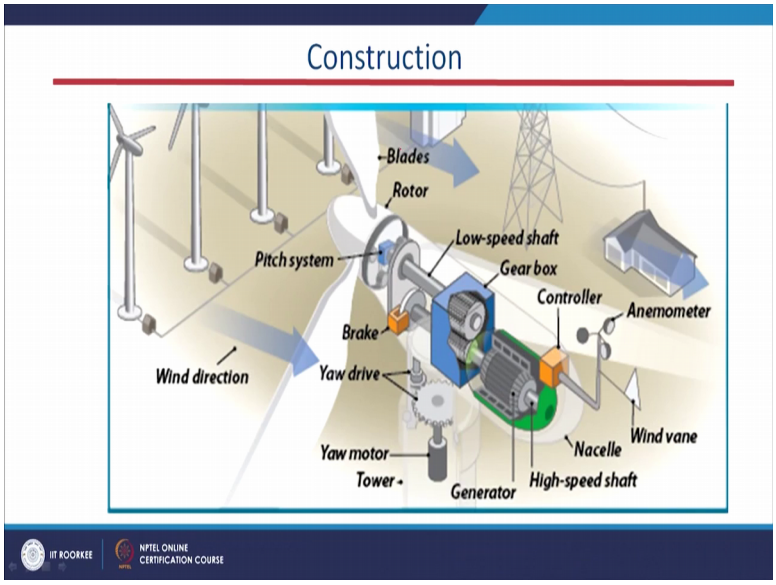

The first one I will just talk about the rotor and the blades. And second system is the pitch, third one we have the low speed shaft then we have gear box, then we have high speed shaft and, then we have generator, then we have controller and of course, we have this breaking system and yaw drive and yaw motors and then the tower.

Now, we will discuss one by one what are the functions of each component coming to the tower of the wind farm. The towers are mainly divided into two categories the first one is the vertical tower and the second one is the horizontal tower.

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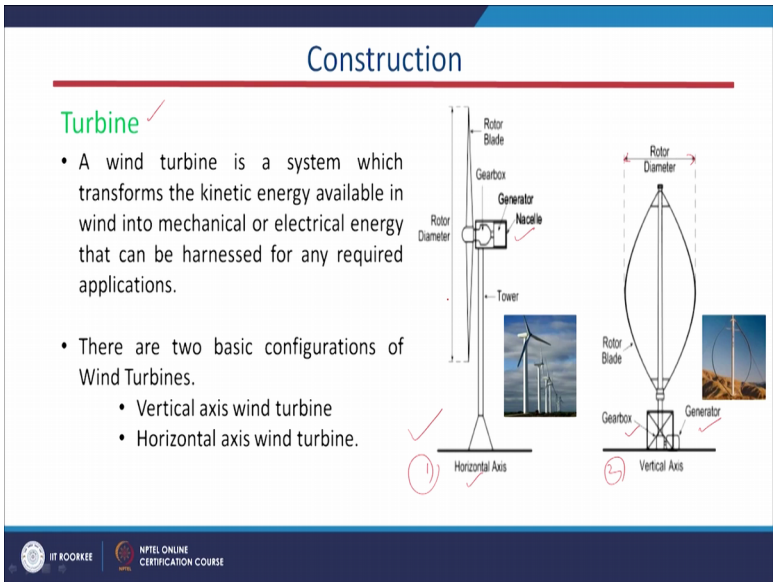

It will come to this figure this is our horizontal blade, or horizontal tower of the wind system, and this is our vertical wind system. What is the difference between these two? The first difference is that in case of horizontal based type of wind system, here the generator and the gear box are mounted on the top of the tower, or top of your this system this is our tower. But in this case the generator gear box are mounted on the bottom.

So, that is the basic difference. And the another point is the diameter of if you see the rotor blade, the rotor blade the rotor which rotates. So, the rotor blade the diameter is measured in terms of horizontal, but here if you see the rotor diameter is measured in terms of vertical. So, that is how this two systems are these two structures are different from each other.

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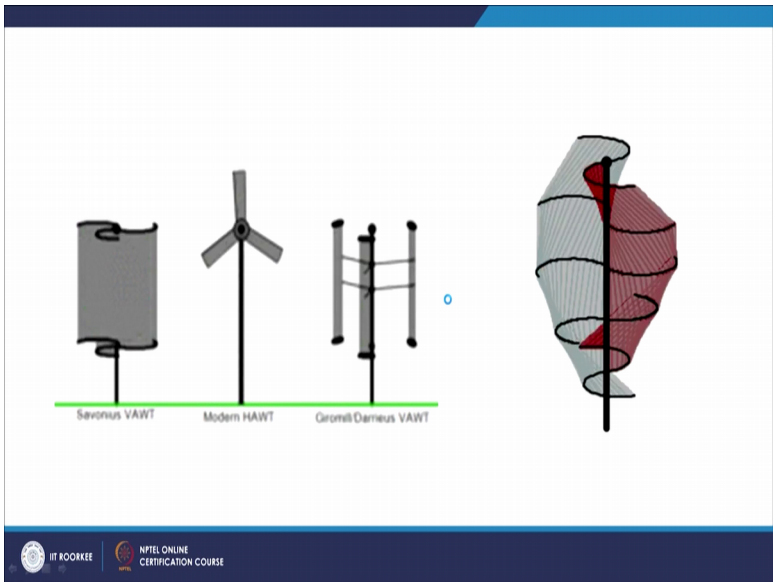

And here some pictorial consist I have just collected, if you could see this is how the vertical blades, or vertical structure rotates and, this is our horizontal structure this is also vertical, this is also vertical.

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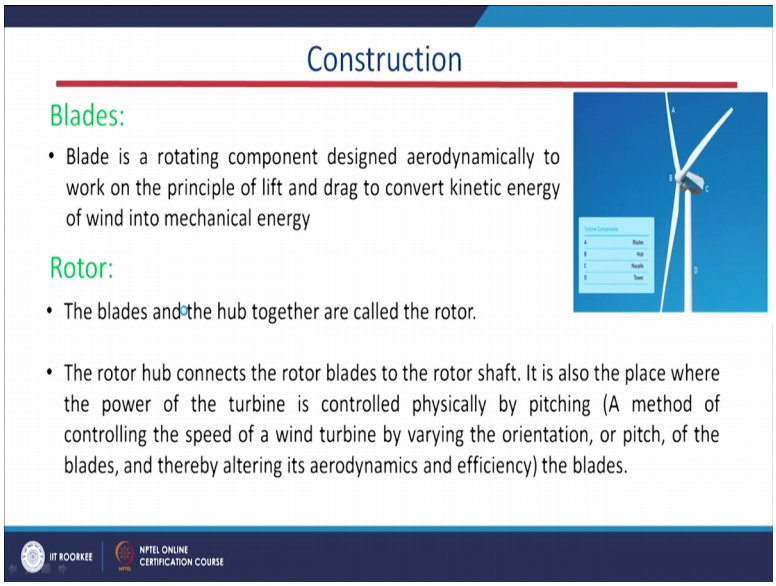

Coming to the blades of the wind fan so, this structure a this is a this is our blade of the wind energy system. What is the function of this blade? This blade is a rotating component which is designed arrow dynamically to walk on the principle of lift and drag, this is important, drag to convert the kinetic energy into the mechanical energy.

This blade is responsible if you will see this figure, this three blades. So, this particular blade designed to convert the kinetic energy, which is present in wind to the mechanical energy.

Coming to the rotor part this rotor is present here, the basically the B is a how this how and the blade together this two things are known as rotor and, this blades it is written here, this blades and the hub together called as the rotor of the wind system.

This particular rotor have is connected to the blades rotor blades and, to the rotor shaft. And it is also plays where the power of turbine is controlled physically by pitching it. So, what is this pitching word what is the meaning of it, it is a method it is a method of controlling the speed of the wind turbine by varying the orientation of the pitch of the blades.

It will vary the orientation of the wind blades, the wind turbine blades then what will happen we can access more wind power, or we can access we can harness more wind kinetic energy, which will be converted to mechanical energy that is known as pitching of the blades, and that mechanism is only possible using this rotor section of the wind system.

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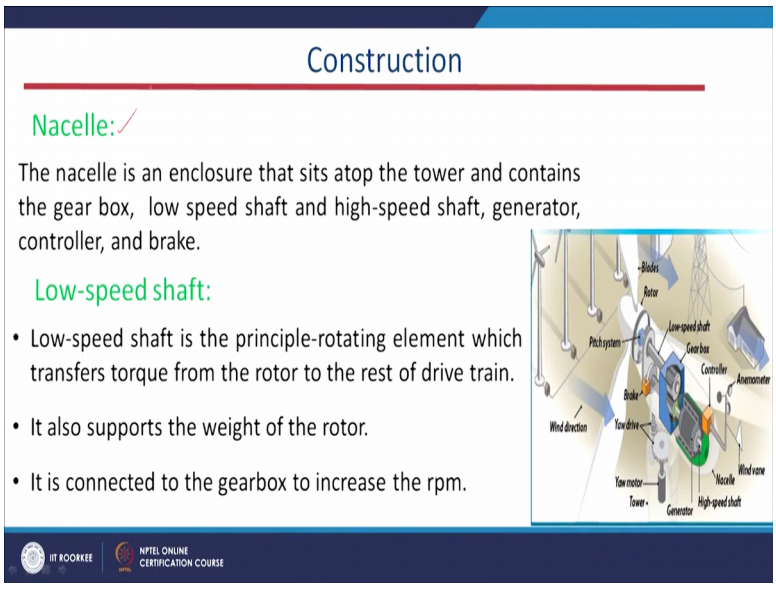

Now, coming to the nacelle this nacelle means it consist of the first one it contains the gear box, will come to function of the gear box, and next one is the low speed shaft and the third one is the high speed shaft generator, controller and the brake.

So, this all the elements together called as nacelles of the wind energy system and, here if you could see this particular picture so, this here the nacelle and this nacelle we have the generator, we have this controller, we have the gear box low speed shaft and also high speed shaft, all are present inside this nacelle of the wind system.

Now, coming to the low speed shaft, low speed shaft it is principle rotating element which transfers a torque from the rotor to the rest of the drive train. It transfers the torque from the rotor to the rest of the drive chain. If you will see here this is our rotor and this is our blade and, if the wind comes and it heats to the rotor the blade, then the blades are rotating along with the rotor. So, then this particular low shaft low speed shaft will transfer this particular energy, or kinetic energy rotational speed to the next section of the wind energy system.

That is what and also it supports the weight of the rotor, this low speed shaft also supports the weight of the rotor. And third function is it is also connected to the gear box to increase the RPM of the generator, this is very very important this low speed shaft is also connected to the generator to the gear box to increase the RPM of the generator.

That is also another function of this low speed shaft and, what about this gear box.

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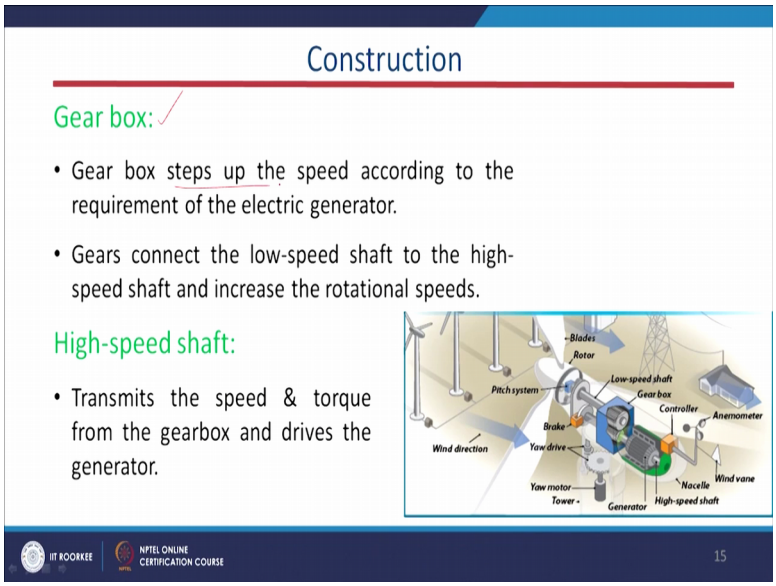

The gear box steps of the speed according to the requirement of the electric generator. Inside the wind system we have electric generator, basically we will we have DFIG nowadays doubly fed induction generator and also we are also seen some cases also we use the PMS (Refer Time: 18:29) this permanent magnets synchronous generator. And in that case to step up the speed according to the requirement, what is our requirement where we can get optimum electrical power, or optimum torque of the machine. So, according to that we have to basically step up the speed. So, that is possible using this gear box system, inside this in a wind energy system.

Now, this gear box connects the low speed shaft to the high speed shift, this two are this low speed shaft and the high speed shaft are basically connected with using the gear box system and to increase the rotational speed of the machine. Now what is the function of this high speed shaft? This high speed shaft is basically the shaft of the generator, the generator which is mounted and the top of it this tower and inside this wind energy system, it generates it basically converts the mechanical energy to the electrical energy.

Now, the function of this high speed shaft is it transmits the speed and torque from the gear box and, drives the generator that is the function of this high speed shaft. Now, what is the function of this brake? If you could see this figure here is the brake.

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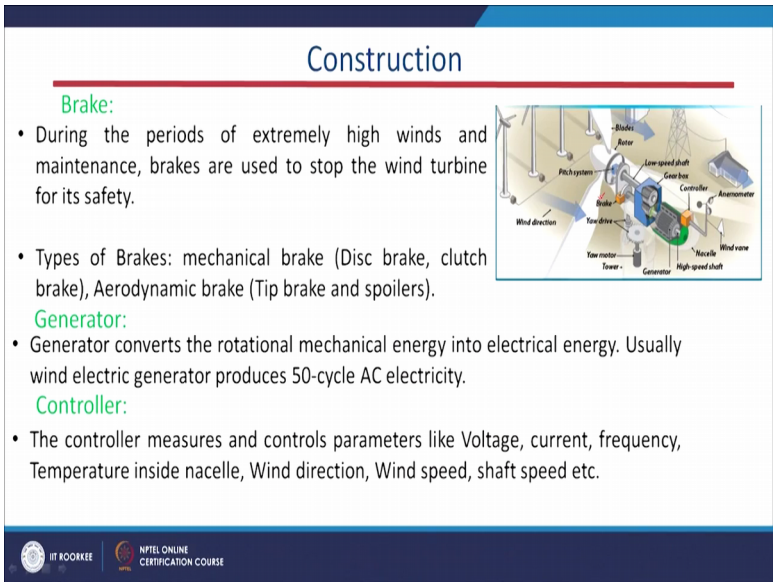

The braking system is a always desirable in every system because, it is a safety consent of the wind system. What is the function of this brake system? Basically during the very stormy condition and, extremely high wind flow. So, we have to basically brake the system operation. So, in that case the braking system is the system which controls or which brakes, the operation of the system. It stopped the wind turbine for its safety that is what the brake system does.

Now, and types of the brake basically we use mechanical brake, or also sometimes we use aerodynamic brake system. Coming to the generator part we will discuss more about this generator section in the subsequent slides, that it converts the mechanical energy to the electrical energy, that is what our requirement. From the wind energy system we need the electrical energy finally, and the controller basically it it will see the controllers are also desirable it is not desirable its essential part of every renewable energy system. s

So, similarly in case of a wind system we have controller, this controller basically measures and controls parameters like voltage, current, frequency and temperature inside this nacelle and, also it controls the wind direction wind speed and shaft speed.

Because our wind direction wind speed are directly or indirectly linked with our output electrical power. So, we have to control if we are we are interested to control the voltage current, or frequency output of the generator so, we have to also control the wind speed

and also the shaft speed and also the wind direction. So, the direction where we could have maximum power generation.

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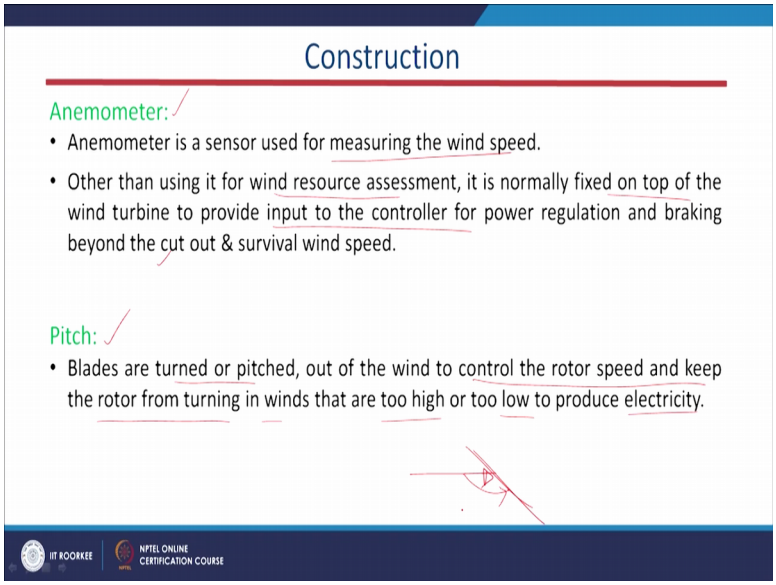

Now, this anemometer is also there it is a basically sensor, which measures the wind speed here, it is it measures the wind speed and it is further it is used for our controlling purpose only, it is a feedback it will be a feedback to the controller. And for rain resource assessment it is normally fixed on the top of the wind turbine.

This anemometer is basically mounted on the top of the wind energy system tower and to provide our input to the controller for power regulation, power regulation and braking beyond the caught out and survival wind speed. Again this anemometer is also very important equipment as far as the controlling of the wind system is concerned, because if will if you do not know the wind speed presently so, we cannot control the system operation.

So, that particular measured wind speed will be sent to the controller, presently what is wind speed if it is within the range within the stable operation of the wind system so, it will just operate in steady manner, otherwise we have to cut we have to stop the operation.

And then this pitch is also important, pitch that already we have discussed, that this blades are turned or pitched out of the wind to control the rotor speed and skip the rotor from turning in winds there are two higher to low to produce electricity.

Basically the blades has now are designed in such a manner (Refer Time: 23:10) means it is a given certain direction, with respect to the direction of the wind the access of the wind I mean this wind blades it keeps some angle.

So, if this is my wind direction and this is my blade direction, I mean the axis of the blade so, what is angle they are just extending. So, that is how we have to keep in such a manner pitch angle of the blade so, that it will it will just get highest energy from the kinetic energy from the wind system.

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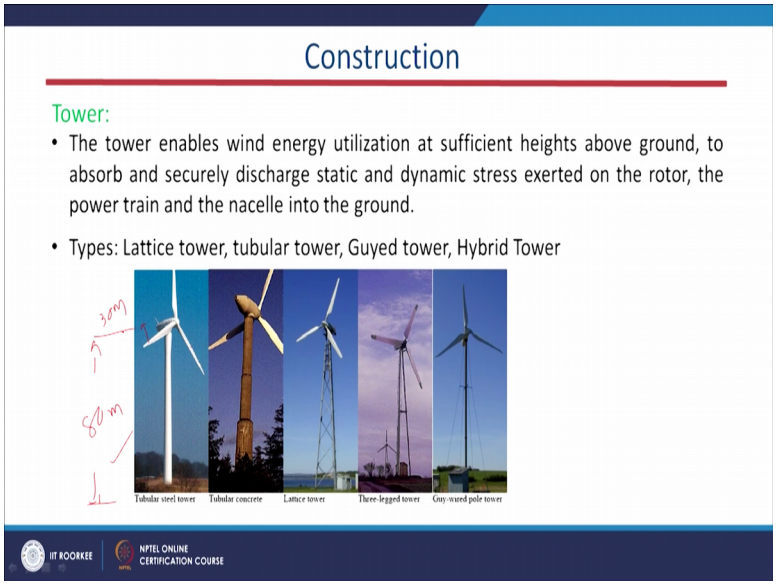

The towel is also important here, if you could see different type of towers we have demonstrated like tabular steel tower, we have tubular, concrete, lattice three legged and different types of tower and for aesthetic look good look and, we are planning also different other types of tower so, also in research in construction.

So, and remember this tower height is in some cases this steel tower the height is almost about 80 meter. The blade size is within 30 meter. So, and it is quite I mean if it is a land based wind energy system, the height we have to increase because in the top layer the wind speed is higher than the bottom layer.

That is why the wind speed I mean the tower height is quite large.

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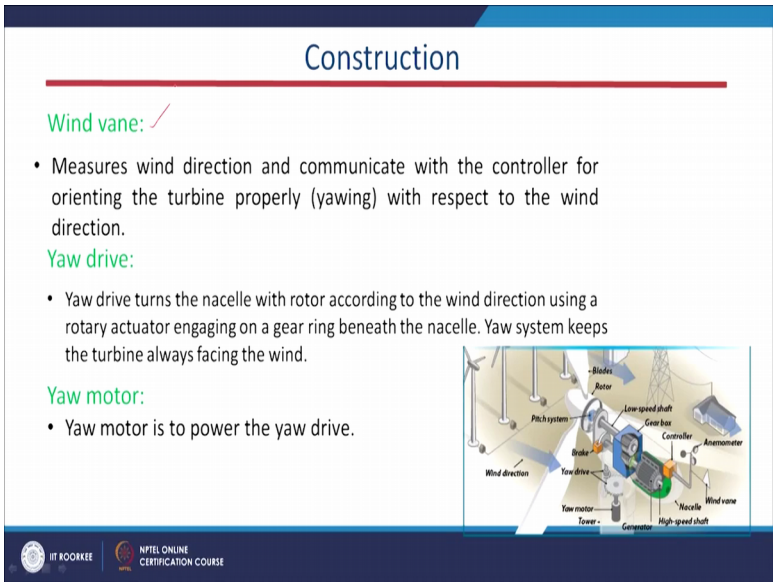

And this is our wind vane basically the it is an equipment, which is present inside the wind system, here it is if you will see this figure this is our wind vane. And this wind vane measures the wind direction it a does not measure the wind speed the wind speed is measured by this anemometer.

The wind vane basically measures the wind direction, because we have to also control we have to know the wind direction. And communicate with the controller for orienting the turbine properly and, that if we if I know the wind direction properly in what direction the wind is I mean the it is high, I mean the content the kinetic energy, because we have harness more kinetic energy.

So, in that case to orient the turbine in a proper manner the this yawing system is essential, we have a this yaw motor, yaw drive yaw motor so, this two are installed in this tower of the wind system and when it is required so, the wind turbine will be oriented accordingly to the towards the wind direction. So that we can access more kinetic energy, this is how this wind drive yaw motor operates.

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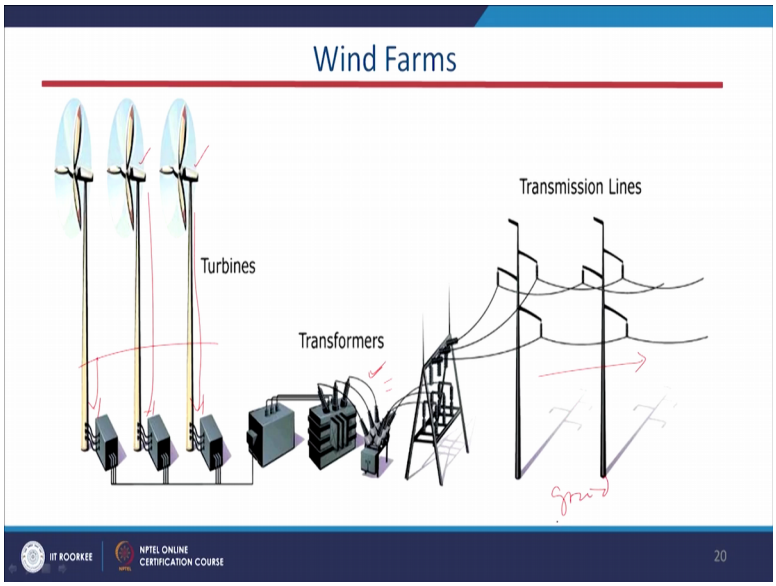

Now, this is a very typical wind farms picture here, our wind turbines and we have the generator basically the here, it is the this is a nacelle section, where the generator is present and from there we will take out the electrical power.

And, here the these are the transformers and which will step up the voltage to higher level and further also, we have this further stepping of the voltage and this particular voltage on power will be sent to the nearest grid system. This is our grid system and is a grid tired wind farm system. Basically this wind farms are located, or connected near to the it is not near to our grid system. It is far away from the grid system.

Now, does we are also planning HVDC link based wind farm system means, if the power is generated by the wind system, we can send the power to the HVDC links to the nearby grid system. The HVDC system can transfer more power in comparison to the AC system. It is very far away from the grid, then we can take the help of HVDC, otherwise we can connect the wind generate power to the nearest grid using the AC lines.

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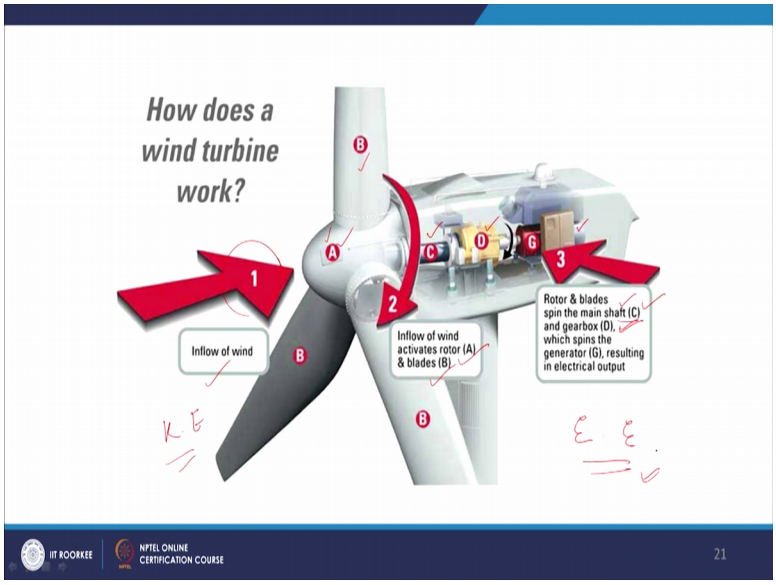

Then come to the principle of operation of the wind system, that is a very simple picture I have kept, this A and B together called as the rotor of the wind system. And this is the flow of the wind, the first stage is the flow of the wind and second this second stage, in flow of wind activates the rotor and blades. This A stands for the rotor and this B is the blade.

Now, when this wind due to the wind flow, the rotor and blades together they will rotate. Now, after this we have this C here we have the main shaft, due to this rotor and blades movement and this main shaft it is here will rotate, through the gear box this gear base is the D section. We have main shaft, we have the gear box.

Now, together this our main shaft and next is our generator and this is our another high speed shaft. So, this two things will rotate together and finally, the electrical energy output will be there so; that means, we have here the kinetic energy and we have here electric energy output. This is the input power and this is the output power in case of the wind energy system.

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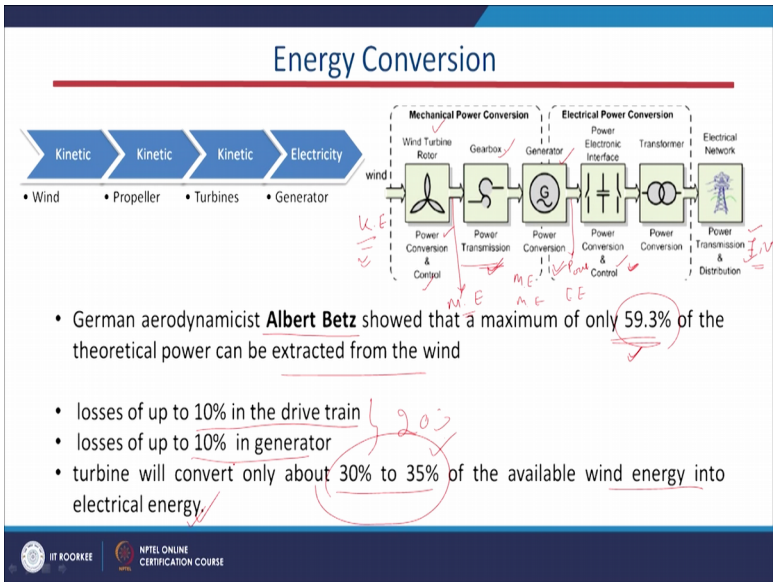

And these are some of the stages these are the block diagrams, the first stage the power energy conversion part is there, as well as the wind turbine rotor is concerned, at the wind turbine rotor section will have the power energy conversion. What is that type of power energy conversion? The input will be the kinetic energy, the output will be mechanical energy.

The first stage is basically conversion of kinetic energy to mechanical energy and, second stage we have again the gear box. This gear box will convert basically you know the it will just control the speed of the shaft. So, that it will just maintain the RPM of the generator at the required value or required level.

So, that we can harness more power at the maximum torque speed of the generator, or maximum point of the wind speed that is what the aim of this gear box, it will step up it will increase the speed of this generator and this conversion again is mechanical energy to mechanical energy at this stage. Now, coming to this section, the generator section we have this mechanical energy is converted to electrical energy. And here is the output the electrical output P out is here, it starts from here.

Now, after this generator we have power electronic interface, because in case of AC circuits like, we if we have like different systems of frequency; let us say wind system has some frequency and a grid has some certain frequency.

So, if you could have like electronic interface so, easily we can match the frequency of the grid and the with the frequency which is generated by the wind energy system that quite possible using the electronic devices. And so, that is why we have this power energy conversion and apart from this, we can also like for transferring purpose if it is a long distance, what we do we first a rectify the wind energy, like because the wind system generates AC power.

And just like your solar system, it generates DC power and here we will get AC voltage or AC power and, that particular AC voltage AC power will be converted to DC using this conversion rectifier system. Next the DC will be converted to AC using the invertor section and, that is what this power electronic interface does. And after that the AC system or AC signal will be connected to the our power system through a proper stepping of the voltage and of course, because we have to match the frequency and voltage of this particular grid system.

That we have to synchronize the wind energy system with the nearest grid and it is a German aerodynamics, he said Albert Betz, he said that maximum of 59.3 percent of the theoretical power can be extracted from the wind not more than that. That means 59.3 percent of this kinetic energy can be converted to electrical power P output, that is what the maximum thing maximum energy we can expect from the wind kinetic energy. And losses up to 10 percent in the drive train and 10 percent in the generator so, we have 20 percent loss overally.

Now, how much left out that is 32 35 percent available wind energy into the electrical energy system. And this turbine will convert this much of energy see, because we have also losses 30 35 this 35 percent of this wind energy is going to be converted to electrical energy.

Now, we will discuss here about the different types of wind energy system, where we will talk about different types of missions, how they are used to convert the mechanical energy to the electrical energy, or kinetic energy to mechanical energy; then it will be converted to electrical energy.

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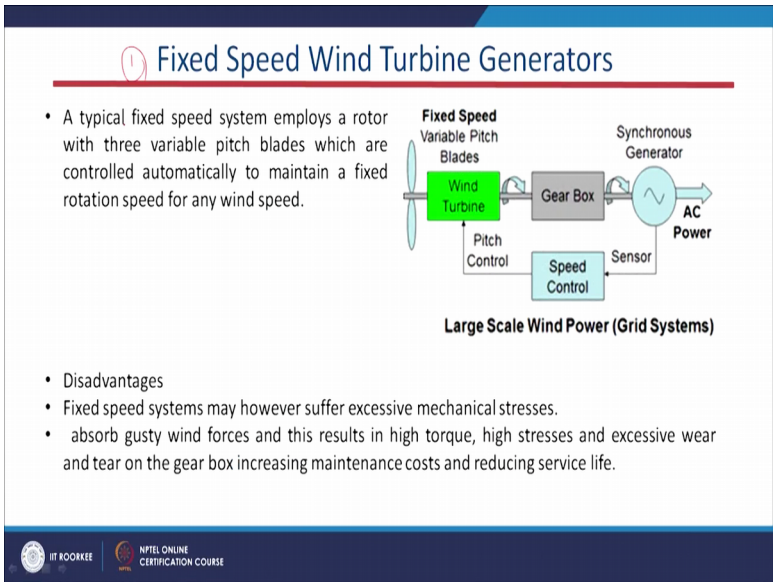

The first one is fixed speed wind turbine generators and, in this case if we will see this one it is a large scaled wind power and it is a grid system here, it is the wind turbine.

The wind turbine provides the mechanical input to the gear box and it will go to the synchronous generator. And for controlling this speed of this synchronous generator, we have sensors which will sense the speed of this machine and, it will just send to the speed controller. And accordingly it will just control the pitch angle of the blade and, that is how this particular fixed speed wind turbine generators work and finally, we will get the AC output.

Now, if you look at particular schematic diagram, here we do not have any electronic device or electronic interface, there is no rectifier there is no invertors are used in this particular system. Directly the generator output is going to be connected to the grid system and, this is quite challenging, because you know this wind speed is varying in nature if the wind speed varying in nature.

So, it is very intermittent in nature in that case; obviously, we may not get the power at the every time equal amount, or sometimes it may happen there is no wind so, there is no power generation. So, in that case the control I mean of this particular system is very challenging using this sensors of the which the sensors, which sense the speed of the machine. So, today we will stop here and the next class, we will talk about the different

types of synchronous generators, which are going to use the DFIG system which is basically the main part of this wind energy system.

And so, in this particular lecture we have discussed the very basics power scenario of India and, where this what are the different states we generate the wind energy system and, after that we have discussed the fundamental principle of operation of this wind system and its constructional features. And just know we have finished one part that is the fixed speed wind turbine generator.

Thank you so, much.