Wind Energy

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Lecture 08: Wind Turbine Basics

Welcome back. So, we continue our discussion on this particular topic of wind energy. We have gone through all these kind of fundamentals of the fluid mechanics. Initially, we looked at the renewable energy, the status and all this stuff. Now, slowly with that kind of knowledge, now, we'll move to the discussion or the detailed discussion of wind energy. So, to continue with that discussion, what we'll do first, we'll try to look at some of the fundamentals of wind and the brief history of wind turbines and then we will move to the different wind turbine technologies and then slowly we will move on the discussion of aerodynamics and things like that.

So, what we are going to do today is that basically we will look at different wind energy and turbines and that kind of things. So, to do wind energy, the important thing to know is that what is wind, okay! and obviously the questions that arises that what is wind how is wind generated so these are some pertinent question that one has to kind of answer before. So, in one hand you can say that wind is air in motion. That means the air that we have which is already in motion.

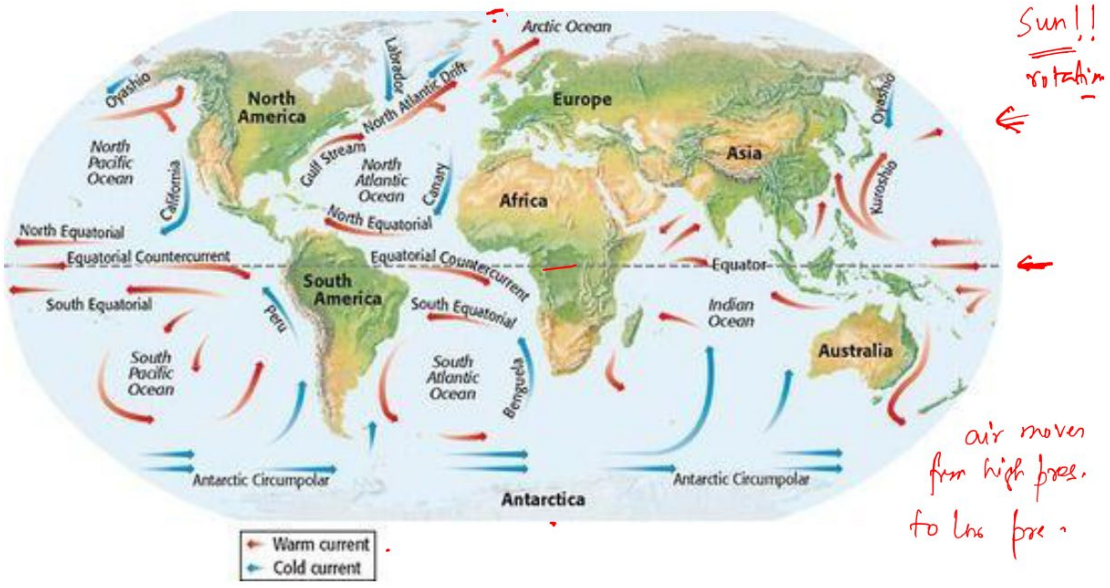
So wind is also the result of conversion of the potential energy of the atmosphere into kinetic energy due to some pressure differential. Most prominent feature of climatology in India is the monsoon circulation. So obviously, one can. But one hand, you can kind of. So primarily, if you look into the major source of this wind, which is air in motion, or one can say the original source, is essentially on this Earth, is the Sun.

So, why? Because this is the primary source of all this. Because the Sun heating happens on the Earth's surface and due to uneven heating of the Earth's surface and the rotation, the wind produces. So, if you see this complete picture here, you can see the different circulations. Obviously, the red one is marked as a warm current. The other one is the cold current.

So, what you have that this uneven heating is also associated with global winds that we just talked about is kind of caused by the pressure difference across the outside due to this

uneven heating of the earth by solar radiation. For example, if somebody wants to look at little bit in more detail, the amount of solar radiation which is absorbed at the earth surface is always higher or rather one can say is that greater at the equator than the poles. So, these are the poles. So, it will be always higher at equator what this does so one can always see that that you have more heating along this you have poles are not getting heated that much so the variation in the incoming energy the difference for this variation sets of the convective cells in the lower layers of the atmosphere which is that's called the troposphere i mean or in a simple model one can think that the air rises at the equator and sinks at the poles because this equator is getting heated up more compared to these poles. So air rises at the equator and sinks at the poles.

And that's why this circulation of the atmosphere that results from this uneven heating of this earth's surface is also influenced by the rotation. So rotation is another key factor. the obviously heating and the rotation, okay! so, on top of that you have this seasonal variation which is different time of the year one can see the different variation so all this gives rise to this variation in the circulation so in a nutshell this special variation in heat transfer to this earth atmosphere, create the variation in atmospheric pressure. Pilt which causes air to move from high to low pressure. So, air moves from high pressure to low pressure.



So, what one can see there is a pressure gradient which kind of gets established in the vertical direction but obviously it can have an effect due to this gravitational force and other things. So, that's how the circulations are going to impact this wind's motion and all these things or rather getting the wind is created. Now this is where the importance of the wind energy comes to the picture because you can understand that heating of earth surface is a natural process, rotation of the earth surface is also a quite natural process

and other things that is happening and obviously sea water level plate movements and all these things so obviously primarily this heating and rotations that creates this pressure differential which is going to cause this motion of the wind. And wind has quite a bit of energy. So, typically the kinetic energy of the wind is quite high.

That's the idea of this renewable energy production method or approach using this wind energy here. So, whole idea is that wind is treated like a fuel and this energy content of the wind that can be transformed for getting electricity and other things. So, to do that you have some requirement of the land area, I mean typically it's the 1% of the land area which is needed to have this kind of installation of the wind energy. So, if I put this information in that way, it's just like I have an alternative fuel source which is wind. So, that one can use to extract or harness energy.

Now, if we go back little bit of the history, this wind energy started long back when this was used for different purposes. And this picture is nice picture. Most likely these are coming from Europe and if not wrong in Netherlands where wind energy was used for and that's what they call it a windmill because these are the configuration of the turbine but the energy that you extract out using that you use for cutting of the woods and things like that. But yes, starting of wind energy is all this the whole development happened. So, we can see that how these things progress.

So, as I said that harnessing energy from wind power or wind is not something in absolutely a new idea okay it was used earlier but with the more and more demand towards the running non-renewable energy sources this has gained quite a bit of popularity or this has gained a lot of popularity and people have been emphasizing a lot different countries so that whoever has wind availability or wind potential where the turbines can be installed to extract out the energy from the if you look at the first wind energy system which was in the ancient civilization in the parsia so it was vertical axis windmill So, it is very connected to a vertical shaft which is grinding stone for milling. So, this is what you can see on the ancient age. Now, similarly in the middle age, so it was introduced in the North Europe where the horizontal axis windmills, so these are what I said the horizontal axis windmills because due to the motion of the wind, this whatever energy you get that translate into some motion to cut wood and all these things then 19th century in US where you have water pumping using windmills in the america so, where 1888 first large size wind electricity generation turbine which is 17 meter in diameter the generating power of 12 kilo was introduced okay then 1890 lewis electric company of new york cell generated to retrofit onto existing windows so then 1920 to 1950 propeller type two blade three blade so that's how you can see the and then euro leads to decline in wecs. okay! so that is how the progress was happening okay now,

modern era if you look at it so if you see some nice beautiful installation in some of the europe you can see these are the offshore wind turbine installations obviously we'll talk about this more when you move on so these are offshores so what has happened is that scale increase happened commercialization happened competitiveness took place grid integration so, now we have three blade horizontal axis wind turbine and if you see this picture with the size how it is increasing obviously, that has also increased the power production capacity okay, now one which here it is a six megawatt in a real turbine so we have already talked about that more and more swept area is increases because the wind power is area into velocity cube. so, one is that if you can increase the area so that's what it is happening here increasing area that is increasing power but also the velocity to increase but more you increase the size is going to increase, i mean more you try to generate power by increasing the size obviously the size of the turbine is going to be so so this is how in a cartoon you can think about wind physics basic that it's more like an so if we put them together so, what we have we have atmospheric air in motion that is what is wind energy source is the solar radiation primarily absorbed by different earth surface, converted through convective processes due to this temperature difference to generate this motion.

So, we have spatial scale, planetary scale, the global circulation, synoptic scale, weather system, mesoscale, local topographic and thermally induced circulation, microscale, urban topology. Now, that's how you can have different type of wind And, you can also think about different types of wind energy. So, if we look at the planetary circulations, there could be jet stream, there could be trade winds, there could be polar jets. You have geostrophic winds, you have thermal winds, you have gradient winds, you have topographic winds, wind storms, land breeze, sea breeze, down draft, typhoon, tornado. So, there are, by the nature, different kinds of things you have so that kind of allows you to have different types of windows wind types so, if you look at the wind energy this is a picture from a 1.

5 megawatt turbine in texas US. So, just shows that the structure of the size and you see the people sitting there for the maintenance work or some kind of when work so wind points operate on a simple principle so the energy in the wind it turns these blades which are having some kind of a airfoil shape and all these things and turns around a rotor, rotors and all these things sit here in this particular we'll see that what are those things The rotor is connected to the main shaft which spins and generates to create electricity. So, it's a simple you have a mechanical motion which is turning and generating the electricity. That's what it is. So, wind turbines are mounted on a tower to capture most of the energy.

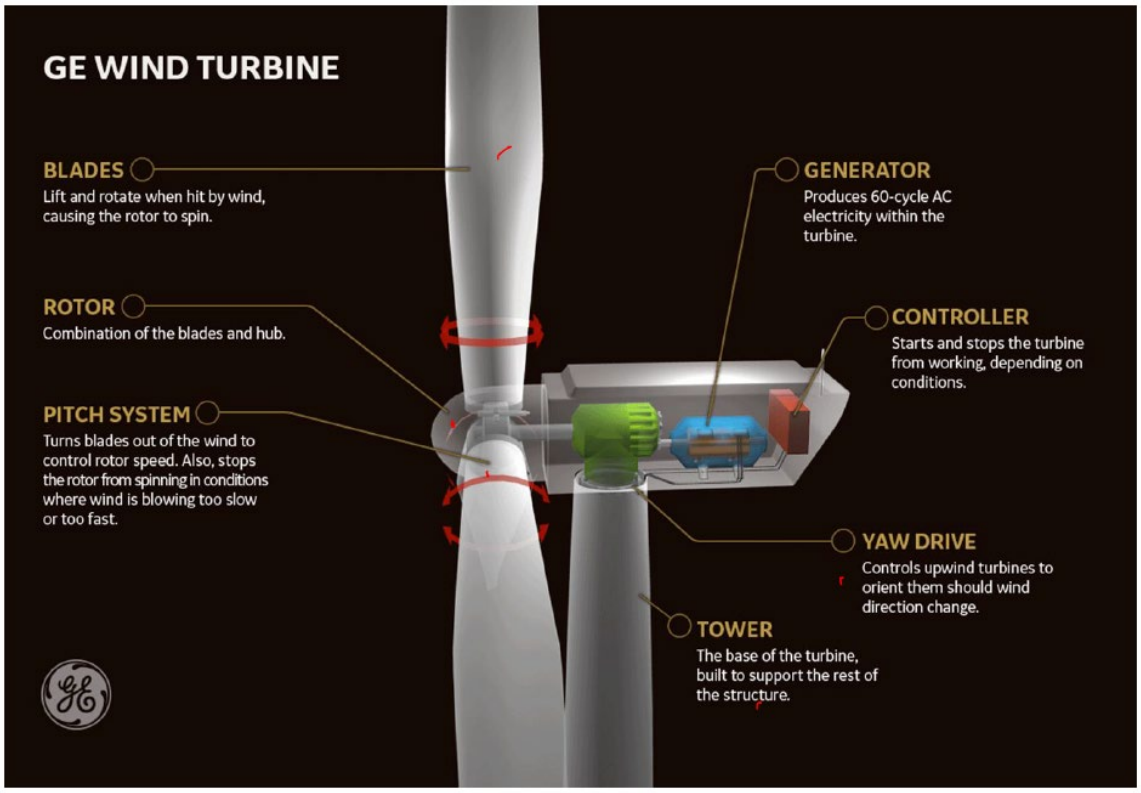
So if you have certain height then this could be above the ground that could be advantageous for less turbulent wind which would allow you to, also, wind turbine can be used to produce for some home and building they can be connected to a grid or more widespread electricity distribution so depends on the kind of that so now if we look at the some of the advantages of the wind energy it's a clean and renewable source of power so that is one of the advantage This is cost effective because you are using wind as a natural fuel. You have rapid growth of industry and large potential because a lot of private partners, public partners, they are collaborating or having their joint venture. But yes, as we know, there is nothing comes at free. So, there is a cost to pay is that wind reliability that means to use wind energy or generating power through wind important resource or important key gradient is that the reliability of the wind that means throughout the year we should have a sustained wind speed and all these and these are the things we will talk about more and more as we move on the discussion because why they are going to play an important role, and how this distribution can vary. So, there are places where you can have turbines installed, but maybe throughout the year you don't have the proper wind flow.

So, how that varies the production of the power and all these things. So, wind reliability is an important point, which includes a lot of other factors. So, which may include that, where are you going to install the turbine, whether the availability is there or not, throughout the year, what is the variation. Throughout the month how is the variation? Throughout the week how is the variation? Throughout the day how is the variation? So, all these are going to be considered when somebody wants to install a turbine in a particular location or try to optimize that how much wind one can produce and things like that. Now when you talk about this large horizontal axis wind turbine there is always a threat to wildlife because it rotates along a bigger diameter so anything any birds environmental things there would be some issues because if they are within this domain then there is a chance of having it with the turbine blades and all these obviously some noise and visual pollutions are also there okay now what are the Key components of these wind turbines.

This is horizontal axis wind turbine because we will later talk about vertical axis wind turbine as well. But this picture is all horizontal axis wind turbine. So you need one foundation above which things are going to be. Then you need a tower.

So this is the tower. We will come to that in the next picture where things will be much more clearer. You need rotor which is housed here. You need vessel. gearbox you need high speed shaft you need generator control system your mechanism your mechanism is going to actually change the motion of the blades and things like that so i mean this is the

tower and you have a blade then you try to depending on the width you should be able to move like that so those kind of mechanisms also need to be installed there Here is the picture of a GE wind turbine, these are your blades, this is where your rotor, this is your pitch system, yaw drive, tower, controller, generator and all these. So, yaw is a twisting or oscillation motion of the moving ship or aircraft around vertical axis.



this is what if we talk about the wind turbine as i said if the air is coming from this side perpendicular to the this thing so this is called the air motion so depending on the wind coming from this side the blade should be aligned to some extent pitching is that this is the horizontal axis around that the pitching happens so obviously you can make little bit of adjustment to the blades so that, so this is these are some of the key components of the turbine horizontal axis wind turbine and their mechanism drive which is sitting so you can see from the base is the foundation and the base at the bottom top of which the tower is there and then you have so typical turbine characteristics that one can think about the rotor diameter is up to 120 meter how wide is one up to one so up to six megawatt now but 15 megawatt offshore which is essentially this 15 megawatt is an latest nrel us national renewable energy laboratory their design which has been tested typical cutting wind speed will be three to four meter per second rated wind speed could be 15 meter per second cutoff wind speed typically 25 meter per second and things like that now it depends where we install these turbines so onshore Typically 2 megawatts, some up to 4 megawatts, but restricted due to the logistical difficulties of transporting blades by road. So onshore output capacity is not very high compared to the offshore output capacity,

which is quite high. Where the turbines are available, largest can be available and you can install there because it's on the onshore, so you don't have the other hazards like land, transportation, wildlife, noise, pollution, things like that. Oh, that is one of the advantages. So as of today, your offshore production capacity is quite higher.

I mean, three to four or five times magnitude higher than the onshore capacity across the world. Also, that can lead to some other challenges like building larger turbine for offshore is one of the keys to reducing the steel height unit cost of offshore wind energy. So, not only that, the installation of the offshore turbine kind of poses a different kind of challenges. So, that's another thing that one can think about. Now, again coming back to this particular picture where you can see as we have increased the production capacity how the turbine size has gone up.

you can see this is 126 meters typically airbus 380 which is one of the largest aircraft the wingspan is 80 meter now you think about 126 meter how big is this so that means to install it and now this is going to be more higher for 15 megawatt survive so, This kind of large size turbine, as we say that power always increases with the area. So, if our area is higher, then you can have larger turbine for producing capacity. But at the same time, handling, maintenance of this kind of large size turbines are not very easy. Because this gives you an idea when you compare with the Airbus 380.

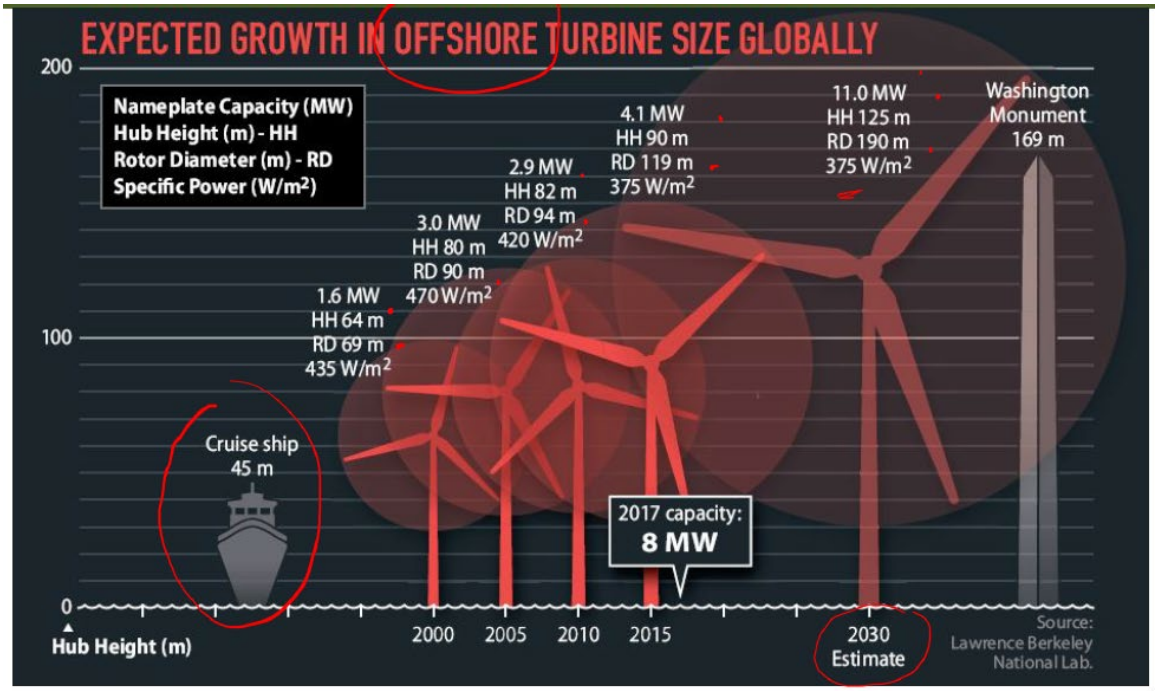
And that's such a big aircraft. It cannot be kind of landed in every airport across the world. There are specific airports where they can actually allow that landing of that big aircraft. And you talk about 5 megawatt, where that 126-meter turbine blade is such a big one. And 15 megawatt, this is quite higher than that. Now, similarly, if you look at the trends in the onshore wind rotor diameter and turbine size, and this is a distributions at different country wise.

So, this is how the year wise that has, I mean, this data is from the old data, but just to give you an idea, how this trend is varying across the country and how that is changing with the diameters and all these things. So, now expected growth in offshore turbine size globally. So, You can see very interestingly the cruise ship which is 45 meter. We have 1.6 megawatt which is height is rotor diameter is 69 meter.

3 megawatt rotor diameter 90 meter, 2.9 94 meter, 4.1 190, 11 megawatt 190. This is what we expect by 2030. as we so this is again we are talking about and this is specific power and the so the trend or the increasing trend with the size that is obviously these are offshore turbine so more and more power generation capacity has been established you

need a larger swept area of the turbine so more larger swept area obviously that can pose different challenges it poses challenges of the design optimization optimization includes everything not only optimizations about the turbine performance and all these things optimizations also one can think about the logistical optimization that the geometrical locations transportation of the electricity to the grid or nearby places so everything should include in this optimization process it's not only the design optimization process that i mean then design optimization then installation Then you have these things, what you call transportation. Then power transmission or power distribution.

So, where you produce, you might need to transmit that produced electricity to the nearby places or some grid. Then from there, you will try to distribute. Obviously, later on when we talk about the turbine technology, you can see that what wind turbines what kind of current or electricity it produces and what we use at the household level our daily use we we use alternative current but turbine produces direct current so these are all these different kind of factors that one has to I mean so more and more larger we increase in the size yes You can produce more power, but at the same time, one has to keep in mind that there are the other challenges as an engineer you are going to face. How am I going to design this? How am I going to manufacture? Yeah, one important factor is that design optimization and manufacturing. So, How am I going to manufacture this? And all these things you have to install as a system level integration where you need to connect that, okay, how am I going to transmit my electricity from there to grid or the nearby usable places and things like that.



So these are the challenges, the key challenges that you have while you are increasing your size. At the same time, it is also true We need to increase the size to increase our production capacity or energy harnessing capacity. We'll continue this discussion in the other session. So we'll stop here and continue from there in the other session. Thank you.