Wind Energy

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Lecture 36: VAWT (contd..)

We'll continue our discussion on vertical axis wind turbine. I mean, what we have started talking about, the basic working principle of vertical axis wind turbine. And, then since these are mostly drag-based, so like we looked at different kind of, I think this is the last discussion topic where we kind of stopped on that the different kind of these drag coefficients and how they vary because eventually your drag coefficient data is going to contribute to your drag force calculation. So, that is what we talked last time. This you can see, you could see here the multi-stage turbine. That means you have one kind of structure or the frame and then you have four, one, two, three, four turbines which are connected in one particular structure.

the whole idea one can think about here is that it is kind of similar of a putting horizontal axis turbine in a kind of a farm here since these are size i mean they are small in size the vertical axis turbine and they are portable also so they can be built like that so similar thing one of that helical design as the similar kind of structure. So, you see these blades are of helical shape but if you see in total the footprint or the size of the complete turbine including the gearbox and the other components they are not very large so kind of a four of them could be installed in that kind of a one single foundation like this and if they are portable if possible they can be also uh some optional installations could be carried out uh i mean one of the simple reason for that in the offshore you have a good wind availability so once you have good wind availability, then you can always carry out this exercise and you can install this kind of different structure of the turbines and all these things and then use make use of that so obviously when you use multiple of them the advantage that you get out of that that your overall power coefficients can be increased or multiplied by that many times of this thing so now this is again a darius type so this is a darius type vertical axis wind turbine bitten where one this one you see the kind of a carb blade But overall principle, if you see, this is a Darius type and this is the, so, this probably one can think about front view and this is probably, the side view and you could see how these airfalls are going to obviously, they are having some blade pitching mechanism so airfoil could change their pitch so this is something a slight different between horizontal axis wind turbine one can think about horizontal axis wind turbine your blade has the rotor blade has a fixed pitch angle at a particular section obviously when you go from I mean if I let's say go from this is hub to tip so at multiple section there could be different aerofoil but you could have a fixed pitch angle and obviously the pitch motion can be a little bit controlled but not completely as the wind direction changes or if you have too much of incoming flow change and things like that Whereas, in this particular case, in the particular situation of vertical axis wind turbine, what you could do is that you have this airfoil sitting here. Now, this airfoils could be, so now this is a structure like I have a shaft like that and This is the blade of a vertical axis wind turbine which could be connected like that and they are kind of rotating. So, the thing is that this blade pitch angle, this could be fixed.

so, that means like a horizontal axis wind turbine this could be fixed and keep on rotating or they can have variable pitch mechanism, so, this is the advantage you have compared to horizontal axis wind turbine the situation is such that the in horizontal axis wind turbine if you try to build something with variable pitch actually that's going to be a big problem because the turbine blade diameter or the rotor diameter is quite high whereas in the vertical axis wind turbine this variable pitch mechanism could be an easily doable choice and usually done in fact to be to mention here um the similar kind of darius concept and all these are they are available in the hydro kinetic energy also and there also you have axial which is comparable like our horizontal axis wind turbine and this Darius type and all these they are comparable they are also in hydro and hydro this variable pitch and all these are very very handy and they kind of help you to achieve the power output and things like that and now the point here is that so this is the advantage that you have compared to vertical axis wind turbine in the horizontal axis wind turbine you can achieve this kind of things and here you could see some installation of this kind of an this kind of an carb blade installation so these are carb blade but, it's installed in a i mean kind of an form kind of and this is how closer view it shows that how big that is now if you try to look at in little bit more details about the component and all these things so here is the image of that that where you can see what are the some i mean those important components and that one vertical axis wind turbine may have okay you see this upper half this is lower half this is the rotor blade and it is curved like this but then you have generator sitting here you have the gearbox and everything so this is your kind of a small basement compoundation then only one set but this height could to be high as high as your horizontal axis wind turbine but usually not that much because these are for small power generation purposes but they are quite mobile they can be transported easily and installed in to cater to the small requirement of energy demand or supply demand such kind so Now, the question is, you could see this particular, this is called the another, I mean, similar concept of a small gyro mill Jarius vertical axis wind turbine. This is in Colorado, where it has been installed like that. So, you capture the wind and I mean, obviously, when you are exposed to the wind and you get this kind of, what do you call, the power generation which can cater to this small. So, that's a nice picture of basic, this various type vertical access wind turbine installation for local neighborhood applications or things like that. now, here now we come back to see how these turbines actually produces the power and so as we discussed earlier primarily there are two concept which are i mean used one is the drag based.

So, the drag-based concept, what happens is that you have these blades which are sitting on the, I mean, obviously connected with the rotating shaft and there is a concave surface and convex surface and when the flow comes and hitting the concave surface, then it rotates and the convex surface comes this side. So effectively, this difference in the forces and all these that creates the that creates the torque and that torque is finally used to produce power so, if you see the net torque for this drag based case it's a difference between these two turbine and their torque so, what you have so then you find out the complete torque where your drag coefficients are there which is cd1 is one drag coefficient cd2 is the second drag coefficient velocity distance from the net force density blade area and all this thing so this is uh quite uh straightforward that once you consider this. The other case is the lift-based. This is a various type of these things. So, I mean, the drag-based, one can think about it's a kind of another classification that we have already discussed earlier is the savonius kind of things.

And, this is the various kind of things. But as you see, these are the straight blades. You can clearly see this airfoil section here. they are connected with the main shaft with the connecting rod or supporting arm and then the bottom, you will have the generator assembly and all these things would be there, okay so, here you have this tangential velocity wind velocity resultant velocity angle of attack airfoil chord that span and if you look at one particular airfoil here okay and then try to see the distribution of the forces so you could easily see the component of the lift and drag forces and then you have the resultant forces come based on angle of attack here so again this is your velocity triangle kind of similar concept that we have used in the horizontal axis wind turbine so it's a respect to so when the wind is coming then in respect to a particular plane of the aerofoil so you take one airfoil and see how that looks like but you are looking it from the top so this is the cross section so that you get this cross section things and when you look at from the top then wind would hit the blade in this fashion because the blade is at angle of attack so the cl and cd force coefficients one can find out so these are the standard way to find out that then the tangential and normal force which could be taken into two component of this cl sine alpha cd sine alpha and all this component and finally the power is the t into torque into omega and torque is the Ft with the radius. So, that's how you calculate the things.

Now, if you compare the Newton's law of motion so then you could I mean, easily see the linear motion to the rotational motion and the parameters. So, there will be position X here, the angular position theta because it is rotating in an angle. So, with the reference frame, so you'll have that theta. velocity v here the angular velocity, omega acceleration a angular acceleration alpha motion x equals to vt here theta equals to omega t then v naught plus a t omega naught theta and acceleration, so they go by the similar fashion which follows exactly the newton law of motion then the linear inertia m then moment of inertia i F equals to MA, I alpha, MV, air angular moment I omega, work FB, tau theta, half MV squared, half I omega squared, power FB, tau omega. This is what we are interested in so that once we got the torque and we get respect to that thing.

Here is another picture of a vertical axis wind turbine which is again Darius type. And this was in how you can see the structure is made such that this can be used to go for all maintenance purposes and things like that. And the connecting arm is taking the rotor blades away from this foundation structure so that it never touches or there is no possibility of getting it I mean getting it interfered or there could be interference, all these things. So, that's how the picture of the vertical axis wind turbine that you get to see. Now, if you come little bit more details about now straight blade vertical axis wind turbine, this is the name Darius is usually associated with the curved blade version of the Darius pattern.

but a lot of work over the past decades have gone into development and analysis of the straight blade version of vertical axis wind turbine which is also known that H vertical axis wind turbine or we sometimes call it H type Darius so because the blades are straight not curved but the original invention of Darius was curved blade so obviously, One of the great research came up in 1970s regarding that. Now, Gyromille is another consequence of adopting a vertical axis wind turbine is the apparent velocity of the wind in a particular location. If you see this is the wind coming in and the blades which are going to expose to that and every time you have angle of attack, the theta from the centre, when you have beta, So, the blade is travelling upstream because if it is rotating like that with that angular velocity so you have local wind velocity you have velocity due to blade movement you have resultant wind velocity. So, essentially this again going to, so, if you see at the every blade there is a velocity triangle associated with it. and the reason is the simple because you have wind coming in the blades are rotating so there will have this r omega component and there would be a resultant and there is will lift force also because of the flow passing over the airfoil so obviously you end up getting those resultant component of the force now, When the blade is travelling upstream that is azimuth angle is beta 0 to 180 degree so beta is varying like that.

Resultant air velocity on the blade is greater than the tangential velocity of the blade which is relative to the stationary frame of reference. Now, when the blade is travelling in this quadrant that is the third and fourth quadrant. the resultant speed is generally less than the tangential velocity. So, that you can see from this and this velocity triangle, whereas the other two showing slightly different. So, which in turn means that the blade is continuously changing the angle of attack and obviously may not be optimal.

throughout its rotation about the axis of turbine. So, how to improve the situation? So, to improve the situation there are various ways it has been tried to optimize the blade pitch angle. So, which is the pod angle relative to the tangent of the path of the blade as a function of beta. there are different ways one could achieve this one is the mechanical mechanism with levers or push rods connecting between the blades and the main rotor shaft or aerodynamic mechanism, so, one way you try to control through aerodynamic mechanism which could be to some extent kind of an active control but the other one is more like a passive where you try to have this some levers or rods connecting so that you try to change that effective pitch which is going to change. Turbines which seek to optimize the blade pitch angle known as viromills although some authors refer to this cycloturbine.

So, these are the now if you see this straight blade wind turbine need to control the power output of the device at high wind speed. and the active pitch control of the blade would result in unsafe complex mechanism. So, this is wind coming in and this is the rotation or rotor rotation and there could be blade rotation. So, this is where the blade is continuously also changing their pitch. So, here it says that this particular work says that the straight blades could be hinged and their midpoint so that the angle of blades relative to the axis of rotor could be adjusted by mechanical actuator.

So, here you talk about the mechanical actuators to handle such conditions and all these things. So, the pitch mechanism which was activated by the movement of aerodynamic forces around the pavement, so that can oppose the centripetal force and this can act like a stabilizer mechanism or stabilizer mass attached to the radial arm, okay! so, ideally what it does that the aerodynamic force overcomes the stabilizer moment and permits pitching before stall occurs, that means, when they are continuously changing so what happens is that these blades are continuously changing and rotating like that so, this is how this happening the continuously changing the flow is coming and hitting the airfoil like that so there is a possibility of flow detachment so when that happens then there could be stall so by changing the effective angle of attack so all this whole idea is that your angle of attack of the airfoil if this is your airfoil so if this is your angle of attack which is going to expose to the oncoming wind then there could be a separation and stall so you effectively change it so that flow remains at once you passes that point then you again change the angle of attack, because sometimes i mean it's a mechanism because your angle of attack change is required to increase your lift and the lift here is going to make the sap to rotate so obviously if you have more and more rotation you are going to get more power that is a simple mechanism that is what it works upon but since this is the aerofoil which is rotating and exposed and wind is coming there could be separation so you change that you allow the flow to attach passes that point then again you change your angle of attack so, it just continuously that is what it doing the variable pitch because it changes its speed and obviously once you do that you got significant improvement in the power productions and all these things So, this could be, you can visualize a little bit, I mean, much better way here. If you see, this is how the original, I mean, the whole three blade constructions with all the connecting rod, you have main shaft and bottom foundation. And if you, so this is the, I would say the front view, and this could be your, uh top view because you get to see this airfoil the section of that particular blade and you see they are connecting with the main shaft and this is the second link and how they are from the top you could see that and what happens is that this is your now this is again a top view this is again your top view but with variable orientation okay so you could see that the airfoil here at zero degree now when it came so this could be the angle but the second one can second rod can change it and again it comes here so that you make it pretty parallel to the flow and here again you change it so effectively you keep on changing and then rotating so along with the rotation keep on doing that so this is an from the research paper which has been taken you could see that how they are done you have a, i mean, this clearly shows you how whole thing is manufactured so this is your main rod and the and then the arm and there you have some kind of a spring okay, and the spring is connected with another connector and then the secondary pull rod so that means if the blade is going like that you kind of the second rod can pull it down and that is connected with the spring obviously this should be controlled by aerodynamically so well you say this this case how this pitching has been changed in this case so the spring plays an active role here so here is the another closer view of this spring system connecting to that and this is where you could see that how this mechanism basically that secondary rod cam profile mechanism is going to work so ideally they rotate and this spring and the secondary connecting mechanism try to change that thing in a kind of an this is kind of a combination of active and passive control one could say like that way I mean similar way I mean you could see this different component of sensors and all these things in one foundation you have multiple turbines which are constructed and they are obviously, giving you more power output. And like horizontal axis wind turbine also the blade design is an important aspect of it.

So, your blade actually commands the performance of vertical axis wind turbine. So, various types of blades are shown here. This is lift and drag based vertical axis wind turbine. You have multi-blade vertical axis wind turbine. Then you could see the J-type vertical axis wind turbine here.

J-type vertical axis wind turbine here. This is vertical axis wind turbine with kind of a flapper. So, all these different kind of mechanism that you could see these designs, these are tried to, I mean, improve the performance parameters so the performance when you talk about the performance is essentially you try to maximize your power that's the final objective that's what you come up with different kind of sometimes active sometimes passive mechanism and try to but advantage here compared to the horizontal axis the size of the complete turbine is absolutely way significantly lower and they can be portable and they could be installed in different places and then maintenance becomes easier and you could have a different kind of designs of the blades could be completely curved twisted helical and different shapes and different this kind of mechanical mechanism to control the pitch and things like that but to be specific easily controllable system because the size is way smaller than the horizontal axis wind turbine Obviously, the power output is also order of magnitude different in horizontal axis wind turbine. But in this case, the size is small. That's why, multiple of them could put it in one place and try to extract out energy which can cater to small need and things like that.

So, we'll discuss this part details in the next session. Thank you.