Wind Energy

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Lecture 48: Mechanics: Simplified Hinge-spring model

Welcome back. So, we continue the discussion on the hinge spring model. So, what we have discussed so far that the different components of hinge spring model, what you have. different components and then what the hinge and spin does and different direction of the motions and then we'll be primarily focusing on this flapwise motion. So, this is discussion on hinge spin model. So, we'll develop this simplified model idea here is that though this model is simplified but this incorporates all the interacting effects so, that we have a simplified system to now so, when we develop this the development includes how the rotor response to the following process of loads.

So, it could be rotor rotation, steady yaw rate, steady wind, yaw error, linear wind shear. So, essentially this whole development of this linearized model incorporates the effects how the rotor responds to this set of nodes, including rotor rotation, gravity, steady yaw rate, steady wind, yaw error, linear wind shear. So, all these are part of that. Now, these loads may be applied independently or, combination also this can be applied independently or in combination.

So, what this analysis would provide a general solution for the rotor response which is, So, solution which will be a function of blade azimuth, the angular position of blade rotation. so, obviously the solution would contain different terms one could be independent of azimuth position then it could be a function of sine of azimuthal position or the function of cosine of azimuthal position so the solution will have three terms one is that independent of azimuth position, function of sign of azimuthal position, function of sign of position. So, this essentially would contain the different components. So, the whole development is broken into two components. Number one, pre motion Number two, forced motion.

Okay. So, the free motion that includes the effects of gravity and rotation and this includes steady wind and steady yaw. Now anything we deviate from here the steady wind or steady yaw. So, any deviation will be considered as perturbation. So, if it is a steady yaw or if it is a steady wind, it can be consider as a perturbation.

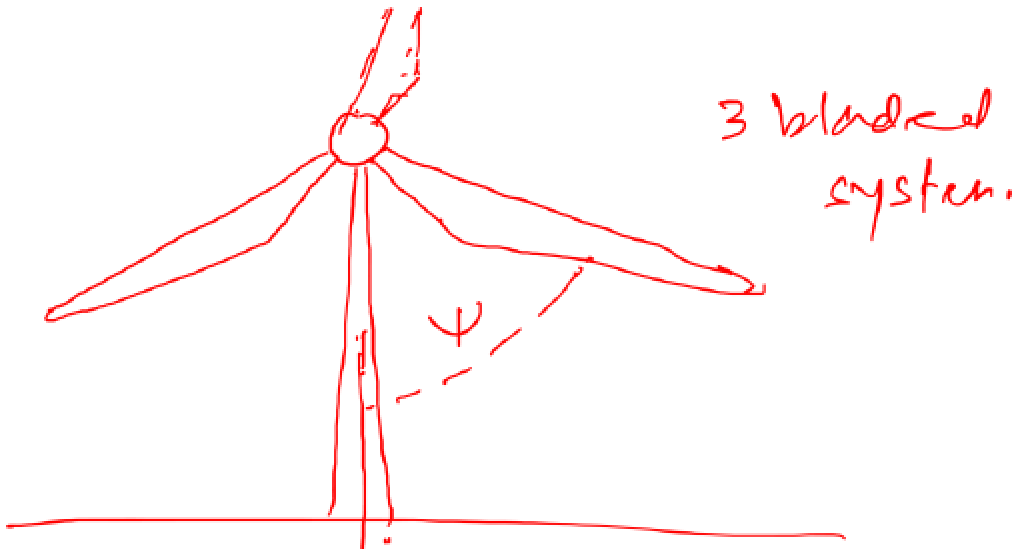
So, now the thing that is important. So, these are the overall picture of the development of the hinge pin model. So, one is that the rotor responds to different forces. So, what we talk here is that To develop that simplified model, we'll look at the rotor response to different forces. It includes rotor rotation, gravity, steady yaw rate, steady wind, steady yaw error, linear wind shear.

And then these forces we will consider sometimes independently and their subsequent effect model development. or, we take some of them in combination depending on the impact of those sources of the forces now the solution that finally eventually will evolve that would be the function of blade azimuth and the angular position of the blade rotation so, we would consider some independent of the azimuth position then function of sine or cosine and then the solution would evolve accordingly And, while doing this particular development, so we'll consider two ways. One is the forced motion or free motion. The free motion includes the effect of gravity and rotation. Forced motion includes steady wind and steady yaw.

And, any deviation from those steady wind or steady yaw would be considered as an perturbation to the system. So, this is the overall idea. or based on which we are going to develop this simplified the important thing is that coordinate system okay so one has to define the coordinate system because this should be important to derive all the model analysis their model development and their analysis all the equation of motions So, what we can see is let's say particular wind turbine. Let's say if we say this is a turbine and we have all the blades. Okay, so what is important from this line to this is side, every center.

So, that is, so where we can apply that. So, here, what is the, three bladed system. Okay. And so, what are the the factors that affect the emotion one geometry two rotational speed, three blade width. And any other external forces that would be considered as we keep on doing our analysis.

Obviously, some assumptions are there. Okay. So, what we can say that A, the blade has a uniform cross section. Okay. B, the blade is rigid okay! and the blade hinge may be offset from the axis of rotation the blade hinge may be offset the axis of rotation d when rotating the rotational speed is constant.

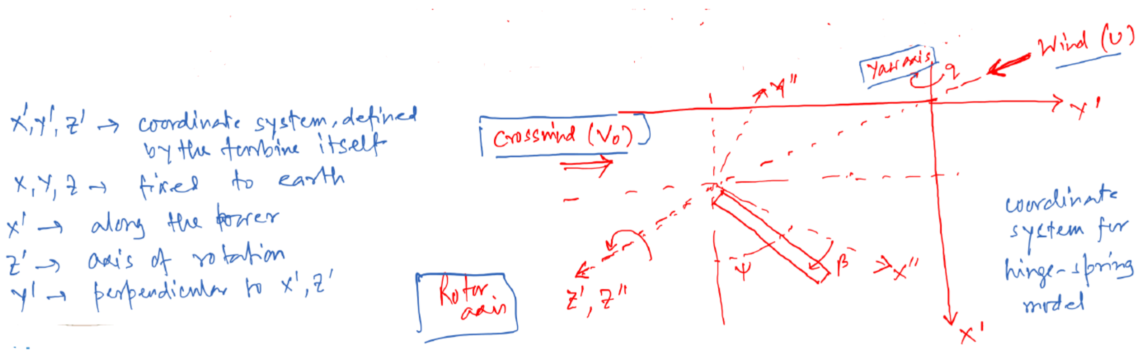


So, these are some of the assumption that would be associated with this. So, any other hinge spring stiffness or offset for the model, we would take into consideration while discussing this whole thing. Now, I mean, it's too. So, we'll kind of draw this system. So, let's say, okay, so here we'll have So that's the one.

And this should be one there. This goes there. Yeah. And all this, we have this. And this is something.

Yeah. Now we say. This this. this is xi this is beta okay this is y double prime this is double prime this is my rotor axis This is V0. This is x prime, y prime. This is wind speed, u. This is q that is essentially my your axis okay! this is wind this is crosswind this is rotor axis so that's uh pretty much the axis system so, this is my coordinate system for inch in model okay! so, here what we have we have x prime y prime z prime these are coordinate system defined by the turbine itself okay Whereas X, Y, Z speaks to Earth.

X' is okay. Z' is perpendicular. to explain. Get one.



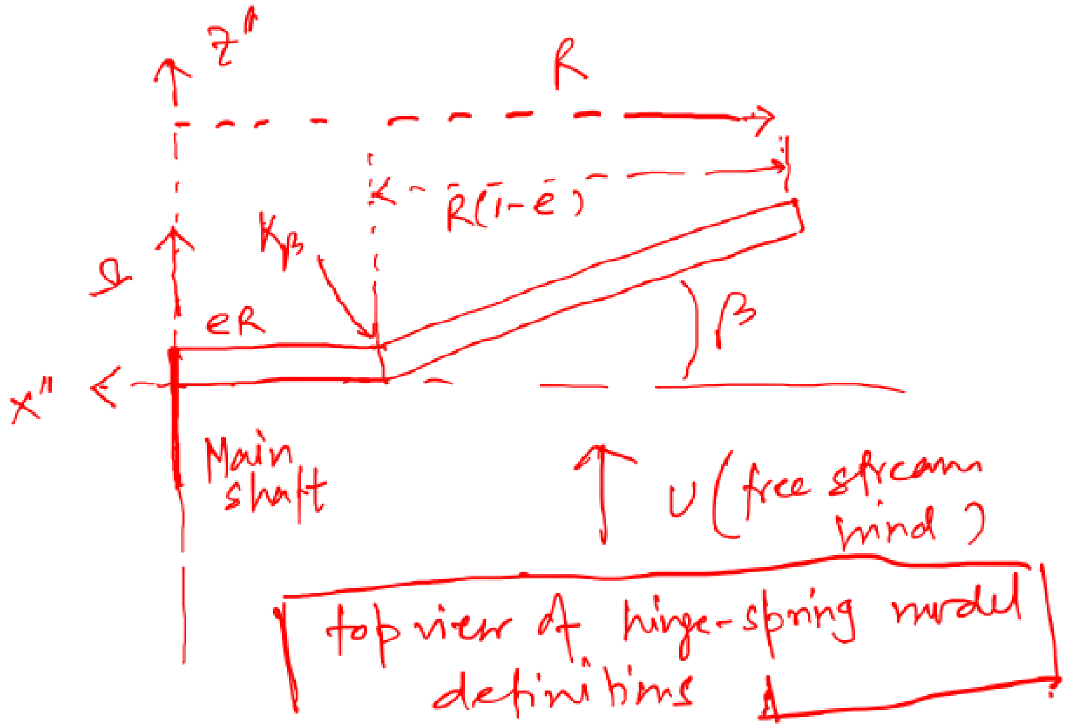
OK. Now we have. It's double prime, double prime. These are. Axises.

Routed with. The rotor. So, for this. For this. graph or configuration shown here. X double prime is aligned with the blade but in the plane of rotation. Size and azimuth angle of the blade with respect to expand.

So, blade itself is turned out of the plane of rotation by the flapping angle beta. So, beta is the flapping angle. So, essentially the blade itself is turned out of the plane of rotation by beta. So, also this particular figure reflects the assumption that the direction of the rotation of the rotor, so the direction of the rotation of the rotor and is consistent with right hand rule with respect to the positive sense of the X, Y, Z axis. So, specifically when looking in the downward direction the rotor rotates clockwise.

Now, we can see the other thing. Basically, let us say So this is a double prime. This is Omega.

Get double prime. This is R. This is beta. main shaft which is free stream wind and then that is r into 1 minus e that is e into r So, that is K of beta. So, that's the top view of Hint-Spring model definitions. So, that's what you will get to see. So, this top view here, what it shows that, that a blade which has rotated past its highest point that is azimuth of phi radians and is now descending.



So, specifically the view is looking down the y double prime axis so that's what you'll have this I mean what you see here that this is the picture that you have. So, I mean, we have these assumptions to develop that. I mean, some of the assumptions like the blade has uniform cross section, blade is rigid, hinge may be offset from the axis of rotation. Then we have this coordinate system here where x prime i mean x y z is attached to the earth x prime y prime and z prime or z prime that's the coordinate system defined by the turbine itself that means that coordinate system is sitting on the turbine so one you have x y z and the earth then we are sitting one reference frame and the turbine that is designated here x prime y prime and z prime then if you see x prime is along the tower that means if this is my turbine tower then x prime is along the tower z prime is the axis of rotation that means this is z so this is how it is rotating And Y prime is perpendicular to that X prime and Z prime.

Okay. And, then you have X double prime here, Z double prime, Y double prime. These, are the axes which rotate with the rotor. That means as rotor blades rotate, so this X double prime, Y double prime and Z double prime also rotate. So, here, as it's shown, essentially your, so this would be X double prime. So, X double prime, actually aligned with the blade, but in the plane of rotation.

And psi is the azimuth angle, beta is the flapping angle, okay? And then we have this top view of this thing where you can see. So, this is looking down through the y double prime axis. And then you get to see how this blade is hinged. with the radius of the rotor dia along with that. So, this is what the coordinate system that we define to develop the model.

So, that we have all the information in place to carry out the development. We'll continue this discussion in the next session.