Breakthrough research for testing and arranging vertical axis wind turbines

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The Shepherds Flat Wind Farm is an 845 MW wind farm in the U.S. state of Oregon. Credit: Steve Wilson / Wikipedia.

The sight of propeller-like rotating blades positioned high up the pole of a tall horizontal-axis wind turbine (HAWT) may be familiar to many. Often grouped in wind farms, HAWTs provide significant amounts of energy for local communities. One drawback to HAWTs is the large space they take up, needing to be placed far apart from each other. If placed too close together, the turbulence and wind velocity deficit caused by one HAWT can make a neighboring HAWT output much less power.

To address this, researchers are looking at vertical-axis wind turbines (VAWTs), which could be either arranged in groups or interspersed within HAWT arrays. A VAWT has an overall cylindrical shape, with the blades aligned parallel to, and rotating around, the pole on which the rotor is mounted. These "egg-beater" VAWTs tend to be much smaller than the "propeller" HAWTs, typically about 10 times shorter in height, and output only about 0.1 percent as much power per turbine.

Anna Craig, a mechanical engineering doctoral candidate at Stanford University, and her research team recently studied modeling VAWT array arrangements, the results of which they report this week in the *Journal of Renewable and Sustainable Energy*.

While a single VAWT is not as energy-producing as an individual HAWT, the wind flow synergies created in a closely-spaced array of VAWTs can potentially generate up to 10 times more power per unit of land area than an array of widely-spaced HAWTs.

"For the vertical axis wind turbines, what you get, especially as you place them in close transverse proximity to each other, is that they can actually interact positively," Craig said. "Although it is still an active area of research, we think that the VAWTs can have blockage effects causing speedup around the turbines that helps downstream turbines. They can also have vertical wind mixing in the turbine's wake region, which assists in the wind velocity recovery."

Craig said researchers agree that there is more research to be done on VAWTs before they can be deployed at an energy sector scale. However, Craig and her colleagues provided significant insights into one central

VAWT challenge: how to research, test and develop insights for effective array arrangements. They did this in a lab experiment because field testing is currently very expensive, and computer simulations are not yet refined enough or are too computationally expensive.

"Right now the majority of numerical simulations are either fully two-dimensional or are three-dimensional, but use highly simplified, effectively two-dimensional models for the turbines. Neither approach can capture the vertical flows, which are critically important in the energy dynamics of a VAWT system," Craig said.

Craig and her colleagues believe that this lab experiment and similar follow-ups offer important possibilities both for in-field arrangements and refining numerical simulations. They conducted the experiment in the large water flume at the Bob and Norma Street Environmental Fluid Mechanics Laboratory in the department of civil and environmental engineering at Stanford, with the system's water flow effectively representing the wind flow.

Craig set up roughly 1,300 1-inch gears between plates, which were reconfigurable during the experiment. On top of these gears sat approximately 300 rotating cylinders mounted to create a 10-foot-long array, with the cylinders effectively representing VAWTs. They tested a total of 10 different arrays with different configurations.

"The three variables I was looking at were spatial configuration, rotational configuration, and height configuration of the elements," Craig said. "I wanted to find out how the interactions between elements could set up larger scale flow patterns."

The experiment illuminated the VAWTs' time-space averaged vertical flow, which is significant for turbine arrangements.

"What I saw is this net vertical flow from above the array, down into the array and out the sides of the array, which was somewhat unexpected." Craig said. "These net vertical and transverse flows eliminate horizontal homogeneity within the array and introduce a new mechanism by which the energy resource within an array can be replenished."

For future studies, Craig said this experiment offers important insights for both numerical and in-field testing.

"The three-dimensionality of the flow through the array is critical to understanding the energy dynamics of the system," said Craig. "This paper really focuses on allowing us to design appropriate numerical and experimental studies."

Craig is optimistic about VAWT technology and its potential uses, noting that in the future it might be interspaced within HAWT arrays and brought to places that are not amenable to the much larger HAWTs, such as islands and cities. She says that VAWTs could also potentially be less environmentally impactful than HAWTs.

"We should consider numerical or even field experiments with larger numbers of VAWTs because the laboratory experiments have shown that the physical mechanisms are there for these larger arrays of turbines to work," Craig said.

More information: "Low order physical models of vertical axis wind turbines" *Renewable and Sustainable Energy*, Feb. 28, 2017. DOI: 10.1063/1.4976983

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