WINDLETTER

THE MONTHLY NEWSLETTER OF THE AMERICAN WIND ENERGY ASSOCIATION

Volume 28 Issue No. 11

SMALL TURBINE COLUMN:

Back to the Basics— Quantity + Quality = More Electricity

--Mick Sagrillo, Sagrillo Power & Light

The past two columns have analyzed the two "enemies" of a wind turbine: ground drag (www.awea.org/windletter/090818_AWEA_WL.pdf) and turbulence (www.awea.org/windletter/091022_AWEA_WL.pdf). As those columns pointed out, ground drag affects the quantity of the wind, while turbulence affects the wind's quality. In this column we'll take a look at just how important these variables are.

First, though, let's briefly review the concepts of wind quantity and quality.

Quantity and quality

Wind, like water, is a fluid and, therefore, follows the same set of "rules" as water, the branch of physics known as fluid dynamics. If you have ever watched a river flow, you'll notice that the water is quite sluggish near the bank, but its speed increases with distance away from either bank. The river flows fastest in its middle, the greatest distance away from the bank. This is due to the friction that occurs between the moving fluid and the stationary bank. Increased separation reduces this friction, resulting in greater velocity of the fluid.

This is precisely what we want for our wind turbine: greater fluid (that is, wind) velocity. Ground drag, the friction between the moving winds and the fixed Earth, is reduced considerably with tower height. Reduce ground drag with distance above the Earth and you increase wind speed, or the quantity of the wind. This is why wind farm turbines are placed on such tall towers -- they seek to harvest the greatest quantity of wind at the site.

The second component of the wind, quality, refers to the turbulence caused by the ground clutter around your home or place of business. Trees and buildings cause the wind to tumble and swirl, which reduces the energy available in the wind that can be converted to electricity by the wind system. In addition, the chaotic motion of turbulence causes increased wear and tear on the wind turbine. Wind farm developers strive to site their projects a fair distance away from farm buildings, fence rows, and woodlots to minimize the amount of turbulence from such obstacles. That's because buildings and trees impart a double whammy on a wind turbine. They reduce the quantity of the fuel as well as compromise the quality—both undesirable effects if we wish to maximize electricity generation.

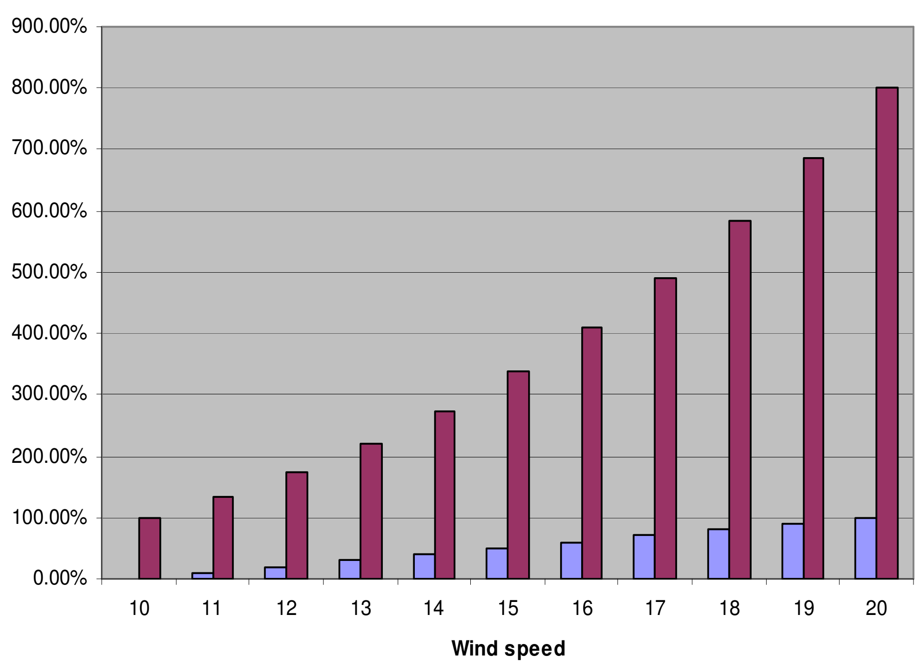
The power equation

The phenomenal influence of these two crucial variables becomes evident in one simple equation. The equation for determining the amount of power in the wind available to a wind turbine to convert to electricity is

$$P=1/2dAV^3$$

In this equation, *P* is the power available at the turbine rotor, *d* is the density of the air, *A* is the swept area of the rotor, and *V* is the wind speed. At a given location, we have no control over air density, so for any given wind generator with a given swept area, the only real variable is *V*, wind speed. Therefore, we can rewrite the equation to say P~V, or more appropriately $P \sim V^3$.

For those who understand the power equation, this is stunning. The V^3 portion of the power equation means that there is not a one-to-one relationship between increasing wind speed and potential electrical generation. Doubling the wind speed does not result in a doubling of power available to the turbine (a 100% increase), but an *800%* increase, all because of V^3. This is illustrated in the below graph, in which the blue bars each represent a 10% increase in wind speed and the purple bars represent power available in the wind.



The upshot of this is that very small increases in wind will result in considerable increases in the power available in the wind. For example, wind velocity increasing from a paltry eight miles per hour to only 10 miles per hour, a 25% increase in wind speed, results in a whopping 100% increase in power in the wind. Again, this is why wind farm turbines are mounted atop such tall towers: to maximize the fuel available to the turbines.

Lessons

A wind turbine close to the tree tops or the roof line of buildings suffers from lack of fuel, the wind, due to ground drag. In addition, the turbulence caused by the surface clutter at the site will further reduce wind speed and also cause increased maintenance on the turbine as well as shorten its life. In light of this, shorter towers than the site requires are no bargain because the turbine is not producing much electricity and its life expectancy is decreased.

Nevertheless, people often rationalize a short tower height based on the cost of the turbine. I have heard it said that a small wind turbine in the size range of 1 or 2 kW or so does not justify the expense of a tall tower, which could be four or five times the cost of the turbine. Worse yet, others look to completely forgo a tower and mount the wind turbine on the roof of a house. This reasoning completely ignores the physics of fluid dynamics that dictates the tall tower in the first place based on ground drag and turbulence.

To illustrate this, let’s use the example from above. If a given tower height has a 10 mph wind speed, and shortening the tower results in a 20% decreased wind speed to eight mph, we’ve saved money on the tower, but we’ve also reduced the quantity of fuel available to the wind turbine by a 50%, as well as compromised the quality of the winds by increasing its turbulence.

Taller towers invariably result in the wind turbine generating more electricity. As you get away from the surface of the earth, ground drag—or the surface friction between moving air masses we call “the wind” and the surface of the earth—and turbulence both diminish. As a result, wind speed—or V—goes up. V^3 considerably amplifies that increase.

To quote Steve Wilke at Bergey Windpower, “More tower, more power.”

Next time we’ll look at the rules of thumb for sizing towers.

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Editor’s note: The opinions expressed in this column are the author’s and may not reflect those of AWEA’s staff or board.