SMALL WIND TURBINE BASICS

Part 3

by Dan Fink

In parts 1 and 2 of this series, I tried to explain the basic physics and math of wind turbines and how they relate to power output potential. If you are seriously considering installing a wind turbine for your on- or off-grid home or cabin, it is critical to know what range of power output you can expect at different wind speeds. The key concepts from parts one and two are that potential power from the wind increases by a factor of 4 when the diameter of the rotor doubles, power increases by a factor of 8 when the windspeed doubles, and that wind turbines must fly well above any obstructions. So, a potential site must have good winds with little turbulence, and the swept area of a turbine is far more important than the 'manufacturer's rated output.' If provided by the manufacturer or from independent test data, the figure 'estimated power output per year in kilowatt hours' is the most important data on which to base your decision of whether to buy a wind turbine, and which size and model to purchase. Low winds require a large turbine to make any useful power.

SITING

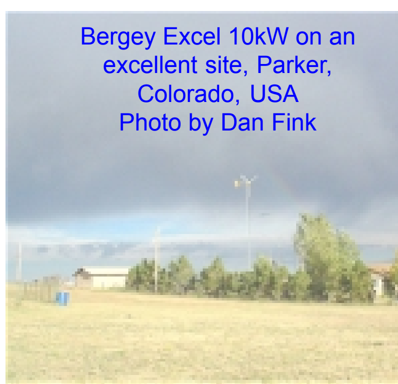
Installing a wind turbine close to the ground is very much like installing solar panels in the shade – a large part of your investment is wasted. General guidelines are that wind turbines should fly 30 feet above any obstruction within 300 feet. Windspeeds increase as you go higher, and turbulence decreases. Turbulence affects all wind turbine designs, and besides dramatically reducing potential power, turbulent winds near the ground buffet any turbine, causing serious stress on all components and sometimes premature failure.

In general, urban and suburban wind turbines are possible only on a very small scale because of local building codes and impact on neighbors. And 'small scale' means a very small turbine, which won't do much to offset the typical power use of a typical suburban home. (see parts 1 and 2). Most building codes require that any tower have a 'fall zone' that does not impact any neighboring property, and also restrict the height. Locations near airports have tower codes even more strict, and your relations with neighbors regarding aesthetic and noise concerns must be addressed. If you are on a small urban or suburban lot with many houses nearby, your best bet may to be to invest the money you considered for a wind turbine into refitting your home with energy-efficient lighting, appliances, and heat, with the future option of a photovoltaic system in mind too.

If you are in a more rural area and can comply with local restrictions, it's important to put your tower as high as you can at the best possible location. This is expensive—in general a good tower will cost **at least** as much as the wind turbine that will fly on it! Local geography, property lines, and cost may limit your tower options. Up here in our remote mountainous area, many of us are forced to cheat the 30-foot -above-300-foot rule all the time. The key factor is, how much are you investing in your wind turbine and tower? If it's homebrewed and inexpensive, just fly it as high as you possibly can—if you built it, you probably know how to fix it. If turbulence from being flown too near the ground causes a failure, your loss is only some repairs and engineering lessons learned. If you just dropped big money on a commercial turbine, you'd be crazy to fly it too low—and no commercial installer would even touch the job! Seek expert opinions, they often cost only a couple beers.

Photo Comparison of Sites

So let's have a look at a few pictures taken at real sites to see what makes them suitable, or not. We'll start with a couple of good ones:



Bergey Excel 10kW on an excellent site, Parker, Colorado, USA
Photo by Dan Fink

Homebrew 1.5kW turbine flying high in Colorado, USA
Photo by Dan Fink

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Homebrew turbines flying at pretty good sites, Colorado, USA.
Both could use another 10-20 feet of tower
(notice local tree heights)

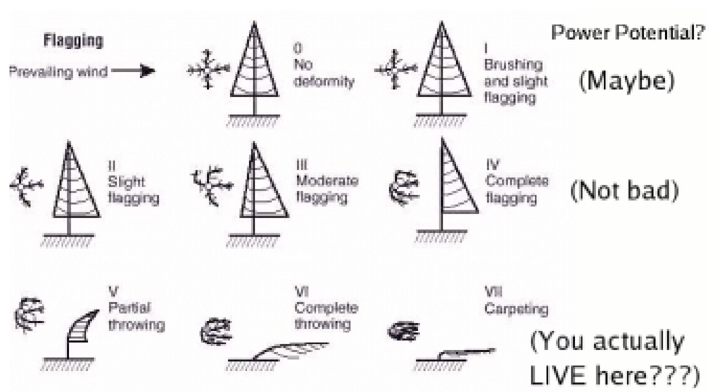
All photos on this page by Dan Fink

This could perhaps be a 'little' higher?!

An alternative car alternator - or is it a swamp buggy?

Opinions vary on whether detailed wind data acquisition should be used for a siting decision, or simply general wind data for the area. My opinion is that the cost of your pre-purchase data acquisition should directly correlate to how much you are planning to spend on the installation. Are you looking at spending US$30,000 for a 12 kW Bergey to offset your home or business power use on the grid? Darn right, erect a meteorological (MET) anemometer tower and collect data for a year or two, then take it to an expert analyst. Planning to spend US$3000 on a small commercial or mid-size homebuilt wind turbine for an off-grid home? Put up some inexpensive logging anemometers on PVC pipe masts, and watch your input during windy months or for a whole year. US$800 on a tiny wind turbine or homebuilt mid-size model for your vacation cabin? Just do it! Keep in mind how much power you can expect from different sizes of turbine in your area, and the importance of flying it as high as possible.

Useful data on wind power potential at a given site can be gleaned by simply observing the wind first hand. Ridge tops are usually the best turbine locations, so how tall are the trees on your ridge? How big a tower do you need to get 30 feet above them? About how fast is the wind blowing each time you visit? Keep a log. And how fast are the trees growing in height each year? Do the trees on your ridge have more branches on one side than the other? Such tree 'flagging' can also be a rough indicator of wind potential at a site. Also, talk to neighbors that have lived in the area a long time.



Griggs-Putnam Index of Deformity

Index	I	II	III	IV	V	VI	VII
Wind, mph	7-9	9-11	11-13	13-16	15-18	16-21	22+
Speed, m/s	3-4	4-5	5-6	6-7	7-8	8-9	10

GP Index – Courtesy NREL

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Wind data logging can be as simple and cheap or as complicated and expensive as you choose to make it. If you are planning a substantial investment, choose your logging equipment accordingly. Some government and non-profit organizations are making advanced wind data logging systems available on loan for zero or small cost – search Google for "anemometer loan program" to find details for your area.

A professional-grade, ready-to-fly logging MET anemometer system (including 30-meter tilt-up tower) can be had from NRG Systems for a cool US$3000—intimidating, but not if you are looking at spending US$30K on a turbine. US$600 to NRG systems will get you an excellent professional instrument, even capable of plotting the Weibull distribution of your wind speeds (see part 1)—you build your own tower or tree mount for it, and be sure to fly it high or else turbulence will compromise your data. Home weather stations by Davis Instruments, Oregon Scientific or LaCrosse come in at around US$300. For bottom feeders like me, US$40 will get you the parts to build a homebrew Anemometer built from a bicycle speedometer, or an even cheaper Easter egg anemometer. And check out the Vortex anemometer from Inspeed.com for a US$60 commercial versions of the bike speedometer anemometer, and a US$99 anemometer with computer interface and software that give an on-screen display and also puts your wind data directly into a spreadsheet file.

Chasing a storm with a Vortex anemometer
Courtesy Inspeed.com

TOWERS

There are two basic types of towers for wind turbines:

Fixed – The kind you have to climb. If you (or a friend, or a professional wind turbine installer) don't mind high climbing and know the necessary safety precautions, harnesses, and knots, a lattice tower with 3 guy wires can be very cost effective. The tower sections, and finally the wind turbine, are raised one at a time using a gin pole and davit, or the whole thing at once with a crane. Lattice tower sections are often available used or as surplus. Freestanding, fixed towers are more expensive: wider at the base and narrow up towards the top, but they need no guy wires. At very steep, craggy or tree-filled sites, fixed and freestanding towers have the advantage that a much smaller 'footprint' of level ground free of trees is needed.

Professional wind turbine dealer, installer and mechanic Victor Creazzi of Aerofire Wind Power on a routine service call.

Seriously acrophobic Dan Bartmann of Otherpower.com is assisting. Victor wisely refrained from any 'tower-top humor' after he got DanB up there!

Photo by Dan Fink

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Typical freestanding tower with no guy wires.
Requires a large concrete base.
The turbine shown is an Atlantic Orient located at the NREL, NWTC, Golden, Colorado, USA

Photo by Dan Fink

Tilt-up – This is a great alternative for non-climbers, though it is often more expensive. A tilt-up tower has the big advantage that you can do all your adjustment and maintenance to the turbine while it's on the ground, instead of while you are hanging from the tower top. It also uses a 'gin pole' to raise it, but in this case the gin pole is a lever arm that stands straight up when the tower is down, and lays along the ground when the tower is up. Tilt up towers use 4 guy wire locations instead of 3, and the guy anchors must be perfectly square to the tower base. Tilt-up towers are generally made of steel pipe, which is heavier and more expensive than lattice. The prospect of high climbing a fixed tower might convince you that the added expense (and required large level area, clear of trees and obstructions) of a tilt-up is justified.

A 40-foot tilt-up tower being raised via pickup truck and gin pole. Colorado, USA

Photo by Dan Fink

Tower Bases and Guy Anchors

The tower base actually does not receive much stress compared to the guy anchors—once the tower is erected, all of the force on the base is straight down, from the weight of the turbine and tower. Fixed towers require a chunk of concrete at the base, and the manufacturer's specs will tell you how much mud to pour. A metal plate is bolted into the concrete and the lattice sections attached to the plate. Freestanding towers need even more concrete – with no guy wires, the weight and depth of the base are critical. Again, follow the tower manufacturer's recommendations.

Tilt-up towers benefit from a concrete base because of the side forces when raising or lowering the tower, but some perfectly good commercial designs use a flat metal base that's simply spiked directly into the dirt. What's most important is the strength of the guy wire anchors, which are usually either concrete or (when digging is impossible) large metal pitons sunk into holes drilled into the rock, and further secured with masonry epoxy. Fixed towers give you a little leeway on exactly where the 3 guy anchors are placed, but tilt-ups don't. If the 4 guy anchors on a tilt-up are not perfectly square and level with the base and each other, the side guy wires may alternately tighten and loosen during raising and lowering. This requires diligence and very slow action by the owner during erection, because wire rope guys don't give any visible indication of how much tension they are under—they look the same whether there's 100 pounds of force on them or 1000. A broken guy wire can be a disaster for the turbine, tower, and could even kill the owner. Seek expert advice if you've never raised a tilt-up tower before! It would be wise to do the same if you're thinking of a fixed one, too.

Lightning Protection and Wiring

Wind turbine towers must be properly grounded or induced current from a nearby lightning strike could fry the rest of the components of your power system. Generally, the metal components of the tower and turbine are grounded to one or more ground rods near the tower base. The electrical wires from the turbine are NOT bonded to this ground—they run into the house, and are grounded by the power system's main ground. Very tall towers may have a ground rod at the base plus an additional ground rod at each guy anchor, with all guy wires that connect to that anchor bonded together.

The wires from the turbine to the house must also be properly sized to avoid too much resistance heating loss. Follow the manufacturer's recommendations, and be sure to factor in

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the tower height when making your calculations. Many turbine manufacturers no longer make their mid-size models in 12V configurations, it's now 24V or 48V only. Low voltage 12V systems will need thick, expensive wire, and internal losses in the turbine's generator are also a problem at 12V. If you are pricing wire for installing a 12V turbine a few hundred feet from your house, you'll quickly see the advantage of upgrading to a 24V or 48V power system!

Power Regulation

Almost all small off-grid wind turbines use what's called a 'dump load controller' to regulate their power input to the system. The raw output of a small wind turbine is "wild AC," meaning it varies in both frequency and voltage and is not directly useful for much of anything. The controller converts this to DC for charging the home's battery bank, and the batteries themselves regulate the incoming voltage level. They keep it down to their own voltage, UNTIL the batteries are full – at that point, they can't regulate the voltage any more. Solar panels can simply be disconnected from the system, but disconnecting a running wind turbine (letting it 'free wheel') can be a disaster. The turbine will overspeed and possibly come apart. It must always be connected to a load.

That's where the dump load comes in – when the batteries fill, the controller starts diverting all or part of the incoming power to electric air or water heating elements in your house to keep a load on the turbine without wasting the incoming power. Commercial turbines come with this system included, and homebrew builders usually make their own heating element arrays and use a commercial controller (such as a Trace C-40 or C-60) set in dump load mode to handle the diversion.

Grid-tied systems are regulated in a similar way. If the system includes batteries, the only difference is that the grid itself is the dump load, and any extra power beyond what your home is using runs your electric meter backwards. In systems without batteries, a special grid-tie inverter is used (one example is the WindyBoy) to convert the turbine's wild AC directly into sync with the grid.

Noise, Birds and Bats

After your wind turbine starts flying, you'll start getting questions from friends and neighbors about noise, dead birds, and dead bats. There are some pretty noisy commercial wind turbines on the market, but most are extremely quiet. If noise is a concern for you, be sure to talk with your dealer or installer and visit some working small turbine installations to hear the noise for yourself. I usually describe the sound of our homebrewed turbines up here as about the same as someone riding by the house on a bicycle. In higher winds, the turbines make a bit more noise, but the noise threshold is just barely above the sound of the wind in the trees.

Bird kills (and more recently, bat kills) are a big issue for the under-informed, and those people who are against wind power development. In reality the issue is minor and stems from early utility-scale wind installations such as the wind farm at Altamont Pass in California 30 years ago. This installation was inadvertently sited in a bad area of the local ecosystem, full of raptors. Commercial wind farms have been sited with birds in mind for many years now, and derisive names like "Raptor-matic" and "Cuisinart in the sky" are just anti-wind-power hype. The biggest modern killers of birds are power lines, cell phone and other communications towers, pesticides, and domestic cats. See Mick Sagrillo's article on bird kills for the AWEA for more details. We have over a dozen wind turbines flying in our local off-grid area, and no one has reported a single bird kill, ever.

The bat kill issue has only cropped up recently and only at certain installations, but the problem is currently being worked on by the best and brightest ecologists and engineers. Just like the bird problems 30 years ago, the issue seems to stem from bad siting of the turbines in bat flight paths instead of any intrinsic danger from the blades. Zero dead bats reported up here. Though we recently got to witness a pair of male Broadtail Hummingbirds engaged in an aerial duel in, around and through the blades of a local turbine running during high winds—an amazing display that caused no harm to the birds, and was like watching the Ornithological Olympics for us!

Wind Turbine Watching

Before my wind turbine went up, I cursed the constant February winds that blast our high mountain location. Now, I see the wind in a new perspective. In fact, I find watching wind turbines to be much more entertaining then watching television. Those first slow rotations in a gentle breeze provide the anticipation, and the excitement kicks in when the wind gets strong enough to give the correct angle of attack on the blades to provide lift (see part 2 in the August 2005 edition of ESSN) – the acceleration is dramatic. And then watching a turbine furling in high winds is a lesson in physics beyond compare. Be sure to find a spot in your house where you can sit and watch your turbine through a window, and see both your anemometer and power input meter at the same time. In addition to the wind power that you are harvesting, you'll gain power by shutting off the TV too!

Dan Fink