Small wind turbines don't use the same technology found on the megawatt-scale behemoths populating wind farms. Here are a few of the main differences.

The backyard WIND TURBINE

Question: What *don't* you see on this small wind turbine from Windward Engineering? Answer: Lightning arrestors. The only practical means of protecting small turbines from lightning is to ground the towers and guywires. Electronics on the ground can be protected with surge arrestors, but there is little to be done about a strike on the tower itself. Our advice: Stay away from wind-turbine towers as thunderstorms approach. In contrast, much-taller megawatt-scale turbines typically incorporate Franklin-type lightning rods inside their blades which conduct strikes to the nacelle skin and tower to eventually reach a ground rod in the tower base.

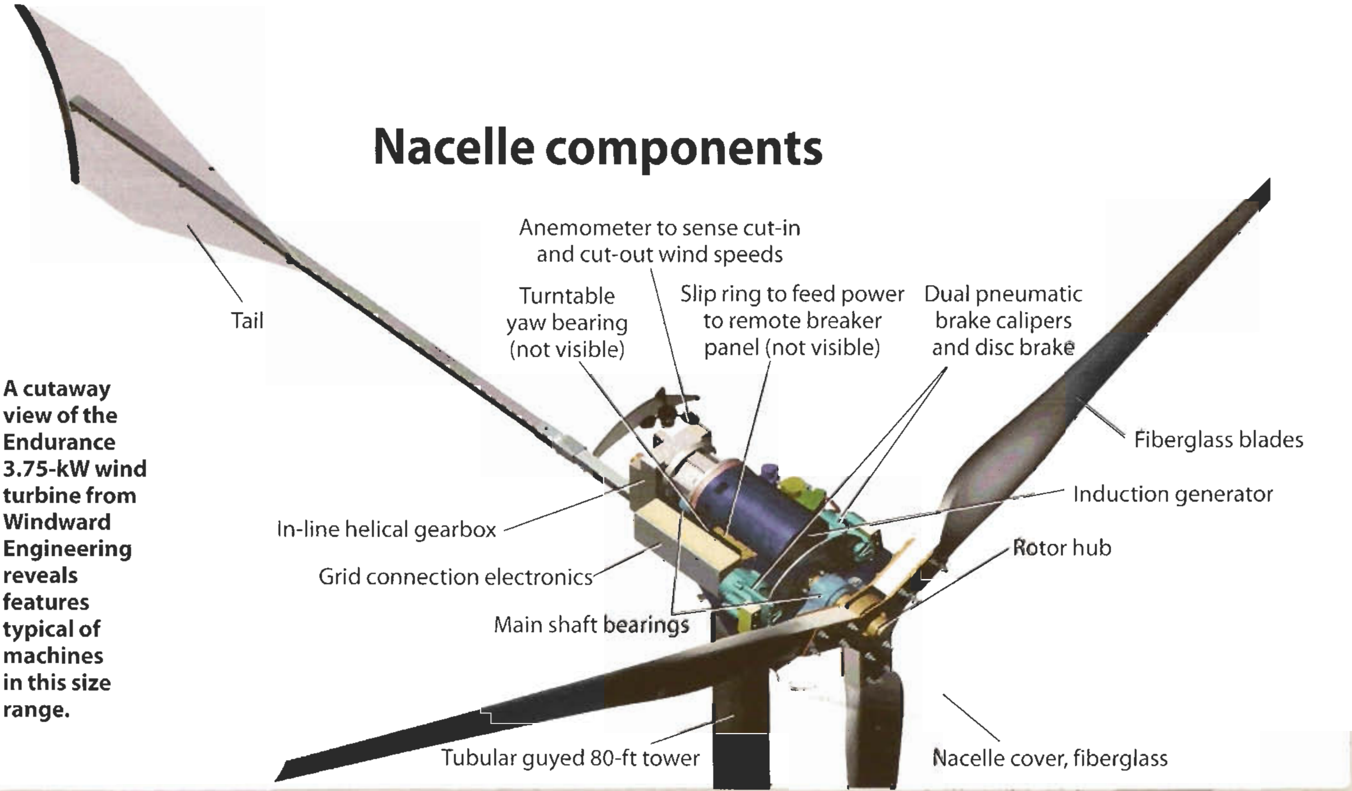
It takes a 50-story crane and a task force of people to erect a wind turbine able to generate megawatts of power. The story is different for a turbine going up in someone's backyard, however. Put down a concrete pad and some anchor points, bring in a three-person crew, and you can be up and running with a 10-kW turbine atop an 80-ft tower in a day or two.

Time was when turbines putting out power measured in kilowatts were strictly the domain of hobbyists who cobbled them together using old alternators, hand-made props, and discarded pieces-parts. But thanks to tax incentives that make backyard wind more economical, most small wind turbines going into service today are professionally built and installed.

"Last year federal tax incentives for small wind passed. That opened up a national market for small wind that used to vary depending on state incentives," says engineering consultant Dr. David Laino of **Windward Engineering LC,** Spanish Fork, Utah. Windward both consults on turbine projects and makes its own line of small-scale machines.

"With these incentives in place, you are doing really well if you can get your investment back after seven years," Laino says. "And the way most utility net metering laws are written, you want to size the turbine so it delivers at most 100% of your utility load. That's because, in general, the utility does not pay you for any power you generate and don't use yourself. So if you install a turbine that is too big, you give away some of the electricity it generates."

According to Laino, it has been the changes in tax incentives and not technological advances that are driving small wind. Nor does the wind turbine itself constitute the primary difficulty when making an installation. "The main headaches for the homeowner are not with the tur-



A cutaway view of the Endurance 3.75-kW wind turbine from Windward Engineering reveals features typical of machines in this size range.

bine. They usually concern getting past the zoning board, dealing with a major construction project, and working with the utility for interconnection," he says.

Construction work for a turbine installation starts to sound a little like that for an addition on your house. It typically entails digging a hole for the tower foundation, constructing the necessary rebar cages, and hauling in roughly 9 yd^3 of concrete for the pad. Most turbines today mount atop guyed masts and the anchor points for guys may sometimes need concrete foundations as well, depending on the soil conditions.

Local ordinances for wind turbines often specify standards and limits on factors such as audible noise, shadow flicker on adjacent property, visual appearance, and safety. In particular, they increasingly call for redundant braking of the rotor in the event the turbine sees dangerously high winds.

Inside the nacelle

The requirement for rotor braking is one of the few cases where local codes impact what goes on inside the wind turbine. Turbines big and small all have some means of slowing the rotor in high winds. But the task of slowing the multiton rotor on a megawatt turbine is far different from that on a backyard model where the entire nacelle and blades might weigh less than 700 lb.

Small turbines deal with high winds in two ways, by turning the blades out of harm's way and by applying a brake. The usual way of getting rotor blades out of the wind is with a furling-tail arrangement. Here the prop mounts a few inches to the side of the vertical axis of the mounting pole. This produces a small turning force on the whole unit. Small turbines have a tail boom that mounts a few inches to the opposite side, producing the same amount of turning force the other way. The tail boom mounts on a pivot such that it breaks away when high winds apply a sufficiently high turning force. The prop then turns to the side of the vertical mounting pole on which it pivots and no longer faces into the wind. The tail also turns such that the prop and tail boom fold together. Some small turbines also furl by tipping backward using a hinge and spring arrangement.

Local ordinances increasingly demand that wind turbines also include a brake. The typical implementation uses a disc and electromechanically actuated calipers. If the turbine overspeeds, the calipers actuate to slow its rotation. The brake also gets actuated by hand to hold-fast the rotor during maintenance.

Turbines having permanent-magnet generators can also apply braking by shorting out their stator windings. This opposes the magnetic field of the rotating magnets to slow the rotor shaft rotation. However, this is one avenue of braking not available to utility-scale turbines. The rea-

Authored by:
Leland Teschler
Editor
leland.teschler@penton.com

Key points:

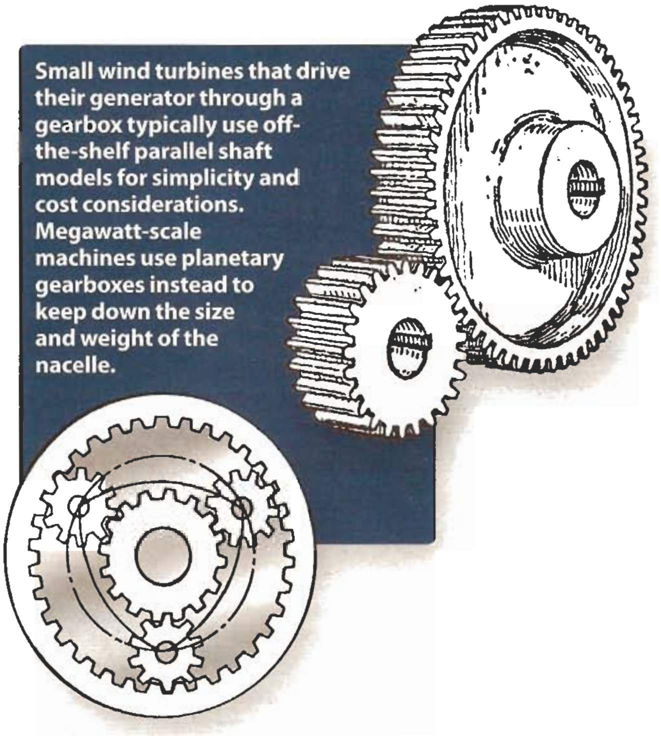
- As one might expect, the internals of a small wind turbine differ from what's found in megawatt-scale machines.
- Local ordinances can be the biggest hurdle to installing small wind turbines.

Resources:

Windward Engineering LC, *www.windwardengineering.com*

How a synchronous generator works, *www.talentfactory.dk/en/tour/wtrb/syncgen.htm*

For those who insist on building their own small wind turbine, here is one good resource: *www.scoraigwind.com.*



Small wind turbines that drive their generator through a gearbox typically use off-the-shelf parallel shaft models for simplicity and cost considerations. Megawatt-scale machines use planetary gearboxes instead to keep down the size and weight of the nacelle.

son is that most backyard turbines are direct drive — the generator connects directly to the rotor shaft. So any braking that the generator applies impinges directly on the rotor shaft. (A few such devices employ a gearbox between the rotor shaft and the generator, but the gearbox is typically a simple single-stage parallel-shaft design.)

In contrast, utility-scale turbines are not direct drive (though a few advanced designs now on the drawing boards explore such a configuration). Instead, megawatt-scale turbines connect the rotor to the generator through some kind of a planetary gearbox. The planetary configuration is the usual choice because it provides a high power density for a gearbox with a given amount of weight, important when the gearbox is the heaviest item in the nacelle. Planetary gearboxes also are relatively efficient with efficiencies in the 95% range and can deliver a large speed-up ratio in a small volume. This comes in handy for large turbines that typically use synchronous generators which must run above synchronous speed to generate power. (On the flip side, planetary gearboxes typically experience significant bearing loads, and bearing failures have been an issue on some large turbine gearboxes.)

It should also be noted that large turbines incorporate a blade-pitch control scheme that adjusts the blade pitch to keep the rotor spinning at an acceptable speed as wind conditions vary. Feathering the blades stops the rotor during emergency shutdowns or when the wind gets dangerously high. Small turbines lack such facilities.

Grid connections

There are significant differences between the generators carried on small wind turbines and their utility-scale counterparts. The most common small wind generator is a permanent-magnet (PM) alternator. It basically consists of permanent magnets supplying a field that induces electrical current in the stator. Use of permanent magnets makes it is possible to pack numerous magnetic poles into a small space so an alternator spinning at a fairly low speed can generate a high output voltage.

One disadvantage of permanent-magnet alternators is that their output voltage at higher speeds is difficult to regulate. The result is that above a certain rotor-shaft speed, additional work done by the rotor simply heats the alternator coils rather than generates more electricity. Some systems may incorporate solid-state electronics that switch the stator coil at high speeds to somewhat mitigate the effect.

The generator output typically goes to an electronic circuit dubbed an inverter, though it is in actuality a combination rectifier and inverter. It converts the generator output to dc which then is converted to ac at the grid frequency. When connected to the ac power lines, the inverter output automatically syncs up to be in phase with the power line. This is because the inverter isolates the generator dynamics from those of the grid so the inverter frequency is the only factor that must adjust.

The situation is different for megawatt-scale machines. Most use synchronous generators that substitute coils for the permanent magnets found in a PM alternator. The coils serve as electromagnets to generate the magnetic fields for the generator. They actually pull some power off the grid to create these fields. The strategy of using electromagnets rather than permanent magnets is necessitated by the large magnetic fields involved in megawatt-scale generators. Permanent magnets would eventually demagnetize in such an environment.

Also, the amount of power involved in utility-scale turbines forces them to incorporate power-conditioning circuitry that backyard turbine makers needn't worry about. The main requirement for utility connections on backyard machines is that the turbine disconnect itself in the event of an outage on the ac lines. But big turbines must, among other things, incorporate special grid-fault ride-through circuits that let the turbine quickly resync itself with the grid voltage after brief short circuits on the power lines.

Despite the drawbacks introduced by such measures, large turbines are still more efficient than backyard models at turning wind energy into electricity. One reason is that big turbines employ variable-speed control and active, variable-pitch control. Another is that the size of the hub on a big turbine is small relative to the area swept by its blades. Smaller machines have a less-pronounced hub/swept-area ratio which, because hubs do no aerodynamic work, puts them at an efficiency disadvantage to their megawatt-scale cousins.

Finally, there are indications that a lot of potential backyard wind-turbine owners are oblivious to the relative scale of possibilities with small wind turbines. "We still run into homeowners who think they are going to put a tiny turbine on their roof which is going to power their whole house," says Windward's Dave Laino. **MD**