Small Wind Powered Electric Generation Systems

An Online Continuing Education Course for Engineers

Course Number: R-2006

Credit: 2 Hours / 2 PDH / 2 CPD

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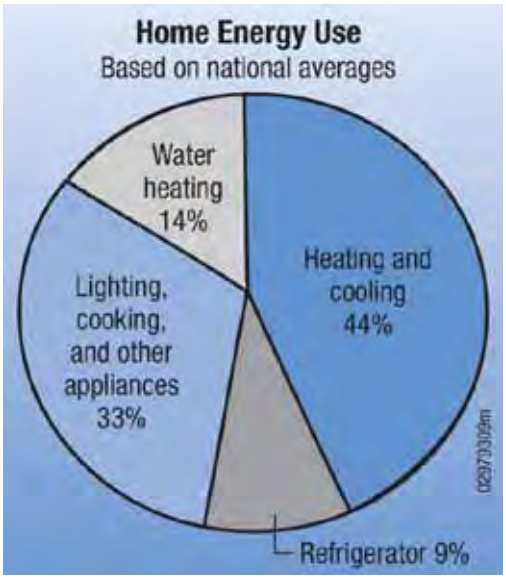
INTRODUCTION

This course introduces the basic design concepts for small wind powered electric generation systems.

Small wind energy systems are nonpolluting and one of the most cost-effective renewable energy systems. Depending on the wind resource, small wind energy systems can lower electricity bills by 50% to 90%, as well as prevent power interruptions and help reduce the high costs of extending utility power lines to remote locations.

In 2003, the U.S. wind generating capacity increased by more than 30%. Wind power plants of various sizes now operate in 32 states with a total generating capacity of 6374 MW of power, enough to meet the energy needs of more than 3 million homes. The goal of the wind energy industry is to contribute 100 GW of wind electricity to our nation's energy supplies by 2020.

By meeting that goal, wind energy will help secure our nation's energy future and clean up our environment by displacing about 3 quadrillion BTUs of primary energy per year and 65 million metric tons of carbon equivalent per year. Small wind electric systems can make a significant contribution to our nation's energy needs.



Home Energy Use: Based on national averages

HOW DO WIND TURBINES WORK?

Wind is created by the unequal heating of the Earth's surface by the sun. Wind turbines convert the kinetic energy in wind into mechanical power that runs a generator to produce clean electricity. Today's turbines are versatile modular sources of electricity. Their blades are aerodynamically designed to capture the maximum energy from the wind. The wind turns the blades, which spin a shaft connected to a generator that makes electricity.

Homeowners, ranchers, and small businesses can use wind- generated electricity to reduce their utility bills. This grid- connected system installed for a home in Norman, Oklahoma, reduces the homeowner's utility bill by $100 per month.

HOW TO ACHIEVE MAXIMUM ENERGY EFFICIENCY

Before choosing a wind system, you should consider reducing your energy consumption by making your home or business more energy efficient. Reducing energy consumption will significantly lower utility bills and reduce the size of the renewable energy system needed. To achieve maximum energy efficiency, you should take a whole-building approach. View your home or business as an energy system with interrelated parts, all of which work synergistically to contribute to the efficiency of the system. From the wall insulation to the light bulbs, there are many ways to maximize efficiency:

- Reduce heating and cooling needs by up to 30% by investing just a few hundred dollars in proper insulation and weatherization products.
- Save money and increase comfort by properly maintaining and upgrading heating, ventilation, and air-conditioning systems.

- Install double-paned, gas-filled windows with low-emissivity (low-e) coatings to reduce heat loss in cold climates and spectrally selective coatings to reduce heat gain in warm climates.
- Replace lights in high-use areas with fluorescents. Replacing 25% of the lights can save about 50% of the lighting energy bill.
- When shopping for appliances, look for the Energy Star® label. Energy Star® appliances have been identified by the U.S. Environmental Protection Agency and U.S. Department of Energy as being the most energy-efficient products in their classes.
- For more information on energy efficiency, see Energy Savers in the For More Information section.

IS WIND ENERGY PRACTICAL?

A small wind energy system can provide a practical and economical source of electricity if:

- the property has a good wind resource
- the property is located on at least one acre of land in a rural area
- the local zoning codes or covenants allow wind turbines
- the average electricity bills are $150 per month or more
- the property is in a remote location without easy access to utility lines
- the long-term investments are feasible

ZONING ISSUES

Before you invest in a wind energy system, you should research potential obstacles. Some jurisdictions, for example, restrict the height of the structures permitted in residentially zoned areas, although variances are often obtainable. Most zoning ordinances have a height limit of 35 feet. You can find out about the zoning restrictions in your area by calling the local building inspector, board of supervisors, or planning board. They can tell you if you will need to obtain a building permit and provide a list of requirements.

In addition to zoning issues, your neighbors might object to a wind machine that blocks their view, or they might be concerned about noise. Most zoning and aesthetic concerns can be addressed by supplying objective data.

In Clover Valley, Minnesota, this 3-kW Whisper H175 turbine on a 50-foot tower is connected to the utility grid to offset the farm's utility-supplied electricity.

For example, the ambient noise level of most modern residential wind turbines is around 52 to 55 decibels. This means that while the sound of the wind turbine can be picked out of surrounding noise if a conscious effort is made to hear it, a residential-sized wind turbine is no noisier than your average refrigerator.

WHAT SIZE WIND TURBINE IS NEEDED?

The size of the wind turbine needed depends on the application. Small turbines range in size from 20 watts to 100 kilowatts (kW). The smaller or "micro" (20- to 500-watt) turbines are used in a variety of applications such as charging batteries for recreational vehicles and sailboats.

One- to 10-kW turbines can be used in applications such as pumping water. Wind energy has been used for centuries to pump water and grind grain. Although mechanical windmills still provide a sensible, low-cost option for pumping water in low-wind areas, farmers and ranchers are finding that wind-electric pumping is a little more versatile and they can pump twice the volume for the same initial investment. In addition, mechanical windmills must be placed directly above the well, which may not take the best advantage of available wind resources. Wind-electric pumping systems can be placed where the wind resource is the best and connected to the pump motor with an electric cable.

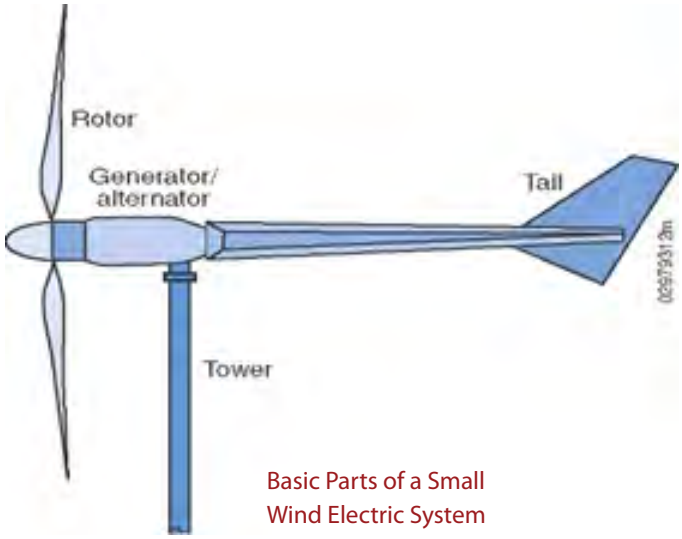
Turbines used in residential applications can range in size from 400 watts to 100 kW (100 kW for very large loads), depending on the amount of electricity you want to generate. For residential applications, you should establish an energy budget to help define the turbine size needed. Because energy efficiency is usually less expensive than energy production, making a house more energy efficient first will probably be more cost effective and will reduce the size of the wind turbine needed. Wind turbine manufacturers can help size the system based on electricity needs and the specifics of local wind patterns.

A typical home uses approximately 10,000 kilowatt-hours (kWh) of electricity per year (about 830 kWh per month). Depending on the average wind speed in the area, a wind turbine rated in the range of 5 to 15 kW would be required to make a significant contribution to this demand. A 1.5- kW wind turbine will meet the needs of a home requiring 300 kWh per month in a location with a 14- mile-per-hour (6.26-meters-per-second) annual average wind speed. The manufacturer can provide the expected annual energy output of the turbine as a function of annual average wind speed. The manufacturer will also provide information on the maximum wind speed at which the turbine is designed to operate safely. Most turbines have automatic overspeed-governing systems to keep the rotor from spinning out of control in very high winds. This information, along with your local wind speed and your energy budget, will help you decide which size turbine will best meet your electricity needs.

This 1-kW Whisper turbine provides direct AC power for the water pump for stock tanks on a ranch in Wheeler, Texas.

WHAT ARE THE BASIC PARTS OF A SMALL WIND ELECTRIC SYSTEM?

Small wind energy systems generally comprise a rotor, a generator or alternator mounted on a frame, a tail (usually), a tower, wiring, and the "balance of system" components: controllers,



Basic Parts of a Small Wind Electric System

inverters, and/or batteries. Through the spinning blades, the rotor captures the kinetic energy of the wind and converts it into rotary motion to drive the generator.

WIND TURBINE

Most turbines manufactured today are horizontal axis upwind machines with two or three blades, which are usually made of a composite material such as fiberglass.

The amount of power a turbine will produce is determined primarily by the diameter of its rotor. The diameter of the rotor defines its "swept area," or the quantity of wind intercepted by the turbine. The turbine's frame is the structure onto which the rotor, generator, and tail are attached. The tail keeps the turbine facing into the wind.

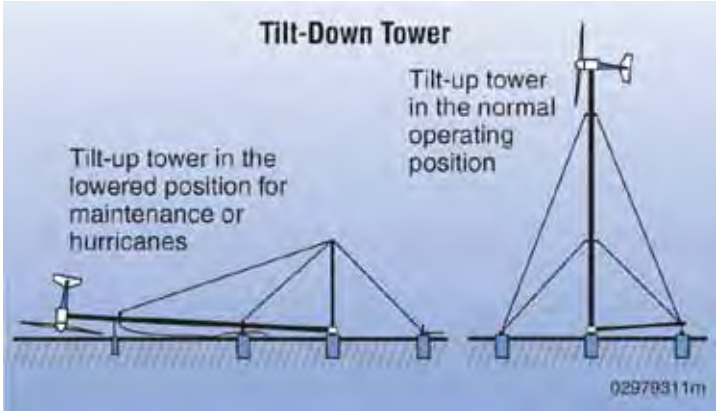
TOWER

Because wind speeds increase with height, the turbine is mounted on a tower. In general, the higher the tower, the more power the wind system can produce. The tower also raises the turbine above the air turbulence that can exist close to the ground because of obstructions such as hills, buildings, and trees. A general rule of thumb is to install a wind turbine on a tower with the bottom of the rotor blades at least 30 feet (9 meters) above any obstacle that is within 300 feet (90 meters) of the tower. Relatively small investments in increased tower height can yield very high rates of return in power production. For instance, to raise a 10-kW generator from a 60-foot tower height to a 100-foot tower involves a 10% increase in overall system cost, but it can produce 29% more power.

There are two basic types of towers: self-supporting (free standing) and guyed. Most home wind power systems use a guyed tower. Guyed towers, which are the least expensive, can consist of lattice sections, pipe, or tubing (depending on the design), and supporting guy wires. They are easier to install than self-supporting towers. However, because the guy radius must be one-half to three-quarters of the tower height, guyed towers require enough space to accommodate them. Although tilt-down towers are more expensive, they offer an easy way to perform maintenance on smaller light-weight turbines, usually 5 kW or less.

Tilt-down towers can also be lowered to the ground during hazardous weather such as hurricanes. Aluminum towers are prone to cracking and should be avoided. Most turbine manufacturers provide wind energy system packages that include towers.

Mounting turbines on rooftops is not recommended. All wind turbines vibrate and transmit the vibration to the structure on which they are mounted. This can lead to noise and structural problems with the building, and the rooftop can cause excessive turbulence that can shorten the life of the turbine.



Tilt-down towers provide easy maintenance for turbines.

BALANCE OF SYSTEM

The parts needed in addition to the turbine and the tower, or the balance of system parts, will depend on the application. Most manufacturers can provide a system package that includes all the parts needed for a specific application. For example, the parts required for a water pumping system will be much different than what is needed for a residential application. The balance of system required will also depend on whether

to the utility grid) require batteries to store excess power generated for use when the wind is calm. They also need a charge controller to keep the batteries from overcharging. Deep-cycle batteries, such as those used for golf carts, can discharge and recharge 80% of their capacity hundreds of times, which makes them a good option for remote renewable energy systems. Automotive

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A Bergey XL.10, 10-kW wind turbine is part of a grid-connected wind/photovoltaic hybrid system that reduces the utility power used by this home in Vermont. The balance of system (upper right) includes from left to right, a Trace inverter for the PV system, a breaker box, and a Powersync inverter for the wind system.