THE Locomotive

THE full STORY

The Changing Face of Wind Power

By John Latcovich

Wind power is entering the new millennium with a roar. The wind energy capacity around the world has grown from under 2,000 MW in 1990 to more than 13,400 MW at the end of 1999. Growth in the past three years (1997-1999) has been phenomenal. During this period, the amount of worldwide capacity has doubled with a record 3,600 MW installed in 1999. Leading the way have been Germany (1,200 MW), the United States (905 MW), Spain (650 MW) and Denmark (300 MW).

According to the American Wind Energy Association (AWEA), 2000 is expected to be an even better year. These growth rates are supporting claims by the European Wind Energy Association and other organizations that wind energy can produce 10 percent of the worldwide energy supply with the proper incentives. Even with such growth rates, wind power represents only 1 percent to 2 percent of the total power produced today in heavy industrialized countries such as the United States and Germany. That percentage, however, is continuing to increase.

What has caused such a remarkable interest in wind power today? There are a number of factors that have caused this dramatic increase. But before discussing these changes and their effects, the basic characteristics of wind and wind turbines need to be defined.

Wind Energy

The wind is a source of renewable energy that can be attributed to the sun. The radiant energy from the sun results in temperature differences on the earth's land and sea surfaces and in the atmosphere. Changes in the density of air with temperature (hot air rises more than cold air), along with the rotation of the earth result in circulating air currents that we call wind. Wind, however, is not a constant parameter. The energy content (speed and direction) is constantly changing with weather, local surface conditions, altitude, the time of day, and the time of the year (season).

For wind turbines, the challenge is to capture this variable energy in the most efficient manner and convert it to electricity. To harness this energy, it is necessary to keep turbine blades directly in the path of the wind. As you would expect, the amount of wind energy that can be converted to electrical power is directly proportional to the swept area of the turbine or the square of the turbine blade diameter. In addition to the swept area, the other parameter greatly affecting power conversion is wind speed. The power from a wind turbine varies as the cubic power of the average wind speed. Therefore, you want wind turbines with large blades located in areas with strong winds.

Where are the best places to locate wind turbines? In the United States the prime locations are California, Hawaii, the Pacific Northwest, Wyoming, the Great Plains, the Texas Panhandle and the Northeast. These are the locations where most of the new wind turbines are being installed. In other parts of the world, installations are made along the coasts and in the water to harness the available winds.

Wind Turbines

Converting the wind energy to electrical power is accomplished by a series of components and systems that make up the wind turbine. A typical wind turbine utilizes three fiberglass blades that mount to a hub and are supported by a bearing and hollow shaft. These parts make up the wind turbine rotor. This rotor turns between 10 to 35 revolutions per minute (RPM), with the lower speeds applying to the larger diameter blades.

The turbine blades may completely swivel or pitch at the hub (pitch-controlled design) or the blades at the hub may be fixed but the blade tips swivel (passive stall-controlled design). The blade pitch is controlled by individual electric stepper motors or by hydraulic cylinders. The turbine rotor is connected to a planetary and parallel shaft gearbox to increase shaft speed to 1,500 to 1,800 RPM.

The gearbox output is connected to the generator via a high-speed shaft. A mechanical brake with calipers is installed on the shaft to stop the turbine during normal and high wind conditions. The brake is in addition to aerodynamic braking provided by changing blade pitch or blade tip position. The generators are usually 1iquid-cooled (water or water glycol) and are rated for 690 volts.

These major components are mounted to a bedplate and enclosed by a nacelle to protect internal systems from the environment. The bedplate is rotated by the yaw mechanism to keep the turbine pointed directly into the direction of the highest wind. The electronic controller monitors turbine and nacelle instrumentation for all systems and includes provisions for remote monitoring and control.

Installation and Operation

Instrumentation is provided in or on the nacelle for shaft speeds, blade position, yaw position, wind speed and direction, vibration, and various component/system pressures and temperatures. The nacelle and bedplate are supported on a tower made from welding tapered hollow cylindrical sections together.

Ladder access to the nacelle is provided inside the tower along with lighting and required OSHA protection as towers may range in height from 50 to 100 meters (165 to 330 feet). The tower is mounted to a steel reinforced concrete foundation. The transformer may be mounted in the nacelle to minimize electrical losses to the grid or may be mounted at the base of the turbine tower on the foundation. Grid connections are usually made at the foundation.

Operation of the wind turbines is usually automatic. The turbines usually do not begin to produce power and connect to the grid until wind speeds reach 3 to 5 meters per second (7 to 11 miles per hour). At that time, the generator is connected to the grid and power may be produced. Most wind turbines achieve their rated power at wind speeds of 11 to 15 meters per second (24 to 33 miles per hour). They shut down at 25 to 29 meters per second (55 to 64 miles per hour) and have survival speeds of up to 70 to 75 meters per second (154 to 165 miles per hour).

As previously discussed, the growth in wind turbines has been remarkable. This growth can be directly attributed to significant changes in turbine technology, performance, reliability, costs, protecting the environment, and government incentives.

Turbine Technology

First- and second-generation wind turbines were introduced in the late 1970s and early 1980s. These turbines were rated between 30 to 75 kW, utilized blades that were 10 to 17 meters (33 to 56 feet) in diameter, and were mounted on lattice-type tower structures as shown below left.

The machines had a number of problems, including blade and gearbox failures, poor availability, high noise levels, aviary mortality and lightning damage. These problems made the earlier wind turbines technical, environmental and fiscal failures.

Since that time, the turbine blade designs have gone through several generations of design improvements culminating in the current seventh generation of blade designs. Led by wind turbine manufacturers in Denmark, Holland and Germany, these blade designs are larger, lighter, more efficient, and result in transferring lower loads to the gearbox and bedplate.

Blades are now manufactured from improved strength materials (carbon and glass fiber reinforced polyester) from mature manufacturing and quality testing processes. As a result, modern turbines have successfully demonstrated utilizing 47 to 80 meter (155 to 264 feet) diameter blades to produce power ranging from 660 to 2,500 kW. The photo below right shows a modern wind turbine.

Improved Performance

Performance in wind turbines is actually measured in the net kW-hours produced on an annual basis. Improvements in turbine blade efficiency and size have resulted in producing more power, but there are other factors that significantly affect performance.

The first factor is the predictability of available wind energy. The siting process has become highly sophisticated to statistically estimate the yearly available wind speeds at a site, what height the turbine should be set to capture the most energy, and what size of turbines and spacing should be used for optimal performance.

The second factor is the use of variable speed, asynchronous (induction) generators. Instead of running the wind turbine at constant speeds as was done for previous design generations, the turbine and generator can be run at variable speeds which may fluctuate from 10 percent to 60 percent of the nominal speed. As a result, the wind energy from gusts can be captured while still operating the unit safely.

In addition, double wound/rated generators (for example, 250 kW and 1,600 kW windings on the same shaft) allows for using the lower rated generator for low wind speeds and the higher rated generator for high wind speeds. That increases the net production for year. The use of the asynchronous generator results in improvements in power quality and soft interfacing with the grid with thyristors without getting into flicker, brownouts, or other anomalies that plagued some designs.

Increased Reliability

As previously mentioned, the reliability of early generation wind turbines was poor. Since then, the design and safety margins have been increased, not only for blades, but also for shafts, gearboxes and other structures. The number of parts has been reduced, the loads on the gearbox reduced, and higher strength/lighter weight materials are being used.

The most significant reduction in loading comes from the use of the asynchronous generators, which reduces the load on the gearbox as the generator increases or decreases speed as the torque for the turbine varies. The use of electronic controllers for more precise yaw position also has resulted in lower fatigue loads being applied to the turbine. Lightning protection for all units has been substantially improved.

In addition, design and testing standards have been formally defined and are being harmonized between European Union and equivalent U.S. organizations. Although the design and test standards of different manufacturers still lack uniformity, the industry continues to make progress toward standardization. Wind turbine manufacturers are now quoting 20- and 30-year design lives and providing maintenance programs to achieve those equipment lives.

Reduced Costs

The costs for manufacture and installation of wind turbines continues to decrease dramatically. The development of larger units has resulted in a decrease in the $/kW because many of the nacelle components/systems are not dependent on the size of the turbine blades or rating of the generator.

New units today can be procured and installed for approximately $1,000 per kW. Electricity from wind farms can be produced from 3 to 6 cents per kW-hour depending on the size of the units and the available wind. Maintenance costs are in the range of 1 percent to 2 percent of the original investment or about 1-cent per kW-hour. Some manufacturers recommend equipment inspections every six months with an opening or disassembly inspection every 18 months.

Environmental Protection

Inherently, wind turbines are emission free, but there are other issues that needed to be addressed from the early generations. These issues included noise and vibration, aviary mortality, visual pollution and transmission line siting and permitting.

The new blade designs, besides being larger and more efficient, are quieter. Noise and vibration reducing materials are now used in the nacelle, bedplate and gearbox. Using closed tubular towers and eliminating areas where birds could perch and be subjected to electric shocks has reduced aviary mortality rates. Improved siting and ensuring that there are no known flyways or locations where threatened or endangered species are present has further reduced the rates. From an attractiveness standpoint, the new machines are far more appealing than the original designs. Still, proper location of wind farms remains an issue today for some members of the public. Also at issue are the siting for grid transmission lines and turbine access roads.

Government Incentives

Throughout the world, governments are providing incentives to encourage development of low emission renewable energy sources. The U.S. Department of Energy (DOE) has been providing substantial research and development funding to develop more efficient energy sources. The National Energy Policy Act (NEPA) of 1992 provided a production tax credit of 1.5 cents per kW-hour as an incentive for investing in wind energy. President Clinton extended that credit this past December until December 2001.

Deregulation laws in many states are encouraging utilities to increase their renewable energy portfolio. The Clean Air Act of 1990 is also pressuring utilities to reduce emissions where wind energy can be an emission-free replacement for fossil fuel plants. In any case, the result of these government efforts has been to grow the wind turbine energy industry.

What is in store for the future? Expect larger units, possibly up to 5 MW. The size will be limited by blade loads and the difficulty of shipping and erecting units that are much larger. A stronger push for renewable or cleaner energy can be expected as well. The continual improvements in the technology and reliability of the wind turbines coupled with the reduced costs should bode well for the future of wind turbine technology.

John Latcovich is Hartford Steam Boiler's Fleet Manager for Rotating Equipment. He has more than 30 years experience with rotating machinery and works with HSB inspection specialists and clients on rotating equipment technical, operational and maintenance issues.