



Wind Performance Characteristics

Reliability and time variability are factors in wind energy productivity.

Wind energy has several applications, ranging from large fields of wind turbines, interconnected and delivering power to the utility grid, to individual, isolated wind turbines that may or may not be grid-connected. The productivity of wind energy applications is described in technical terms that examine wind characteristics to determine annual energy production. Included in wind energy productivity are factors of reliability and time variability. An understanding of these wind energy performance characteristics is useful for policymakers who are interested in renewable energy.

Wind turbine applications

The range of applications for electricity-generating wind turbines can be grouped into three classes: wind farms, distributed generation turbines and hybrid power systems. The differences between these classes are the size of the installation, the size of the contribution to a total electricity supply (wind penetration), whether the electricity is used for frequency or reactive power, and the degree of integration with other power sources.

The first class, wind farms, consists of large fields of turbines that are interconnected to a utility grid and act in concert with a conventional utility plant. The fields can consist of hundreds of machines that generate hundreds of megawatts of electricity. Smaller wind farms also exist that are useful in different situations.

Distributed wind generation systems incorporate smaller-scale turbines that are connected to a utility grid. These systems are useful for supplying additional generation capacity during near-capacity demand periods experienced by conventional utilities. They also are useful as an alternative to extending the grid to service distant loads. When connected directly to a load, but not to a grid, a turbine generates electricity that is not regulated. Since the output of a turbine depends directly on wind speed, the load must be able to handle fluctuations in energy production without causing damage to either the load or the turbine.

Hybrid power systems can combine wind turbines with diesel generators to form a miniature grid.

Hybrid power systems combine wind turbines and other renewable power sources with diesel generators to form the equivalent of a miniature grid. They typically are used where there is no power grid. At times the wind component of a hybrid power system can generate 100 percent of electricity load. The maximum contribution of wind energy used by most U.S. utility systems is between 10 percent and 15 percent. This percentage is expected to increase as utilities gain operating experience and technology improves.

Wind energy productivity

Though wind energy production is intermittent, it can be measured with some accuracy. The annual energy production of a wind farm is the sum of the energy production from the turbines, reduced to account for various energy losses throughout the system.

Annual/ energy production of a wind system is determined by analyzing the distribution of wind speed.

The following terms are used to describe wind energy productivity. *Wind speed distribution* is a quantitative measure of the number of hours per year that the wind speed lies within specified intervals. The electric power output as a result of wind speed determines the *wind turbine power curb*. When these two measures are multiplied and summed over all wind speeds, the result determines annual energy production, referred to as the *capacity factor*. The capacity factor is a number between 0 and 1 (0 and 100 percent) because annual energy production is less than the summed production of turbines due to a number of contributing energy loss factors within a system. It should be noted that capacity factors for conventional sources also are less than 100 percent due to various types of power outages and other malfunctions.

Wind system reliability

Advances in turbines and system design, coupled with a better understanding of wind gust forces, has led to a dramatic improvement in the reliability of wind energy. This has led to increased percentage ratings of *availability* for wind turbines -- a commonly used operational measure of reliability. Modern wind farms now routinely achieve availability values of 98 percent or more. Maintenance costs for wind energy systems also have improved dramatically, dropping to less than 1 cent per kilowatt-hour (kWh).

Time variability of the power

The most significant technical characteristic of wind energy productivity is its variation over time. *Variability* is measured over a wide range of time scales. Designers are concerned with variability over seconds; the financial community with annual output; and systems operators with the entire range.

While wind varies with time, it is not completely random. A certain degree of wind forecasting is possible. Forecasting is a function of wind characteristics and numerous mathematical and computer measuring techniques. It is necessary to obtain predictability so that wind energy production can be matched to electricity demand.

With the exception of its intermittency, the technical characteristics of wind-generated electricity are comparable to those of conventional sources.

The short-term characteristics of a single turbine's electricity output differ from the output of a wind farm. A single turbine corresponds closely to the temporal characteristics of wind flow. A wind farm's turbine control system can contribute to smoothing electric power output. In the face of changing wind speeds -- particularly high wind speeds -- a control system can modulate turbine blades to maintain the electrical output for the greatest efficiency.

An understanding of these technical characteristics of the electric power generated by wind farms is critical to a utility's use of the resource. Some would contend that none of these characteristics represents significant incompatibility with the balance of the utility system. Further, with the exception of its intermittency, the technical characteristics of wind-generated electricity are comparable to those of power supplied by conventional sources.

This brief was summarized by Jeff Dale, National Conference of State Legislatures, from a *Wind Energy Series Report* by OEM Development Corporation.

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