



Integration of Wind Resources Into Utility Systems

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During the last decade, more than 1,600 MW of wind generating capacity has been installed in California, demonstrating the potential effects of integrating wind power plants into utility systems. As utility interest in wind energy expands to other regions of the country—the Northeast, Northwest, Great Plains and Texas—this positive integration experience can provide valuable insight to utilities as they plan new projects. Inherent characteristics of wind-generated electricity, such as its location-specific resource, intermittent output, and low capacity factor, present unique integration challenges.

Areas of primary interest include the effect of wind plants on utility operations and scheduling—including operating reserve requirements, economic dispatch and unit commitment—integration of wind power into utility systems including interface (or engineering) issues, and planning concerns.

Interface Issues

Interface issues, also referred to as engineering issues, include harmonics, reactive power supply and voltage regulation, and frequency control. Harmonics and reactive power supply are significant utility power quality concerns. While high quality electricity is not necessary for turning on a light switch, computers and other devices rely on consistent, high quality electricity, so it is important that wind power plants deliver electricity that meets the engineering needs and standards of the electric grid. The current trend toward advanced power electronics and the addition of power factor correction devices enables wind plants to deliver electricity that meets utility quality requirements.

Utilities in California have experienced periodic voltage limitations with wind plants located in a remote areas using conventional induction machines that are connected to the utility through transmission lines originally designed to serve only local loads. However, accepted power system engineering procedures and operating practices have helped alleviate system voltage control problems.

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Utilities operating wind power plants connected to weak, isolated grids may also have difficulty maintaining normal system frequency. Southern California Edison and Pacific Gas & Electric have multiple power lines connecting multiple power plants, so short-term variations in wind plant output are small relative to system demand. The system size and strong nature of system interconnection enables the utilities to maintain a normal system frequency; planned integration and accepted power system procedures has adequately addressed all issues that have arisen.

Operating Issues

Operational issues include the effect of intermittent power output on operating reserve requirements, unit commitment, and economic dispatch. Utilities have operating reserves in order to maintain the performance of the system even at peak usage times—such as on a hot day with heavy air conditioning load. Operating reserves guard against sudden loss of generation, off-system purchases, unexpected load fluctuations, or unexpected transmission line outages.

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Short-term fluctuations in energy output are a common characteristic of wind power. Because these fluctuations cannot be accurately predicted, utilities rely on sufficiently stocked operating reserves in order to maintain the integrity of the electric system. The integration of wind power plants into utility systems requires that spinning reserves account not only for the maximum probably demand increase or the loss of the largest single generation resource, but also for the maximum probably decrease in wind plant output over a 10-minute period. At the current wind power penetration levels in California, the variability of wind plant output has not required any change in current operating reserve levels. However, the impacts of wind integration must be determined within the context of the individual, local electric system.

The benefits of wind energy are often discounted because wind is an intermittent resource as power is only produced when the wind is blowing. Economic dispatch determines the optimal loading of each generating unit subject to transmission and reserve constraints. The ability to accurately forecast wind plant output could increase the value placed on wind resources in utility operation and scheduling. Geographic diversity among wind power plants can also reduce the impact of resource intermittency.

Planning Issues

Planning issues include the appropriate modeling and valuation of intermittent wind resources compared to conventional resources. Models that reflect the relationship between variations in load and wind plant output are needed to address utility concerns with operation a wind plant during low load conditions. The ability of integrating large amounts of wind energy into a utility's system will increase with the availability of improved operational and forecasting models. While wind power is given value during peak periods, it remains difficult to quantify, and may be impacted by restructuring.

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Wind development may also create local environmental benefits and other distributed benefits in addition to its energy and capacity value. For example, a wind plant that produces electricity during the early morning hours can reduce peak ozone concentrations in urban areas of southern California by delaying the startup of thermal generation.

Adequately addressing wind resource planning issues requires:

- More wind resource data;
- Additional utility case studies;
- Improved operational and forecasting models; and
- Identification of local environmental and other distributed benefits.

Utilities in California have successfully integrated wind power into their systems without negatively affecting utility operations. Experience in California has shown that accepted engineering procedures and operating practices can be applied to achieve well-designed systems.

This brief was summarized by Margaret Shaheen, National Conference of State Legislatures, from a *Wind Energy Series* report by Robert J. Putnam Jr., Electrotek Concepts, Inc.

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