Wind Energy SERIES
National Wind Coordinating Committee

January 1997
No. 9

Wind Energy Transmission and Utility Integration

Increasing competition in the electric power industry is transforming the way in which utilities do business. In this new environment, a number of major trends can be expected to affect energy transmission and resource integration based on experience with other competitive industries.

Major trends include:
- *Customer choice of supplier*
- *Improved technology*
- *Greater focus on customer satisfaction*

Increasingly, customers will have the ability to choose their electricity supplier. Winners and losers in the electric supply industry will be distinguished by their ability or inability, respectively, to develop sophisticated relationships with even the smallest customers. Technology will play a key role in developing these relationships by providing new products and services that will bring in revenue and develop brand identity. Ultimately, customer satisfaction will determine market share, and the grid -rather than defining monopoly boundaries -- will become the network by which buyers and sellers come together. In addition to providing high levels of reliability and power quality, the transmission grid should be developed to deliver the particular products and services that utility customers will demand.

Other trends of significance will include:

- Increased compatibility between the electric industry and the environment
- Improved asset utilization
- Diversification of the product mix

Wind energy has the potential to play a significant role in meeting each of these emerging trends as utilities prepare for the challenges of a new competitive marketplace. The objective of this paper is to identify and discuss the transmission and utility integration issues that will need to be addressed by utilities and policymakers so that wind energy can realize this potential.

Transmission of wind energy

Until recently, conventional wisdom indicated that much of the land with good wind resources was unavailable for development because of environmental and land use restrictions. In addition, a common perception is that good wind resources typically are remote and are located far from available transmission capacity.

Studies show that 65 percent of totally windy land area in the lower 48 states is suitable for wind resource development.

The first issue has been examined by researchers at the Pacific Northwest Laboratory (PNL) as part of their ongoing wind resource assessment work. They estimate that under a moderate land use scenario with full environmental exclusions, the developable wind resource land area in the lower 48 states is 65 percent of the total windy land area (Class 4 or above), corresponding to 13.8 percent of total land use requirements. The PNL work confirms that the available wind resource is not overly limited by environmental and land use considerations.

The issue of whether capacity is available to bring large amounts of wind energy to the market without the need for extensive upgrades or expansion of existing transmission and distribution systems has been partially addressed by researchers at the Oak Ridge National Laboratory (ORNL) and the National Renewable Energy Laboratory (NREL).

Two recent reports by the ORNL examined whether the integration of new renewable resources would require significant upgrades or expansion of existing transmission and distribution systems to accommodate the required power transfers based on the results of several utility case studies.

In general, the results of the seven utility case studies reviewed in the first ORNL report on transmission system integration indicate that it appears possible to integrate new wind resources on the order of 50 to 100 megawatts (MW) to supply *local* load in *many* areas, *without* the need for significant upgrades to the transmission system.2 In addition, if dynamic methods were used to rate the thermal capacity of existing transmission lines, those lines near good wind resources may be able to increase their theoretical load limit due to the cooling effect of the wind. The use of dynamic rating methods therefore could increase the amount of wind energy that could be integrated into the existing system without requiring an upgrade of existing facilities.

The second ORNL report examined the distributed benefits associated with integrating renewable resources into the distribution system.3 Distributed benefits include:

- Deferred construction of transmission and distribution (T&D) facilities
- Avoided transmission and distribution system losses
- Enhanced reliability

A case study of Orcas Power and Light Company (OPALCO) on Orcas Island near Seattle, Wash., found that more than 42 percent of the benefits associated with the construction of a 1 MW wind farm could be attributed to delayed construction of transmission and distribution facilities and reduced distribution system losses due to the very strong correlation between the available wind resource and the load on the distribution system.4 The distributed concept of wind plant development -- one that could potentially capture distribution system benefits similar to those identified in the OPALCO study -- is beginning to attract some interest in parts of the Midwest, a region with extensive wind resources.

In another recent study, researchers at the NREL found that more than 175,000 MW of potential wind power plant development was within 5 miles of existing 230 kilovolt (kV) (or below) transmission lines.5 The study, however, did not examine the ability of the existing transmission system to accommodate the required power transfers.

Table 1 shows the potential contribution of wind power plants from the NREL report assuming:

- A 30 meter wind turbine hub height
- A minimum Class 4 wind regime (annual average wind speed greater than 14.5 mph)
- PNL moderate land use restrictions

Table 1 Wind Power Potential	
	Average MW
Within 20 Miles of Transmission	401,652
Within 10 Miles of Transmission	284,239
Within 5 Miles of Transmission	175,656

A comprehensive assessment of available transmission and distribution line capacity in good wind resource areas is required to determine the magnitude of the available wind resource within 5 miles of existing 230 kV or below transmission that could be accommodated without the need for extensive upgrades or expansion of the existing transmission system.

Finally, as competition increases in the electric utility industry, customers will be defined by the products and services they request from their electricity supplier, not simply on the basis of their physical location. Assuming that there will be a market for renewable energy -- as evidenced by numerous public opinion surveys that indicate strong support for increased use of renewable resources -- utility planners will be challenged to bring location-dependent resources like wind to that market or risk losing that customer to their competitors.

Transmission access and pricing

Transmission rights of access, wheeling charges and other factors can significantly affect the feasibility and cost of wind power development. Changes to the Federal Energy Regulatory Commission's (FERC) regulation of access and pricing for transmission and regional policies adopted by Regional Transmission Groups (RTGs) could affect the choice of new resources. The manner in which these changes and policies are implemented may present issues that are unique to wind and other renewable resources, giver' their inherent characteristics such as:

- Location-specific resources
- Intermittent output
- Low capacity factor

The purpose of this section is to identify the access, pricing and planning issues that should be considered when setting policy, and their potential effect on wind power development.

Transmission access
The National Wind Coordinating Committee (NWCC) supports the principle that transmission customers should have the same flexibility of service that transmission owners enjoy on comparable terms, including:

- Treating all transmission users equally according to their actual use of the transmission system
- Allowing reassignment of transmission capacity
- Allowing access on a non-discriminatory basis

Changes in FERC regulation of access and pricing for transmission, as well as regional policies, could affect utilities' choice of new resources.

FERC and state regulators are encouraged to foster the development of open, efficient and competitive markets including markets for wind energy. As competitive markets become increasingly regional, policymakers at the federal and state levels may wish to develop policies and rate structures that allow diverse resource areas to be matched with local demand areas without the imposition of onerous access charges or conditions.

Pricing
The ability of suppliers to meet customer demands for energy from renewable resources such as wind may be frustrated by pricing principles that do not reflect the network costs or benefits of dispersed generation resources. Rate structures that reflect the cost impacts of all generation resources on the regional grid should be developed.

Regional planning
The FERC's recent approval of RTGs was conditioned by the requirement that a regional transmission plan that reflects the needs of non-members be adopted by all members. For regional markets to operate efficiently, regional planning must identify those transmission projects that will increase regional efficiency. This will require the identification of generation resources and loads to be served by the transmission improvements. The location of renewable resources must be considered early in the planning process, if the resulting transmission plan is to be comprehensive in its development of a more efficient, long-term transmission grid to service the developing regional market.

Integration of wind resources into utility systems

During the last decade, more than 1,600 MW of wind generating capacity has been installed in California. As utility interest in wind energy expands to other regions of the country -- the Northeast, Northwest, Great Plains and Texas the positive integration experience with wind energy in California can provide valuable insight to utilities as they plan new projects.6 The purpose of this section is to discuss the potential effect on utility operations of integrating wind power plants into utility systems.

Areas of primary interest include the effect of wind plants on utility operations and scheduling -- including operating reserve requirements, economic dispatch and unit commitment -- and the degree to which engineering and planning concerns must be addressed.

Issues associated with the integration of wind power into utility systems have been characterized as either interface (or engineering) issues, operational issues, or planning issues. Interface issues include:

- Harmonics
- Reactive power supply and voltage regulation
- Frequency control

Operational issues include the effect of intermittent power output on:

- Operating reserve requirements
- Unit commitment
- Economic dispatch

Planning issues concern the appropriate modeling and valuation of intermittent wind resources compared to conventional resources.

Based on the wind plant operating experience in California, integration of wind resources has not been a problem in terms of interface and operational issues. Any issues that have developed, such as intermittency and voltage regulation, have been adequately addressed by accepted power system procedures and practices. Planning issues associated with the integration of wind power plants into utility systems is an area that requires continued attention. Additional utility case studies are needed to accelerate utility acceptance of wind energy outside California.

Interface issues
Harmonics and reactive power supply are significant utility "product quality" concerns. With the addition of harmonic and power factor correction devices -- and the current trend toward advanced power electronics -- wind plants can be designed to meet utility product quality requirements.

Utilities may experience difficulty controlling system voltage (e.g., Southern California Edison experiences periodic voltage limitations on its 66 kV system in Tehachapi) when a wind plant using conventional induction machines without sufficient Dower factor correction is located in a remote area and is connected to the utility through transmission lines originally designed to service only local loads. Even in this case, however, accepted power system engineering procedures and operating practices have been adequate.

Issues in integrating wind power into utility systems

- *Interface or engineering*
- *Operations*
- *Planning*

Utilities operating wind power plants connected to weak, isolated grids also may have difficulty maintaining normal system frequency (as documented on the Hawaii Electric Light Company system).7 In the case of Southern California Edison and Pacific Gas & Electric normal system frequency can be maintained due to the strong nature of the system interconnection and the small short-term variations in wind plant output relative to system demand. Again, planned integration and accepted power system procedures and practices have adequately addressed any issues that have arisen.

Operating issues
Utilities carry operating reserve to assure adequate system performance and to guard against sudden loss of generation, off-system purchases, unexpected load fluctuations or unexpected transmission line outages. The integration of wind power plants into utility systems requires that spinning reserves account not only for the maximum probable demand increase or the loss of the largest single generation resource, but also for the maximum probable decrease in wind plant output over a 1 0-minute period. To the extent that short-term fluctuations in wind plant output cannot be anticipated with a reasonable degree of certainty, additional operating reserves may have to be scheduled to ensure the integrity of the electric system. Research indicates that, at the current wind plant penetration levels in California, the variability of wind plant output has not required any change in current operating reserve levels.

The unit commitment function determines the optimal scheduling of generation resources to meet expected system demand and operating reserve requirements, considering generation maintenance schedules, generator startup and shutdown costs, minimum fuel burn requirements, and seasonal availability of intermittent resources such as hydro and wind. For a given unit commitment plan, economic dispatch determines the optimal loading of each unit subject to transmission and reserve constraints. The most conservative approach discounts the potential contribution of wind resources in determining the optimal unit commitment and dispatch schedule. The ability to accurately forecast wind plant output an area that is receiving increased attention in the research community -- potentially can produce significant added value to utility operation and scheduling. Geographic diversity among wind power plants also can reduce the impact of resource intermittency.

Planning issues
Planning issues concern the appropriate modeling and valuation of intermittent wind resources compared to conventional resources.

Models that can reflect the inter- and intra-hourly variations in load and wind plant output are necessary to adequately address utility concerns over the impact on system operations of changes in wind plant output during low load conditions. A utility's ability to integrate large amounts of wind energy into its system will increase with the availability of improved operational and forecasting models. While wind power is considered to have some capacity value on peak, it remains difficult to quantify, and may be valued differently in a restructured electricity market.

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

To adequately address these planning issues, a need exists for:

- *More good wind resource data* such as that currently being acquired through the U*WRAP and STEP programs.

- *Additional utility case studies* to determine the amount of wind capacity that can be integrated into the existing utility system without requiring extensive transmission upgrades or negatively affecting utility operations.

- *Improved operational and forecasting models* that can reflect the inter- and intra-hourly variations in load and wind plant output.

- *Identification of local environmental and other distributed benefits* resulting from wind power development.

Conclusion

California's experience demonstrates the potential effects of integrating wind power plants into utility systems. Wind energy has the potential to play a significant role in the new competitive electricity marketplace. Research has shown that the available wind resource is not overly limited by environmental or land use restrictions, and that it appears possible to integrate new wind resources in many areas without the need for extensive upgrades or expansion of the existing transmission system. Research also has shown that accepted engineering procedures and operating practices can be applied to achieve well-designed systems.

One challenge that remains is to develop policies and rate structures that allow diverse resource areas to be matched with local demand areas without the imposition of onerous access charges or conditions. Rate structures that reflect the cost effects of all generation resources on the regional grid should be developed.

For further information

Further information about the integration of wind energy into utility systems may be obtained from published articles and reports, laboratories maintained by the U.S. Department of Energy, the American Wind Energy Association and the Utility Wind Interest Group Inc. Organization addresses are listed below.

U.S. Department of Energy
Office of Energy Efficiency and
Renewable Energy
Wind/Hydro/Ocean Division
Mail Stop EE-121
1000 Independence Avenue
Washington, D.C. 20585

American Wind Energy Association
122 C Street, NW, Fourth Floor
Washington, D.C. 20001
Tel. (202) 383 2500

National Renewable Energy Laboratory
National Wind Technology Center

Utility Wind Interest Group, Inc.
2111 Wilson Boulevard, Suite 323

1617 Cole Boulevard
Golden, CO 80401-3393
Tel. (303) 384-6900

Arlington, VA 22201
Tel. (703) 351-4492

Oak Ridge National Laboratory
P.O. Box 2008
Oak Ridge, TN 37831

Lawrence Berkeley National Laboratory
1 Cyclotron Road
Berkeley, CA 94720
Tel. (510) 486-5474

Notes

1. Elliott, D. L., Wendell, L. L., and Gower, G. L. (August 1991) *An Assessment of the Available Windy Land Area and Wind Potential in the Contiguous United States,* Pacific Northwest Laboratory, PNL-7789.

2. Barnes, P.R., Dykas, W.P., Kirby, B.J., Lawler, J.S., Purucker, S.L. (1995) *The Integration of Renewable Energy Sources into Electric Power Transmission Systems,* Oak Ridge National Laboratory, ORNL-6827..

3. Barnes, P.R., Van Dyke, J.W., Tesche, F.M., Zaininger, H.W. (1995) *The Integration of Renewable Energy Sources into Electric Power Distribution Systems, Vol. I National Assessment,* Oak Ridge National Laboratory, ORNL-6775/V1..

4. Zaininger, H.W., Ellis, P.R., Schaefer, J.C. (1995) *The Integration of Renewable Energy Sources into Electric Power Distribution Systems, Vol. 11 Utility Case Assessments,* Oak Ridge National Laboratory, ORNL-6775/V2.

5. Parsons, B., Elliott, D.L., and Wan, Yih-huei. (March 1995) *Estimates of Wind Resource Land Area and Power Potential in Close Proximity to Transmission Lines,* American Wind Energy Association, WINDPOWER '95 Proceedings.

6. Putnam, Jr. R.G. (1996) *Assessment of California Wind Plant Operating Experience,* Electrotek Concepts Inc.

7. Smith, J.C., Curtice, D.H. (August 1993*) Small* System *Performance Under High Wind Plant Penetration,* Electric Power Research Institute, TR-102784.

Wind energy can play a significant role in the competitive electricity market.

National Wind Coordinating Committee

The content and form of the papers in this series have been reviewed and approved by the National Wind Coordinating Committee. Committee members include representatives from investor-owned utilities, public utilities, state legislatures, state utility commissions, state land commissions, consumer advocacy offices, state energy offices and environmental organizations. The purpose of the National Wind Coordinating Committee is to ensure the responsible use of wind power in the United States. The committee identifies issues that affect the use of wind power, established dialogue among key stakeholders and catalyzes appropriate activities.

The Wind Energy Series is a product of the National Wind Coordinating Committee (NWCC). The NWCC is a collaborative endeavor that includes representatives from electric utilities and support organizations, state legislatures, state utility commissions, consumer advocacy offices, wind equipment suppliers and developers, green power marketers, environmental organizations, and state and federal agencies.

Issue Brief No. 9a, Issue Brief No. 9b | NWCC Publications