Integrating Utility-scale Wind Energy onto the Grid:
An Informational Resource

Summary

As the use of wind energy continues to expand, utilities and grid system operators are preparing to integrate and manage more of this renewable electricity source on their systems. **The output from wind farms varies with the wind and therefore can pose challenges, but the growing body of experience shows these challenges can be successfully managed -- opening the way for wind energy's benefits to be reaped on a large scale for consumers, the economy, the environment, the resilience of overall electricity supply, and our energy security.**

However, wind energy opponents have recently stepped up their efforts to portray integration challenges as insurmountable flaws. These alarmist allegations are sometimes echoed in the media. Two recent examples include a report by ABS Energy Research cited in the Long Island newspaper *Newsday* in October 2006, and initial attempts by opponents to blame wind energy for a brief but cascading blackout and disturbance that occurred November 4, 2006, in Germany and other European countries.

In fact, not only do reports and experience find that wind energy's potential integration impacts are modest, manageable and offset by both economic and environmental benefits, but **system operators and utilities are preparing for more wind power in the years ahead.** The wind energy industry is working with reliability organizations, utility managers, and regulators on studies, adoption of standards, and policy developments toward that goal. **What's more, some of the very factors that make for smoother integration of wind -- such as better use and expansion of physical transmission capacity, well-functioning electricity markets, diversity of resources, and consolidation of balancing areas -- also make for a more resilient, efficient electricity market for all**.

Background

The European countries that lead in wind power (Denmark, Germany, Spain) "just did it" and successfully built up their wind capacity without preliminary studies into potential integration impacts. Today, Denmark and some states in Western Germany and Spain get 20% of their electricity supply or more from wind. It is only now, at these levels, that utility managers and operators in some of those regions are finding that preparation for the integration of more wind power becomes more important. Such preparation may include improved forecasting, expansion of transmission capacity, and integration of regional power markets.

The U.S. has not yet reached similar levels of wind penetration, although wind makes up 5% or more of the power portfolio of a few utilities and wind will be the second-largest source of NEW power generation coming on line in the country in 2006, for the second year in a row. Even with such small levels of penetration, there have been many more studies and debates about integration issues in the U.S. than in Europe. A turning point was reached in 2005-2006, with a special publication of the Institute of Electrical and Electronic Engineers (IEEE) and a joint paper by all the associations that, together, represent the nation's utilities, which clarified the issues and provided information on the state of the art for wind integration.

Alarmist allegations

In spite of this wealth of authoritative information and reports, opponents both here and in Europe still attempt to present as "facts" what are misleading representations and sometimes outright errors about the integration of wind power into the overall electric system. Such alarmist allegations are not only inaccurate but irresponsible. Here are two recent examples:

ABS study: A UK-based firm, ABS Energy Research, packaged a report (available only for sale at $1,600) with an alarmist sales pitch touting "real evidence" about wind power and questions about claims for the technology. Experts say that the report presents potential problems in a selectively biased way, and those who have contacted ABS to discuss the report have not received a response. Brian Parsons, a researcher on wind integration issues at the National Renewable Energy Laboratory of the U.S. Department of Energy, commented to a reporter looking into the issue that the report "should be put in a trash can." For more see http://www.ifnotwind.org/pdf/061102_AWEA_on_Newsday_ABS_Integration.pdf and http://risingwind.blogspot.com/2006/11/newsday-new-york-times-get-it-wrong.html

Rumors about the Europe-wide November 4, 2006 blackout that originated in Germany: An anti-wind blog in Northern Texas seized on this blackout to claim that "everything that could go wrong with wind power, went wrong. It started in Germany, Europe's leader in wind energy production with over 18,000 Mw. of turbines." In fact, a November 6 Q&A from the BBC on the topic explains:

Power cuts that left millions of people across Europe in the dark at the weekend have raised fears that the continent's electricity network is not up to the task.

How did the failure occur?

The German distributor E.ON admitted it caused the blackouts, by switching off a power cable across the River Ems to allow a cruise ship to pass.

This meant areas to the west were left with a power deficit, while cables in the east were overloaded. Supplies cut out in Germany, France, Belgium, Spain, Portugal, Croatia and Italy.

For the detailed Q&A, see Story from BBC NEWS:
http://news.bbc.co.uk/go/pr/fr/-/2/hi/europe/6121166.stm

The Union for the Coordination of Transmission of Electricity , which oversees transmission systems in Europe, provides regular updates on the on-going investigations into the blackout on their Web site at http://www.ucte.org/news/e_default.asp.

Growing body of authoritative studies

As serious students of the issue will find, recent years have seen a wealth of studies on various aspects of wind energy integration, ranging from technical reviews of actual performance to scenarios analyzing the potential impacts and feasibility of different levels of wind penetration.

A chronological list of most of these studies including links to the studies themselves is made available by the Utility Wind Integration Group (UWIG), an association of utilities that have wind on their systems, at http://www.uwig.org/operatingimpacts.html.

We won't duplicate this effort, but will present conclusions from the 2006 paper on "Utility Wind Integration State of the Art" jointly prepared by UWIG and:

- the Edison Electric Institute (EEI),
- the American Public Power Association (APPA) and
- the National Rural Electric Cooperative Association (NRECA).

The paper, which "does not advocate any particular policy or position," marked a watershed development because **these associations together represent all the nation's utilities**.

According to the report, wind resources have impacts, but these "can be managed through proper plant interconnection, integration, transmission planning, and system and market operations." We highlight some of the findings here and provide some examples to illustrate:

--Cost: The cost of managing possible impacts are found to be incremental (10% or less of the wholesale value of the wind energy at penetrations of up to 20%) and "substantially less" than, for example, imbalance penalties generally imposed by regulators on the market. This means that, at up to wind penetrations of up to 20% of peak demand, a wind farm producing power at 6 cents per kilowatt-hour (kWh) would require at most 0.6 cents (10% or less) in extra resources for balancing the overall system. In other words, when high integration costs are cited, it is likely due either to a lack of understanding of factors affecting integration or a failure to adopt best operational practices.

--Savings: "In many cases, customer payments for electricity can be decreased when wind is added to the system, because the operating-cost increases could be offset by savings from displacing fossil fuel generation, " according to the paper. Xcel Energy, the utility that is the largest purchaser of wind power in the country, has reported that the wind power on its Colorado system yielded a net $9.75 million in savings in 2005.

--System stability: "Further, there is evidence that with new equipment designs and proper plant engineering, system stability in response to a major plant or line outage can actually be improved by the addition of wind generation." The new equipment designs include power electronic controls and dynamic voltage support capability. The American Wind Energy Association worked with the North American Electric Reliability Council (NERC) and the Federal Energy Regulatory Commission (FERC) to develop and finalize interconnection standards --or a "grid code"--for wind energy. These standards are now in place and the interconnection process ensures that new equipment designs are used where appropriate.

--Back-up and contribution to capacity: "Since wind is primarily an energy - not a capacity - source, no additional generation needs to be added to provide back-up capability provided that wind capacity is properly discounted in the determination of generation capacity adequacy." This means that, for planning purposes, wind is largely an energy resource (providing electricity, diversifying supply, saving fuel) with a bit of capacity value or "effective load carrying capacity" (ELCC) (see footnote [1] for definitions of capacity factor, capacity value and ELCC). ELCC calculations for wind can have a wide range, for example from 30% for the Colorado Green wind farm in Lamar, Colorado, to 23-25% in California to as low as 6% in Germany, depending not only on capacity factor but also on how closely wind patterns and wind plant output tend to match the system load (demand) profile.

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[1] "**Capacity factor**" is the average power output of a power plant, or the ratio between the average amount of electricity that a power plant produces and its peak power output. Capacity factors vary depending on the type of power plant and its purpose. Peaking plants may run only part of the time, for example, resulting in capacity factors of 10-20%. Other power plants may normally run much of the time unless idled by equipment problems or for maintenance. A capacity factor of 40% to 90% is typical for conventional intermediate and baseload plants.

For wind farms, capacity factor depends primarily on the average wind speed at the site. Since the wind speed varies, wind farms on average operate at 25% to 40% of their peak power – sometimes more, sometimes less. This does NOT mean wind plants run only 25% to 40% of the time. In fact, most wind farms produce power into the grid between 65 and 90% of the *time* throughout the year.

It is important to note that capacity factor for a wind plant is a matter of economical turbine design. With a very large rotor and a very small generator, a wind turbine would run at full capacity whenever the wind blew—but it would produce very little electricity. The most electricity per dollar of investment is gained by using a larger generator and accepting the fact that the capacity factor will be lower as a result.

"Capacity value" is the expected amount of capacity on which utility managers can rely to meet annual system peak load periods. For wind power plants, capacity value will depend not only on average power output (see above), but on the statistical probability that output will coincide with customer demand and other system characteristics. The more historical data and wind pattern data is available, the more accurate the determination of capacity value for wind energy can be. While wind is generally considered as an energy rather than a capacity source, some wholesale power markets and system planners recognize a capacity component -- or value -- for wind.

"Effective load-carrying capacity**"** (ELCC) is an established measure for estimating capacity value. ELCC and related methods of calculating capacity value continue to be refined.

--Transmission planning and management: “Consolidation of balancing areas or the use of dynamic scheduling can improve system reliability and reduce the cost of integration of additional wind generation into electric system operation,” according to the report. An example of this is the New York State market: a study for the New York State Energy Research and Development Authority (NYSERDA) and the New York Independent System Operator (NYISO), which examined possible impacts of integrating wind power capacity equal to 10% of the state’s peak load. The study found that, given the NYISO’s large balancing area, mix of resources, and existing processes, such an increase could be accommodated in NY state without special measures, and would “reduce system operating costs” largely due to fuel savings.

In addition to the APPA-EEI-NRECA-UWIG paper and the studies presented by IEEE and listed by UWIG, many others have been published or are under way. We will mention two others, released in 2006:

The Electric Power Research Institute (EPRI)’s “Putting Wind on the Grid” looks more narrowly at forecasting and electronic system solutions and even storage instead of broader regulatory policies, but concludes that “combined with other technological advances and deployment trends already under way, regulatory changes of this sort [transmission tariff reform] could help make wind energy a major contributor to America’s electric power future.”

National Grid, an energy company that delivers electricity and natural gas, issued a paper in September (http://www.nationalgridus.com/non_html/c3-3_NG_wind_policy.pdf) on transmission policy issues and recommending a diversified energy supply. The paper noted that the current US transmission system was not built to support competitive regional markets and is not sufficient to integrate planned and potential new generation sources, so additional transmission infrastructure will be required. It also notes that operating techniques for variable-output generation resources, properly structured market rules, and effective transmission policies for regional planning, cost allocation, and cost recovery and incentives will help to facilitate wind power as well as other new sources of generation.

A few of these studies also look at emissions reductions from wind power use. The New York study mentioned above found that “by displacing energy from fossil fired generators, wind generation causes reductions in emissions from those generators.” Based on wind and load profiles for 2001 and 2002, 65% of the energy displaced by wind in New York State comes from natural gas, 15% from coal, 10% from oil, and 10% from imports, according to the study. More generally, as H. Socolow and Stephen W. Pacala explain in *Scientific American* magazine ("A Plan to Keep Carbon in Check," September 2006, p. 55), the variability of renewable power “does not diminish its capacity to contribute [carbon emissions reductions].”

Conclusion

Reports and experience show that wind energy's potential integration impacts are not negligible, but modest and manageable. The wind energy industry is working with regulatory organizations, utility managers and groups, and other stakeholders to further minimize costs and manage the integration of wind power onto electric systems. Such adaptation and preparation becomes more important as the use of wind power increases, just as it does for any technology. When nuclear power was introduced, for example, system managers had to adjust operations to ease the integration of a large, non-dispatchable, single source of electricity that could suddenly trip off-line, and they continue today to typically set their "reserve margin" at the level of the largest nuclear plant on their system.

The level of the costs of managing impacts resulting from wind's variable output will depend on factors that are inherent in the markets in which it operates, such as size of territory, functionality of power markets, and mix of resources on the grid. It's important to note that some of the very factors that make for smoother integration of wind -- such as more efficient use and expansion of physical transmission capacity -- also make for a more resilient, efficient electricity market for all.

Most importantly, successful integration of large amounts of wind power will make for a cleaner, more diverse, and cost-efficient electricity system. Wind delivers tremendous energy, economic, and environmental value: it can provide large amounts of bulk power, reduce overall system operating costs through fuel savings, and reduce emissions of pollutants or the cost of attaining emissions reduction goals. And because this is a domestic source of energy, its growth will bring jobs and economic development opportunities to the country and help strengthen our energy security.

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