Wind & the Electric Grid

Electricity no longer merely lights up the night and keeps our food fresh and cold; it also enables our communication, sustains our mass transportation and drives our economy. As our reliance on electricity has grown, so has our understanding of the negative environmental impacts of using fossil fuels to generate electricity. Around the world, scientists are searching for new, renewable and environmentally friendly electricity generation resources. Wind energy is one of these renewable resources.

Photo Credit: EDP Renewables. Lewis County, NY

Wind power currently provides electricity in over 80 countries, and it has become a significant electricity source in some. For example, Denmark's wind installations are capable of supplying 26% of its demand. Wind can supply 17% of the demand in Portugal, 15% in Spain, and 9% in Germany.[1]

In the U.S., there are currently 36 states with utility-scale wind projects. Fourteen of those, including New York State, have more than 1,000 MW of installed wind capacity each (Texas has over 10,000 MW). Many states now produce more than 5% of their electricity from wind, and four are estimated to produce more than 10% (Iowa, Minnesota, North Dakota and South Dakota.)[2]

In 2010, New York had 1,274 MW of installed wind generation capacity, or about 3.4% of the state's total generating capacity of 37,416 MW.[3] The state has made a commitment to more than double its wind generation capacity by 2015. Currently, wind energy actually contributes approximately 1% of New York's total in-state electricity generation.[4] But New York's wind energy potential is far greater. Based on available wind resources (i.e., areas with wind speeds consistently great enough for energy production), New York ranks 15th in the nation. Wind energy could become a much more significant part of New York's electricity generation portfolio, particularly if both onshore and offshore wind resources are developed. The U.S. DOE estimates that New York could hypothetically host 25,000 MW of wind energy.[5]

How Does Wind-Generated Electricity Affect the Electric Grid?

Demand for electricity changes rapidly, as residential and commercial use of electricity fluctuates from minute to minute. Because electricity generally cannot be efficiently stored, the amount generated and sold onto the

1. U.S.DOE, LBNL Ryan Wiser and Mark Bolinger, *2010 Wind Technologies Market Report.* June 2011.
2. U.S.DOE, LBNL Ryan Wiser and Mark Bolinger, *2010 Wind Technologies Market Report.* June 2011.
3. *Power Trends 2010*, NYISO.
4. *Power Trends 2010*, NYISO.
5. U.S. DOE, 2010, NREL Wind Powering America, Wind Maps and Resource Potential, http://www.windpoweringamerica.gov/wind_resource_maps.asp?stateab=ny

grid must match exactly the amount needed by customers; too little electricity (power sags) can result in a blackout, and too much (power surges) can damage power lines and appliances. Management of electricity production and delivery is done through advance scheduling of generators and rebalancing of their actual output in real time using sophisticated automated programs.

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Wind energy is an intermittent source of electricity generation, meaning wind turbines generate electricity when the wind is blowing, and stop when the wind stops. Wind turbines cannot be scheduled in advance with certainty, and they cannot be turned on any time they are needed; for this reason, they are not considered "dispatchable." The electric grid and the markets for electric power were not developed with intermittent electricity sources in mind. Yet, studies and experience show that wind energy can be integrated into the electric grid with minimal impacts or changes to the system. More than a dozen studies show that significant amounts of wind energy can be integrated into the grid with only moderate costs.[6] A recent study by the New York Independent System Operator (NYISO) found that up to 8 GW of wind energy, or more than 20% of the anticipated peak load for 2018, could be added to the New York State grid with no adverse reliability impact.[7] Modeling for this study assumed the 8 GW of wind energy would be generated at various locations around New York state, based upon an analysis of the state's wind resource (i.e., where there is sufficient wind and land) and where wind projects have already been proposed.

To understand how wind energy can be integrated into the grid, it is important to understand something about electricity market rules and wind forecasting systems.

Wind and Electricity Markets

In New York, the New York Independent System Operator (NYISO) operates the markets for electricity and is responsible for ensuring that we receive electricity safely and reliably. The NYISO is overseen by a federal agency, the Federal Energy Regulatory Commission. The NYISO and the owners of the transmission lines, commonly referred to as utilities, are responsible for ensuring that the lights go on when customers flip the switch. In turn, the NYISO and utilities depend on generators to produce the electricity that customers demand.

In order to insure that the NYISO uses the cheapest sources of electricity first, thus keeping energy prices as low as possible, the state has established an electricity market. Each generator bids into the market at the lowest price at which they can produce a given amount of electricity; the market accepts these bids, starting with the lowest and moving up in price, until the anticipated demand has been met. Then, any generator whose bid is accepted is paid the same as the highest bid taken in the auction (i.e., the most expensive generator sets the price). This system provides an incentive to generators to bid the lowest price they can to avoid being cut out of the market.

Generally, generators must at least recover the cost of the fuel they use to produce electricity (in addition to construction and operation and maintenance costs). Because wind turbines do not require costly fuel inputs, wind energy plants usually bid a low price relative to fossil fuel generators, meaning they are nearly always accepted as a generator. When this happens, the low-cost electricity from wind farms replaces electricity from other, more expensive generators.

6. IEEE Power and Energy Magazine, Nov/Dec 2009, "*Wind Power Myths Debunked*," M. Milligan, K. Porter et al, p. 95
7. Growing Wind, Final Report of the NYISO 2010 Wind Generation Study, September, 2010.

Wind Forecasting Systems

Although the "fuel" for wind plants – the wind – cannot be controlled, it can be predicted. NYISO uses a sophisticated wind forecasting system to predict how much wind-generated electricity is likely to be produced, and this allows grid operators to plan for how much dispatchable generation will be needed in addition to the wind energy. Wind forecasting systems such as that used in New York are becoming increasingly common as wind energy use increases across the country. In New York, the wind generators themselves pay for the system, though that is not the case elsewhere.

Wind energy is sometimes erroneously viewed as a "second-best" energy source since it is not considered dispatchable. But every fuel type has its own characteristics that must be acknowledged and accommodated by grid operators. Nuclear plants, for example, cannot be turned on and off rapidly as natural gas plants can, and cannot run at a low or partial output. Once fully on, nuclear plants must operate at nearly full output; and once they are turned off, it takes several days to get them back to full operation. Coal fired power plants can vary their output more quickly than nuclear plants, but this can also alter the efficiency and economics of the plant. Grid operators are used to managing changes in output from generators, because it is necessary to constantly change output to match the constantly changing demand from consumers. The NYISO, for example, monitors and manages electricity flows every six seconds. The NYISO uses its marketplace rules, computer programs and wind forecasting system to safely integrate wind plant output.

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Electricity markets need a diverse set of resources to best meet the demands of the generation, transmission and distribution system. No one type of generation is perfect, and no one type is sufficient to meet the needs of the state's electricity consumers.

Wind and Emissions Reductions

Wind energy is a "must-run" resource in New York, meaning the NYISO requires utilities to purchase wind-generated electricity when it is available. Thus, electricity generated from wind energy displaces electricity from other types of generation, that utilities would otherwise have purchased. To the degree that wind energy replaces electricity from the combustion of fossil fuels, it reduces pollution. The exact amount of this reduction depends on what combination of fuels is displaced. In New York State, the addition of wind energy to the grid tends to displace natural gas more than other fuels, because natural gas is usually the highest cost fuel. The NYISO's study of the impact of placing additional wind energy on the grid found that by increasing wind generating capacity from 1,275 MW to 8,000 MW, New York could reduce carbon dioxide (CO_2) emissions by 4.5 million tons (8.5%), ni-

trogen oxide (NO_x) emissions by 2,730 tons (7%), and sulfur dioxide (SO_2) emissions by 6,475 tons (9.7%). (NYISO, 2010)[8] CO_2 is the leading greenhouse gas, which causes global warming; NO_x and SO_2 contribute to acid rain and smog. The U.S. Department of Energy has estimated that a nationwide increase in the use of wind energy to 20% by 2030 could reduce carbon dioxide emissions in the U.S. by 825 million metric tons annually.[9]

Photo Credit: EDP Renewables. Lewis County, NY

Some have argued that using wind energy requires dispatchable fossil fuel generators to run at a low level, so they will be ready to ramp up output in case the wind stops blowing, and that this could result in higher emissions from those backup plants, mitigating the emissions benefits of adding wind energy to the grid. However, in the vast majority of cases, this is not true. All electric grids, whether they incorporate wind energy or not, must have dispatchable generators ready to quickly ramp up output to meet increases in demand ("regulation") or to cover for the unexpected failure of another generator ("reserves"). Adding small amounts of wind energy to the system changes these requirements only slightly. For example, the NYISO found that the average regulation requirement increased 9% for every one thousand megawatts of wind energy added to the system at higher levels of wind energy penetration (over 4,000 MW installed).[10] So, although the addition of wind energy does increase to a small extent the need for regulation or "spinning reserves" (generators kept running to help meet real-time fluctuations in demand), it still results in very substantial reductions in fossil fuel use, and a corresponding decline in emissions.[11]

Wind and Electricity Prices

Because wind turbines do not burn costly fossil fuels, adding wind energy to the grid helps lower energy prices by displacing more expensive fuel-based electricity generation sources. In New York, the fuel displaced is usually natural gas, but also at times coal or oil (the fuel sources that bid into the market at the highest prices). In March 2009, the NYISO testified at the New York State Assembly's joint hearing of the Energy and Corporations Committees that for every 1,000 megawatts of wind energy on New York's power grid, wholesale energy costs are reduced by approximately $300 million.[12] In addition, wind helps to stabilize electricity costs by reducing the state's dependence on fossil fuels, the prices of which fluctuate according to changes in worldwide supply and demand.

8. Growing Wind, Final Report of the NYISO 2010 Wind Generation Study, September, 2010.
9. U.S. DOE, 20% Wind Energy by 2030: Increasing Wind Energy's Contribution to U.S. Electricity Supply, 2008
10. Growing Wind, Final Report of the NYISO 2010 Wind Generation Study, September, 2010
11. IEEE Power and Energy Magazine, Nov/Dec 2009, "*Wind Power Myths Debunked*," M. Milligan, K. Porter et al, p. 94
12. Testimony of Stephen G. Whitley, President and CEO, New York Independent System Operator, Joint Public Hearing of the NYS Assembly Standing Committees on Energy and Corporations, March 5, 2009.

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