Task 25 Fact Sheet

Wind Integration Issues

Wind power plants, like all new generation facilities, will need to be integrated into the power system. This fact sheet addresses concerns about how power system reliability, efficiency, and the ability to balance the generation (supply) and consumption (demand) are affected by the variability and uncertainty of wind power production.

How is wind power different from other generation?

The main characteristics that differentiate wind power from other forms of generation are its variability and uncertainty.

- Conventional power plants generate at specified levels that operators can vary up or down as needed—they are dispatchable (except in cases of operational failure).
- Wind power generation varies depending on how wind fluctuates. However, the variations in output are smoothed when many wind power plants are aggregated over an area in a power system (Figure 1).
- To deal with uncertainty, wind power output can be forecast minutes, hours, and even days ahead. Forecasts for minutes or a few hours ahead are more accurate than for 12 to 48 hours ahead. Aggregating wind power plants over a wider geographic area will improve the forecast accuracy at all time frames.

See Fact Sheet: ***Variability and Predictability of Large-Scale Wind Power.***

How do operators balance wind plant output? Does wind power need dedicated back-up?

Electric power systems experience varying electricity consumption (demand), as well as

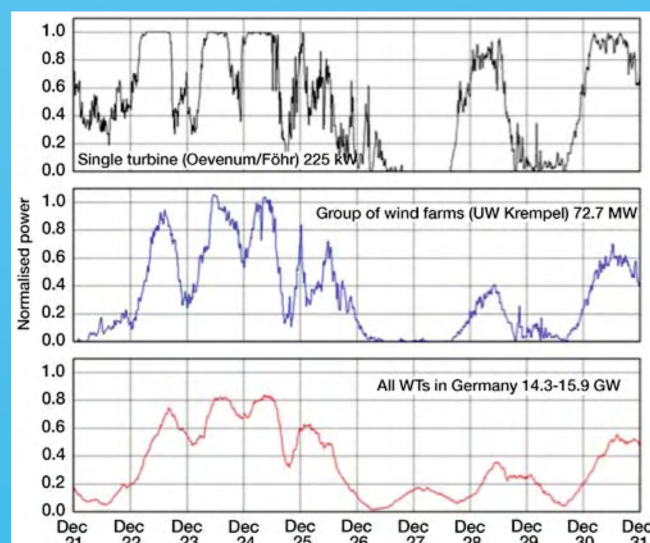

Figure 1. The short-term variations of the single turbine's output (top) are smoothed when aggregated to the output of a group of wind plants (middle). Aggregation of the output from all turbines in Germany (bottom) smoothes the variations even more. (Source: Task 25 summary report, 2009)

failures that cause power plants to go off line; all of these are balanced together with wind power.

- To balance the variations in demand and supply, system operators adjust the output of some plants. In this way demand is met at all instants and demand and supply are balanced.
- Variations of system demand and wind output often cancel each other out. Sudden, large changes of wind and demand are rare and not likely to occur simultaneously.

• Power systems (with or without wind) are balanced by operators at the system level, with all imbalances, between supply and demand, aggregated (net imbalances).

• Variations of wind power output distributed across a large, system-wide area are combined with other uncertainties that the power system experiences. Only the net imbalance at each minute is balanced.

• Because power systems are balanced at the system level, neither dedicated back-up nor storage can be allocated to any single source of variability. Back-up or storage only for wind would be poor and unnecessarily costly uses of power-generation resources.

See Fact Sheet: ***Storage Needs for Wind Power***

How do system operators manage the system during increasing and decreasing winds?

Operators schedule power generation to meet the anticipated demand at each hour and maintain operating reserve for balancing any unexpected variations real-time.

• Supply and demand are balanced by scheduling power plants in advance and by fine-tuning the dispatch of power plants closer to real-time.

• System operators balance supply and demand real-time by using operating reserves—responses from generation operators, who can quickly increase or decrease output from their plants.

• Anticipated increases and decreases of wind power will change the scheduling and operation of other power plants (Figure 2). Unexpected real-time variations will impact the use of operating reserve.

• Generation levels are changed to match to the combined variability and uncertainty of demand and of wind output (the net demand).

• The ability to respond both in the real-time and day-ahead time scales is called flexibility. Large shares of wind power will require more flexibility.

• Often there is more flexibility available in power systems than is used today. However, adding flexibility will be an important consideration for power systems anticipating large shares of wind power. In addition to adding flexibility in demand and generation, changing operational practices can bring more flexibility from existing assets (Figure 3).

See Fact Sheet: ***Balancing Power Systems with Wind Power***

What will operators do when there is no wind?

Power systems need to plan for sufficient generation during high demand situations.

• All power plants have a possibility of failure, with dire consequences during critical hours of demand.

• Wind power plants are not likely to fail all at once. However, there is risk of no wind during critical hours of high demand even with aggregated supply from many wind power plants dispersed over a large region.

• A commonly used metric for system operators when planning for generation adequacy is capacity value, the probability of wind power being available during high-demand situations.

• Capacity value for wind power is smaller than for conventional power plants—about 5 % to 40 % of wind plant rated capacity compared to 80 % to 95 % for conventional power plants. The wide range of values reflects the differences in the timing of wind energy delivery (when the wind blows) in periods of high demands.

• So far, during high demand periods and low wind power production other generation has been available. However, this other generation may be retired in the future when there is a larger share of wind energy in the system. In that case, the system must seek other measures during these rare periods to ensure generation meets demand, such as controlling demand or building low-capital-cost and high-operational-cost (peaking) plants or both.

See Fact Sheet: ***Capacity Value of Wind Power***

Does wind power cause extra emissions?

The primary value of wind power is to offset fuel consumption and the resulting emissions, including carbon.

• Each megawatt-hour (MWh) generated by wind reduces the required operation of other fuel-consuming generation

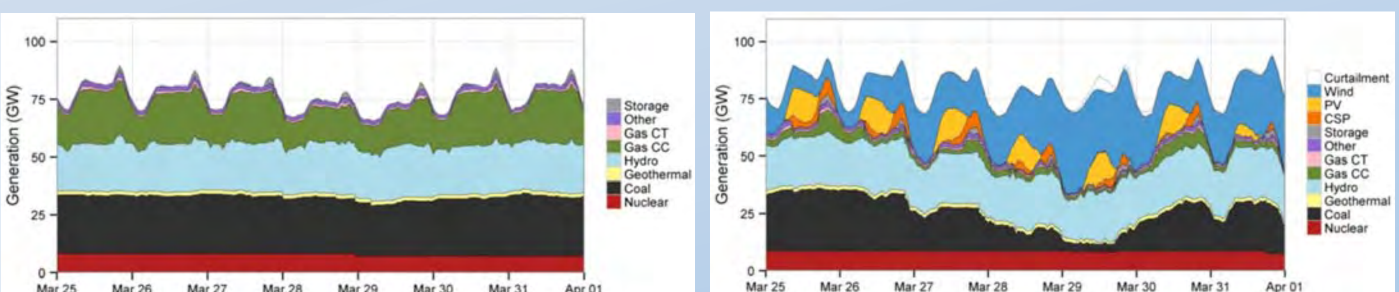

Figure 2. High wind and solar power generation will alter the contribution of more stable generation of conventional power plants, especially coal (in black) and gas-fired generation (in green), when compared to a case of no wind and solar. The example here is for the US Western Interconnect over one week for no wind or solar (left) and for high wind and solar (right).

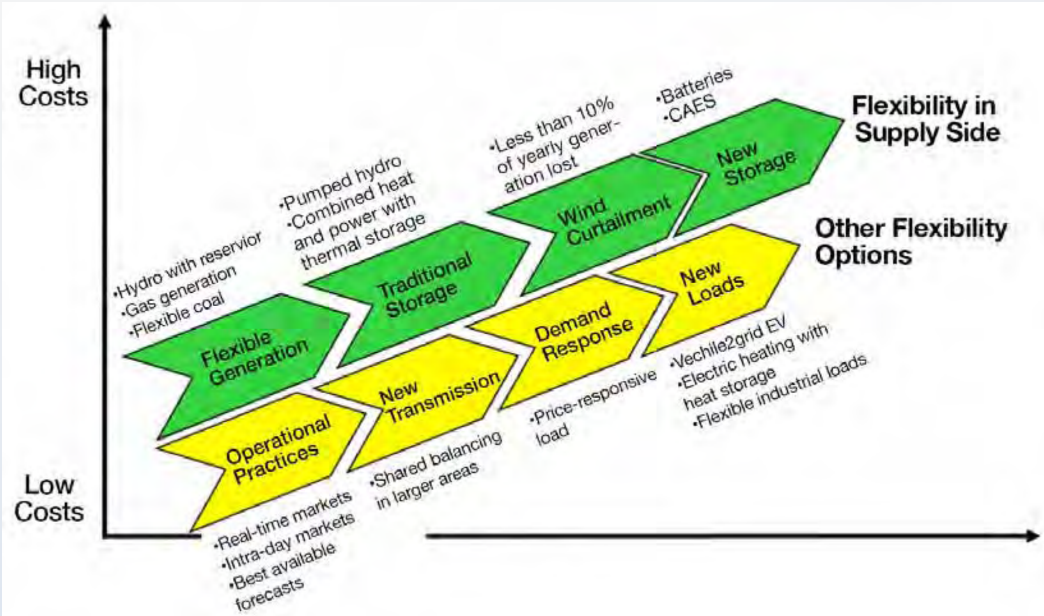

Figure 3. Methods to increase flexibility in power systems. (The relative order of these options is illustrative only)

units; the remaining non-wind generation need only supply the demand that is not supplied by wind.

• At high shares of wind energy, fuel-consuming generators will experience more start-ups, shut- downs, and steeper ramps to compensate for variation in wind generation and demand. Sub-optimal (lower efficiency) operating levels may also be required. Start-ups, ramping, and sub-optimal operation of fuel-consuming generators cause more emissions than operating at steady output levels. Balancing wind power with these units will thus incur some extra emissions.

• The amount of extra emissions from balancing with fuel-consuming generation has been estimated to be less than 2%.

• The increased emission of some generation units is more than offset by the overall reduction of emissions when wind reduces the need to operate fuel-consuming units (Figure 4).

See Fact Sheet: ***Emission Impacts of Wind Power***

How much new transmission investment is needed for wind power?

The need for new grid investment for wind depends on the location of the wind plants and the strength and characteristics of the existing grid.

• Any new power plant usually requires a new transmission (or distribution) line to connect it to the existing power grid. Upgrades to existing transmission lines may also be needed to accommodate the added power from the new plant.

• New wind power plants will alter how the power flows through the existing transmission (or distribution) grid. The power flow direction may change resulting in increased or decreased losses in transmission and distribution. Wind power may also increase or decrease bottleneck situations or congestion.

• Large amounts of added wind power will usually require some investment in the transmission grid, however the resulting transmission grid will benefit the whole power system. For this reason, transmission cost is normally not allocated to a single power plant or technology.

• Overall, transmission is only a small fraction of the total energy price for consumers. Numerous studies to allocate the transmission system costs to wind energy show that the costs are reasonable.

See Fact Sheet: ***Transmission Adequacy with Wind Power***

Compound Emitted	Emission Reduction Due to Renewables	Cycling Impact
CO_2	260 – 300 million lbs 29%–34%	Negligible Impact
NO_x	170 – 230 million lbs 16%–22%	3–4 million lbs
SO_2	80 – 140 million lbs 14%–24%	3–4 million lbs

Figure 4. The increase in plant emissions from cycling to accommodate variable renewables are more than offset by the overall reduction in CO_2, NO_X, and SO_2. (Source: WWSIS2, 2013) (1 million lbs = .45 million Kg)

Can wind power cause a blackout of the power system?

With higher shares of wind power, assessing the impacts of wind generation on power system dynamics will be important.

- The consequences of a blackout are very costly in modern society, so power systems must have a high level of reliability.
- Power systems must stay stable in different power flow situations and during and after faults (any abnormal electric current).
- Studies in Ireland show that during hours when the wind share is more than 50 % of the entire power system, special measures like altering relay protection settings may be needed to maintain reliability. Ireland is a special case because it is a small system and all events are felt more quickly when fewer large power plants are on-line (small inertia).
- In larger, interconnected power systems it is less probable that wind would cause a black out than in small, isolated systems.
- Wind power plants can help support system voltage and frequency during power system disturbances with control capabilities that are important and still evolving.

See Fact Sheet: *Impacts of Wind Power on Power System Stability*

Can lessons learned in countries using wind power be transferred to power systems in other countries?

The short answer is "somewhat."

- Power systems worldwide are quite different in regard to the mix of generation plants, the inherent variability of system demand, the strength of the transmission grid, and the rules and strategies practiced in daily operations.
- Experience and studies conducted so far conclude that for smaller shares of wind power, some basic measures are relevant:
    - o For operational decisions of power plants, it is important to take into account forecasting of wind power output.
    - o System operators should monitor the online generation of wind plants at control rooms.
    - o The grid connection rules for wind power plants should require sufficient system support.
- For larger shares of wind power, wind integration studies of each power system should be conducted to understand relevant integration issues. Integrating more than a 20 % share of yearly demand from wind requires new tools for transmission planning and operational practices.

Is there a limit to how much wind capacity can be accommodated by the grid?

In 2013, five countries had significant (6 % to 30 %) wind power contributions to total electricity consumption and ambitious targets for 2020 (up to 50 %).

- At high shares, there might be an economic limit—a point at which it is deemed more costly to accommodate added energy from wind than the value that it adds to the system.
- So far, instantaneous wind contribution to demand of up to 50 % is considered technically and economically feasible. Investigations are underway in Ireland with more than 75 % contribution to demand of non-synchronous generation like wind.
- Ireland, a small synchronous system, has a goal of about 40 % wind contribution to yearly electricity demand by 2020. Denmark, as part of a larger interconnected grid, is working toward a national goal of satisfying 50 % of its electrical demand with wind in 2020 and 100 % renewables (mostly wind) in 2035.

Associated Publications

Holttinen, H. (Ed.) (2013) Expert Group Report on Recommended Practices: 16. Wind Integration Studies. 1. Edition 2013. www.ieawind.org/task_25.html.

Holttinen, H., et al. (2013) Design and operation of power systems with large amounts of wind power. Final summary report, IEA WIND Task 25, Phase Two 2009–2011. ISBN 978-951-38-7910-5. www.vtt.fi/publications/index.jsp.

Holttinen, H., et al. (2009) Design and Operation of Power Systems with Large Amounts of Wind Power: Phase One 2006–2008. VTT Technical Research Centre of Finland, Espoo, Finland, 200 pp.

Lew, D., et al. (2013) The Western Wind and Solar Integration Study Phase 2. NREL/TP-5500-55588. Golden, CO: National Renewable Energy Laboratory. www.osti.gov/scitech/servlets/purl/1095399.

Milligan, M., et al. (2009) "Wind power myths debunked." IEEE Power & Energy Magazine, vol. 7, 6, ss. 89–99.

More Information

This Fact Sheet draws from the work of IEA Wind Task 25, a research collaboration among 16 countries. The vision is to provide information to facilitate the highest economically feasible wind energy penetration within electricity power systems worldwide. IEA Wind Task 25 works on analysing and further developing the methodology to assess the impact of wind power on power systems.

See our website at www.ieawind.org/task_25.html#