

NOVEL STRATEGIES TO REDUCE VARIATION OF WIND AND SOLAR GENERATION AT ITS SOURCE

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Unpredictable variations in power output from energy sources such as wind and solar can cause problems for electrical grid operators [1]. Electrical power generation must match load to maintain the stability of the electrical grid. Today, this balancing is typically done by fast-ramping gas turbines distributed throughout the grid. However, reducing those variations at the source has potential benefits in some scenarios. On longer time scales, reducing power variations allows more efficient use of transmission capacity [2]. On shorter time scales, reducing rapid changes in power output helps to maintain the stability of the grid [3]. Some methods for reducing power variations, such as energy storage, can also help the grid recover from faults and other transient events. Finally, variable energy sources in small, isolated grids must have their variability tightly controlled to match the load, and may require co-located smoothing services.

Over periods of hours or days, large variations in wind and solar power cause the transmission lines connected to them to be under-utilized. Transmission lines are typically built for the maximum power output of a generator, but wind and solar installations output their maximum power less than 30% of the time. There are four ways for a variable resource to more efficiently use transmission line: either store some energy to be transmitted at less-congested times, co-locate the renewable generator with a conventional generator, build a transmission line with a capacity less than the maximum generator output and occasionally curtail some power that cannot be transmitted, or build the wind plant closer to load than would be optimal from a wind generation standpoint but permitting a higher capacity transmission line to be profitable.

Additional options are available for reducing variations in wind and solar power over periods of seconds or minutes when the variations are smaller. Wind turbines or solar arrays can be arranged in ways that reduce the correlation between them. A recent paper demonstrates that interconnecting wind plants can reduce the high-frequency variability of wind output, however, rapidly diminishing returns are found as the number of interconnected wind plants increases [4]. Wind turbines can also be operated below their maximum efficiency (“curtailed”) to create a small “reserve” of power to smooth out variations, but at the cost of reducing the amount of the wind resource converted to energy.

The primary barrier to implementing the strategies discussed above is cost. These technologies are expensive, but they are expensive in different ways. Some of the strategies have very high capital costs but low operating costs. For example, batteries are very expensive to purchase but cheap to maintain. Similarly, building widely separated solar arrays requires investment in long electrical cables to connect them, but requires very little operating cost. Other strategies have low capital costs but high operating costs. For example, the power output of a wind farm can be curtailed at no cost by changing some settings in the software that controls the turbines, but the owner loses revenue when the turbines capture less than the available wind. Similarly, a gas turbine is relatively inexpensive to install (compared to other types of power plants), but the natural gas fuel is expensive. These different cost structures suggest that different strategies are appropriate for different applications: a high capital-cost, low operating cost strategy may be more appropriate for reducing large and frequent variations, but a low capital-cost, high operating-cost strategy may be more appropriate for small, less frequent variations.

The cost barrier to adopting these strategies can be overcome by requiring their adoption or by offering incentives. Grid operators are beginning to write grid-connection rules that address the variability of renewable resources. The existing grid connection rules for wind and solar power were written when the penetration of variable renewable resources in the grid was so small that it did not affect the electrical grid. The penetration of renewable energy has increased rapidly, fueled by subsidies and Renewable Portfolio Standards (RPS). Grid operators in areas with significant penetrations of wind power, such as ERCOT (Texas), Denmark, Ireland, and Germany, now require that new wind farms be able to limit the rate of power increase and be able to decrease their power output to regulate the grid frequency. Some grid operators also require renewable generators to forecast their power output so other generators can be better scheduled to compensate for their variability.

Market and government incentives can encourage power plant operators to reduce the variability of their power output. Markets can offer a premium price for more stable power, or penalize generators for unexpected variations in their power output. Many grid operators that set prices through market mechanisms have penalties for deviations from scheduled power output, but those penalties have not yet been applied to wind or solar power. Government incentives for renewable resources currently do not address variability. Wind turbines are subsidized based only on energy production, which does not provide any incentive to reduce variability. Solar generation in the U.S. currently receives an investment tax credit, which is neutral from the perspective of reducing variability (and does not encourage energy production from the plant). Unless federal subsidies change significantly, it seems likely that reducing the variation of renewable generators will be driven by market penalties and grid connection rules, which may be suboptimal

RenewElec research will concentrate on the potential strategies and the resulting costs of reducing variability at the point of generation, and evaluating the value of these strategies relative to traditional techniques. The RenewElec team will also investigate existing and potential market structures for renewable energy to determine what impact each is likely to have on renewable energy deployment and variability, and on the electric grid as a whole.

References

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