NATIONAL RENEWABLE ENERGY LABORATORY

Western Grid Can Handle High Renewables in Challenging Conditions

NREL and GE find that with good system planning, sound engineering practices, and commercially available technologies, the Western grid can maintain reliability and stability during the crucial first minute after grid disturbances with high penetrations of wind and solar power.

Phase 3 of the Western Wind and Solar Integration Study (WWSIS-3) investigated the dynamic performance of the Western Interconnection in the fractions of a second to one minute following a large disturbance (e.g., loss of a large power plant or a major transmission line) with high penetrations of renewable energy. Conducted by NREL and GE Energy Consulting, WWSIS-3 focused on large-scale frequency response and transient stability—which are critical to grid reliability, particularly for the Western Interconnection, which has a long history of dynamic performance constraints on its operation.

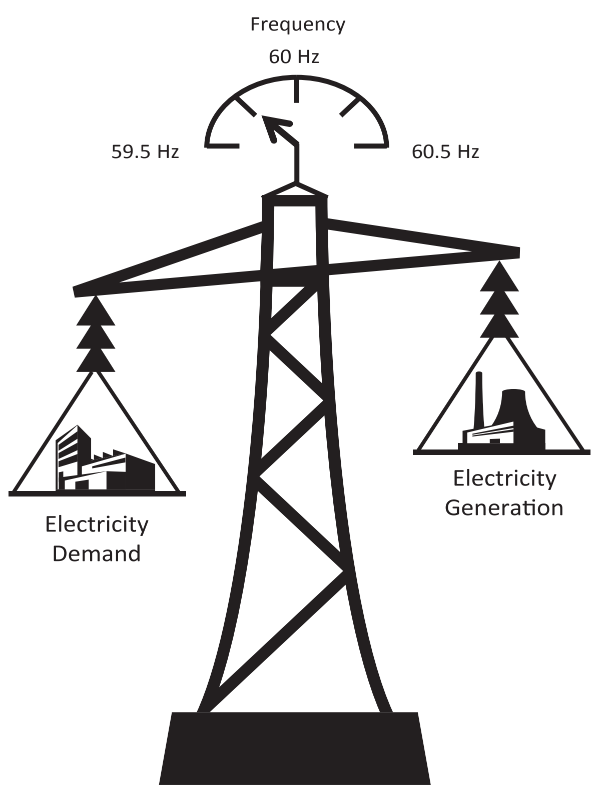
What We Studied: Frequency Response

To reliably operate a large, interconnected power grid such as the Western Interconnection requires a constant balancing of electricity generation with electricity demand. Electricity must be generated at the same instant it is used, so operating procedures have developed to forecast electricity demand, schedule electric generators to meet that demand, and ensure sufficient generating reserves are available to respond to forecast errors and system disturbances. The measure of success in this balancing act is frequency. In North America, that means maintaining system frequency at or very close to 60 Hz.

However, disturbances do occur, including large ones that affect overall system frequency (e.g., abrupt outage of a large generator or a major transmission line). For example, a transmission line outage may disconnect a large industrial customer, and as a result, the total electricity generation exceeds the total electricity demand, and frequency rises. Because operators, in general, have more control over generation than demand, they can execute a generation reduction to regain the balance and return system frequency to near 60 Hz.

A potentially more significant problem is the loss of a large generating plant. As a result of this type of disturbance, the total electricity demand exceeds the total electricity generated and frequency drops, as shown in the figure below. In general, a power grid is designed to withstand the loss of the single largest generator. However, the loss of multiple generators or plants may cause the frequency to drop significantly such that protective devices act to disconnect customers in order to preserve the bulk of the system. It is a serious reliability failure when operators lose the ability to supply all the electricity needed to meet demand.

In summary, frequency response is the overall response of the power system to large, sudden mismatches between generation and load. The primary concern is that the minimum frequency during the worst credible disturbances should not cause under-frequency load shedding, or customers being dropped from the grid.



Electricity demand exceeds electricity generation, and frequency drops.

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

The **Western Wind and Solar Integration Study,** one of the largest regional solar and wind integration studies to date, explores the question: *Can we integrate large amounts of wind and solar energy into the electric power system of the West?*

What We Studied: Transient Stability

In addition to maintaining the balance between electricity generation and electricity demand, power system operators must ensure that the grid can successfully transition from normal operation through a disturbance, and into a new stable operating condition in the 10–20 seconds immediately following a disturbance. The ability to make this successful transition is called transient stability.

The figure below shows a visualization of the problem. The round masses represent generators, with the tension on the various lines representing power transfer. The board at the top represents the simplifying idea of an infinitely large grid connected to this subsystem. The hands represent wind and photovoltaic (PV) generation. They inject power into the system, but are all control and no weight. The scissors represent a disturbance, which might cut a line or disconnect a generator, resulting in the rubbery mass-spring system bouncing around. If the event is too severe or some of the lines are stretched too taut, more lines will break. It is easy to imagine a cascading failure in which each successive break leads to another failure. A substantial part of system planning is aimed at avoiding such unacceptable consequences.

Much of the investigation of WWSIS-3 explored different ways to make the controls of wind and PV generators (the hands in the drawing) smarter. That work showed that available controls for wind plants are effective at improving system performance.

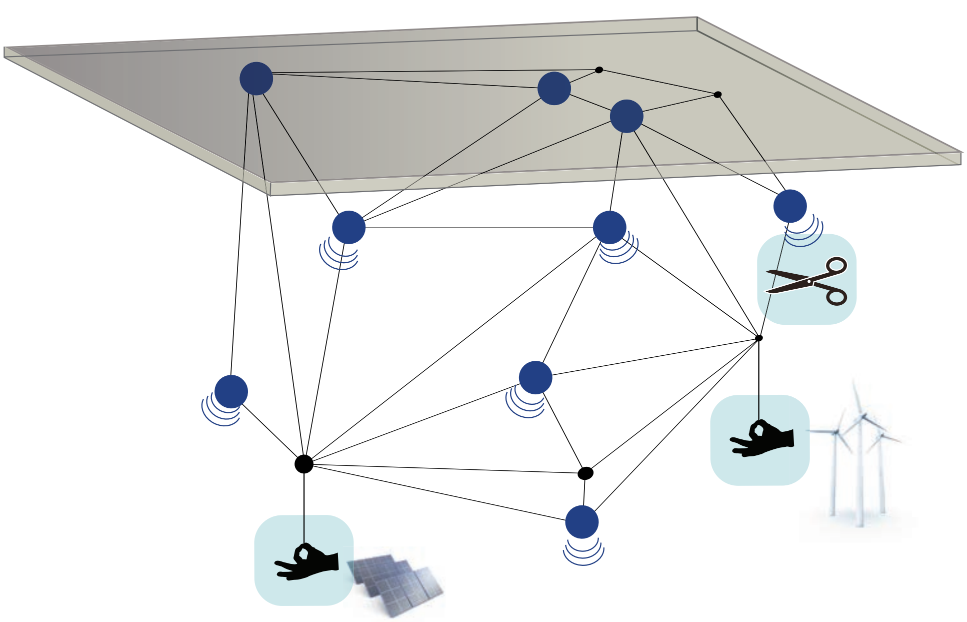
What We Learned

Adequate frequency response in the Western Interconnection was maintained for the conditions studied. Selected non-traditional frequency-responsive controls on wind and solar plants and energy storage were examined, and could improve frequency response. The transient stability of the system is not fundamentally changed by the high wind and solar generation. This does not mean that the system behaves identically. There is, however, nothing to indicate that the system dynamics have changed so fundamentally that radically different means to ensure stability are required.

What This Means for the Western Grid

WWSIS-3 did not identify any fundamental reasons why the Western Interconnection cannot meet transient stability and frequency response objectives with high levels of wind and solar generation, provided good system planning and power system engineering practices are followed.

The fact that the Western Interconnection can handle such high penetrations of renewable energy bodes well for coming years, as our nation shifts to cleaner, lower-carbon sources of energy to address climate change, local air pollution, and other concerns. It is also encouraging to see how renewable energy can contribute to frequency and transient response, resulting in a more reliable power grid.



Download the Report

Western Wind and Solar Integration Study Phase 3: Executive Summary: *www.nrel.gov/docs/fy15osti/62906-ES.pdf.*

Western Wind and Solar Integration Study Phase 3: Full Report: *www.nrel.gov/docs/fy15osti/62906.pdf.*

For More Information

Visit *www.nrel.gov/electricity/transmission/western-wind-3.html* or contact Kara Clark, *Kara.Clark@nrel.gov*.

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