The Western Wind and Solar Integration Study Phase 3: Technical Overview

With good system planning, sound engineering practices, and commercially available technologies, the Western Interconnection can withstand the crucial first minute after grid disturbances with high penetrations of wind and solar on the grid.

Background

Large-scale regional wind and solar integration studies have identified the lack of power system dynamic analysis as a significant research gap. Acceptable dynamic performance of the grid 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) is critical to system reliability, thus there is a need to analyze the dynamic behavior of North American systems under high variable renewable conditions. The Western Interconnection, in particular, has a long history of dynamic performance constraints on system operation—so any dynamic performance changes due to increased wind and solar generation could have substantial impact on all aspects of renewable integration.

The primary objectives of Phase 3 of the Western Wind and Solar Integration Study (WWSIS-3), conducted by NREL and GE Energy Consulting, were to examine the large-scale transient stability and frequency response of the Western Interconnection with high wind and solar penetration, and to identify means to mitigate any adverse performance impacts via transmission reinforcements, storage, advanced control capabilities, or other alternatives. WWSIS-3 evaluated a variety of system conditions, disturbances, locations, and renewable penetration levels to help draw broader conclusions from an analysis of two specific types of power system stability: frequency stability and transient stability.

Four primary study scenarios were developed to represent different system conditions (i.e., light and heavy load) and different renewable penetration levels (i.e., base and high renewables). In addition, a sensitivity scenario with extremely high renewable penetration under light load conditions was also developed.

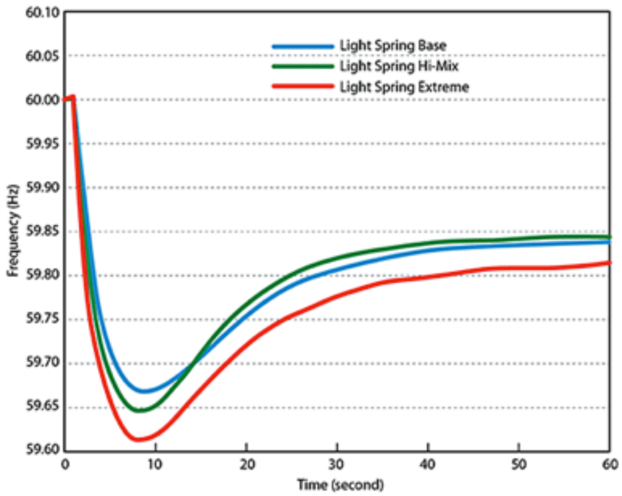
	Light Spring Base	Light Spring High Renewables	Light Spring Extreme	Heavy Summer Base	Heavy Summer High Renewables
Wind (GW)	20.9	27.2	32.6	5.6	14.3
Solar (GW)	4.8	25.6	32.2	1.6	27.2
Penetration (% of total generation)	21%	44%	53%	4%	20%

Frequency Response Results

Frequency response is the overall response of the power system to large, sudden mismatches between generation and load. One concern is that the minimum frequency, or nadir, during design-basis disturbances should not cause under-frequency load shedding (UFLS). In the West, the first stage of UFLS is normally at 59.5 Hz, and the design-basis event is the trip of two fully loaded Palo Verde nuclear power station units for a loss of about 2,750 megawatts (MW). The subsequent frequency excursion is severe, as shown in the figure to the right. However, all cases studied avoid UFLS relay action.

The North American Electric Reliability Corporation also provides a specific definition of the quantitative metric "frequency response." This metric is compared to the frequency response obligation to determine compliance. For all cases studied, the system-wide frequency response meets its obligation.

Current operating practice uses traditional approaches (e.g., commit conventional plants with governors) to meet all frequency response needs. Selected non-traditional frequency-responsive controls on wind and solar plants and



energy storage were examined, and limited application was effective at improving frequency response. Refinements to these controls would further improve performance.

Transient Stability Results

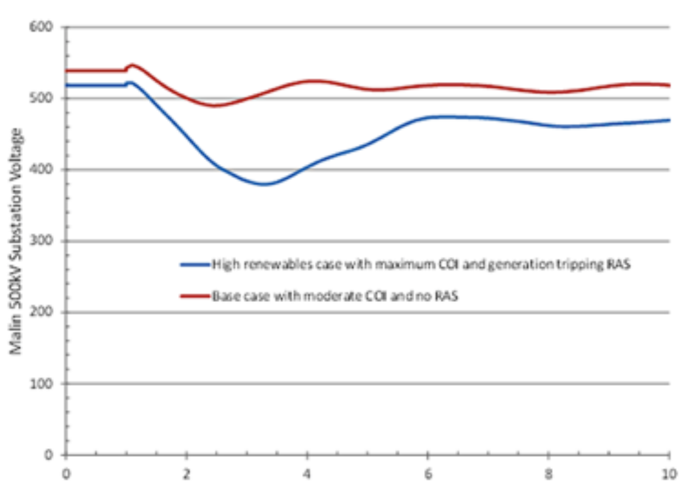
During heavy load conditions, the addition of high levels of wind and solar generation increases the already heavy loading on the Pacific AC and DC Interties to about their present path ratings. High flows on the California Oregon Interface (COI) are well known to be stressful and to require a generation-tripping remedial action scheme (RAS). Stable performance was achieved in both the base and high renewables cases for one of the well-known and critical events for the Western Interconnection, as shown in the figure below. The base case has a moderate level of power flowing on COI and no generation-tripping RAS. The high renewables case has about 30% more flow on COI and employs a generation-tripping RAS.

The investigation suggests that this practice can continue, and that 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 for this event are required.

Conclusions

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. However, good system planning and power system engineering practices must be followed. At a minimum, local voltage and thermal problems will inevitably require some transmission system improvements.

The dynamic behavior of distributed PV generation was shown to have the potential to substantially impact the bulk power system. Distribution is not decoupled from transmission, and it will impact bulk power system operation. Mechanisms are needed to allow balancing areas to both share frequency-responsive resources and make sure that they have adequate frequency-responsive resources within their control. From a transient stability perspective, the system appears to tolerate substantial displacement of thermal generation. However, care will be needed in the event that the system is driven to near-zero commitment of coal plants.



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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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