'Moderate' is the new 'extreme': Weather's impact on growing renewable grid operations

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From severe storms to recent unprecedented cold and heat waves, extreme weather events are impacting electric utilities, grid operators, and ultimately customers like never before. At the same time, the energy

sources that power the grid are evolving, integrating higher percentages of renewable sources.

This evolution in both weather and the power grid is raising new questions about the intersection between extreme weather and the electric grid—and how to maintain and enhance grid reliability as the share of weather-driven renewable energy increases. In a first-of-its-kind study, analysts from the National Renewable Energy Laboratory (NREL) and Sharply Focused modeled scenarios to understand the answers to these questions and change the way we define "extreme weather."

"Our study investigated two questions," said Marty Schwarz, NREL power systems engineer and co-author of the report. "First, we examined whether increasing levels of wind and solar make it more challenging to reliably operate the power system during extreme weather events. Second, we evaluated if these renewable technologies change what types of weather events we consider 'extreme' based on their impact to grid operations."

Understanding the future through the past

To generate scenarios used in the study, analysts turned to NREL's publicly available flagship capacity-planning model for the power sector—the Regional Energy Deployment System (ReEDS)—which simulates the evolution of the bulk power system. ReEDS modeled what the system could look like for the years 2024, 2036, and 2050, showing variable renewable generation levels of 17%, 50%, and 65% of annual demand, respectively.

Analysts also gathered historical weather data and records from select weather events between 2007 and 2013, along with wind and solar resource availability modeled from NREL's Wind Integration National Dataset (WIND) Toolkit, National Solar Radiation Database (NSRDB),

and historical electrical load profiles. This data identified weather events that are essential to modelers, utilities, and regulators to consider in their long-term planning.

Weather events from the historical data were slotted into two broad categories: 1) "high-impact events," such as cold waves, midlatitude storms, heat waves, and tropical systems; and 2) "events posing planning challenges," including periods of low renewable energy resource availability and high electricity demand, as well as high resource and low demand.

With their future grid scenarios in place and a variety of historical weather data, the analysts set out to test how the two could interact.

Charting a new perception of 'extreme'

When we think of extreme weather today, we naturally imagine the events that cause major disturbances to our daily lives and are worthy of front-page news—which is front-of-mind now as we enter hurricane season. However, NREL found the power grid impacts of extreme weather events do not increase as more wind and solar are added to the grid.

That is because wind and solar power remain available even during extreme weather events due to the meteorology of the events themselves. A heat wave that triggers a higher grid load from the use of fans and air conditioning also often coincides with sunny days that enable high levels of solar generation. Similarly, a strong wintertime cold front that increases the need for heating also brings strong wind gusts that can power wind generation to meet those needs.

On the other hand, analysts found that moderately severe, but not extreme hot/cold weather conditions occurring concurrently with

extended periods of low wind and solar resources could be the new "extreme" weather when it comes to the impact on power system operations.

"These findings are specific and limited to the weather that occurred in the historical data set and to the future grid infrastructures considered, but they do point to an overarching conclusion," Schwarz explained, "which is that the most concerning weather events to the future grid are different than the concerning events of today."

The analysis ultimately informed eight key findings which are outlined in the study report.

Navigating the calm after the storm

The changing perception of extreme weather events that emerged from the findings is illustrated by the wind lull that often follows once a cold front has moved through a region. During winter months when solar power is already low, the future grid will rely more heavily on wind power. Generally, wind generation is abundant in the immediate vicinity of cold fronts, but these fronts are often followed by a wind lull of varying severity, with continued cold that causes persistent high loads as people heat and light their homes.

The sample size of weather events explored in the study suggests the calm days following the onset of a cold wave may be among the most important weather for planners to consider when determining capacity needs for future systems that rely on high levels of variable renewable generation.

System planners, policymakers, and researchers can use the findings to test the weather resilience and resource adequacy of future power system infrastructure. The analysis can also be used to test the performance of

integrated resource plans or to explore trade-offs and benefits between different policy options.

Looking toward the horizon

The analysts behind the study cautioned that despite the limitations of the study, the findings are important to understanding the impact of extreme weather in a holistic manner—what happens not just during the peak of the storm but also after and planning for low renewable output periods as the grid is driven by more renewable energy.

These initial results should be further applied to additional power system scenarios and even more weather conditions beyond the study's limited sample of weather events from 2007 to 2013. The analysts are especially interested in studying more recent weather events that can capture the influence of climate change on weather patterns.

"We hope this initial study will help advance our understanding of extreme weather events on the increasingly renewable grid," Schwarz said, "and set us up for more work toward accurate planning and robust reliability for the power system of tomorrow."

More information: Josh Novacheck et al, The Evolving Role of Extreme Weather Events in the U.S. Power System with High Levels of Variable Renewable Energy. www.nrel.gov/docs/fy22osti/78394.pdf

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