Researchers create tool to put the lid on solar power fluctuations

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How does the power output from solar panels fluctuate when the clouds roll in? And can researchers predict these fluctuations? UC San Diego Professor Jan Kleissl and Matthew Lave, a Ph.D. student in the Department of Mechanical and Aerospace Engineering at the Jacobs School, have found the answer to these questions. They also have developed a software program that allows power grid managers to easily predict fluctuations in the solar grid caused by changes in the cloud cover. The program uses a solar variability law Lave discovered.

The finding comes at a time when the Obama administration is pushing for the creation of a smart power grid throughout the nation. The improved grid would allow for better use of renewable power sources, including wind and solar.

Also, more utilities have been increasing the amount of renewable energy sources they use to power homes and businesses. For example, Southern California Edison reported this month that it is adding more large-scale solar power plants to its grid and retooling its distribution system to accommodate the power fluctuations that will follow.

Kleissl and Lave's finding could have a dramatic impact on the amount of solar power allowed to feed into the grid. Right now, because of concerns over variability in power output, the amount of solar power flowing in the grid at residential peak demand times—your typical sunny weekend afternoon in Southern California, say—is limited to 15 percent before utilities are required to perform additional studies. As operators are able to better predict a photovoltaic system's variability, they will be able to increase this limit. In California, a law signed by Gov. Jerry Brown in April 2011 requires all electricity retailers in the state, including publicly owned utilities, to generate 33 percent of their power sales from renewable energy sources by 2020.

Incidentally, Kleissl and Lave's research shows that the amount of solar variability can also be reduced by installing smaller solar panel arrays in multiple locations rather than building bigger arrays in just one spot, since a cloud covering one panel is less likely to cover the other panels, Lave said.

"The distance between arrays is key," he said.

The variability in the output of photovoltaic power systems has long been a source of great concern for utility operators worldwide. But Kleissl and Lave found that variability for large photovoltaic systems is much smaller than previously thought. It also can be modeled accurately, and easily, based on measurements from just a single weather station. Kleissl presented the paper, titled 'Modeling Solar Variability Effects on Power Plants,' this week at the National Renewable Energy Laboratory in Golden, Colo.

His findings are based on analysis of one year's worth of data from the UC San Diego solar grid—the most monitored grid in the nation, with 16 weather stations and 5,900 solar panels totaling 1.2 megawatts in output. Lave looked at variations in the amount of solar radiation the weather stations were receiving for intervals as short as a second. The amount of radiation correlates with the amount of power the panels produce.

Based on these observations, he found that when the distance between weather stations is divided by the time frame for the change in power output, a solar variability law ensues. This operation was inspired by a presentation by Clean Power Research, a Napa-based company, at the Department of Energy – California Public Utility Commission High Penetration Solar forum hosted by UC San Diego in March 2011. "For any pair of stations at any time horizon, this variability law is applicable" says Lave. In other words, the law can be applied to any configuration of photovoltaic systems on an electric grid to quantify the system's variability for any given time frame.

But Lave didn't stop there. He developed an easy-to-use interface in MATLAB that allows grid planners and operators to simulate the variability of photovoltaic systems. Data can be input as a text file, but the interface also allows users to simply draw a polygon around each system on a satellite Google Map. Based on solar radiation measurements at a single sensor on a given day, the model calculates the variability in total output across all systems.

"It is as easy as painting by numbers," said Kleissl. "In Google Maps, photovoltaics show up as dark rectangles on rooftops. Draw some polygons around them, push the button, and out comes the total variability."

Kleissl said he anticipates this tool will be useful to figure out whether problems in voltage fluctuation may occur in power feeder systems with a large amount of photovoltaic arrays. At this point, the solar installations on almost all feeders are still far below the capacity that would cause any major issues. But as the United States moves to affordable solar systems producing energy at lower costs through the Department of Energy's SunShot initiative and continued robust growth in installations, this will change. That's when the tool developed by Lave and Kleissl could become key.

While the tool is being prepared for final public release, the authors would be happy to consider requests by third parties that can provide PV system location and size data to run the tool.

More information: The model development was sponsored by DOE's High PV Penetration Program grant 10DE-EE002055. Further information is available at https://solarhighpen.energy.gov/project/university_of_california_san_diego and http://solar.ucsd.edu

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