How to Manage California's Alternative Energy Grid When the Sun Doesn't Shine

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California's goal of generating 33 percent of its power from renewable energy sources by 2020 will be challenging on days when clouds shade acres of solar photovoltaic panels or when thousands of wind turbines spin more slowly during calm weather. However, researchers at the University of California, San Diego are developing sophisticated forecasting tools that will give California electricity distributors advance notice of meteorological changes that affect solar output. The technology is being developed to allow energy suppliers to more efficiently schedule their fossil-fuel fired plants or energy-storage facilities to meet the state's demand for electricity.

"If we can correctly forecast the distribution of solar irradiation and wind patterns within a small margin of error, we could rely more on alternative energy sources and less on power generated by fossil fuels," said Jim Blatchford, senior policy representative for the California Independent System Operator (CAISO), the non-profit organization that coordinates, controls and monitors most of California's electrical power grid.

CAISO, the California Public Utilities Commission (CPUC), U.S. Department of Energy (DOE), the California Solar Initiative, California Energy Commission, utility companies and others have recognized the importance of accommodating the intermittent nature of solar and wind generation as necessary to meet the state's alternative energy goals by 2020 and beyond. The groups support a variety of research projects intended to solve technical hurdles that stand in the way of full integration of photovoltaic and wind energy into the energy grid.

On March 11, the CPUC approved $9.3 million to fund projects designed to resolve impediments to integrating photovoltaics into the grid. One of the awards was for a $548,000 project led by UC San Diego and includes San Diego-based EDSA Micro Corporation and collaboration from CAISO and San Diego Gas & Electric (SDG&E). (UC San Diego has raised $137,000 in matching funds from non-university sources.)

UC San Diego researchers led by Jan Kleissl, assistant professor of environmental engineering in the Department of Mechanical and Aerospace Engineering, have used 16 weather stations on the 1,200-acre campus to measure solar radiation every second and map clouds continuously. The data can verify a predictive model that uses satellite data to predict how moving clouds will affect the power output of 6,000 photovoltaic panels on the campus.

"We are interested in partnering with Professor Kleissl on his meteorological forecasting research because his models could help reduce the state's energy costs and its carbon footprint," said CAISO's Blatchford.

UC San Diego researchers in a second project also are designing tools to accommodate, well before 2020, the expected reversals in electricity flow and voltage dips from photovoltaic arrays onto distribution systems. Mitigating the technical challenges of two-way flows of electricity is a relatively new and significant challenge for utilities resulting from the "high penetration" of solar photovoltaics in California over the next decade.

The high-penetration solar project also involves EDSA and San Diego Gas & Electric. "This effort is one of many we are involved in to ensure that we are able to accommodate higher levels of intermittent renewable energy without any adverse impact on reliability, an issue that is critical to SDG&E," said Lee Krevat, director of smart grid for SDG&E. "We are the first utility in the continental U.S. to commit to a 33 percent renewable energy goal."

The high-penetration solar project is being funded by a $1.9 million grant from the DOE under the American Recovery and Reinvestment Act (ARRA) that is being matched with a $500,000 letter of intent from the California Energy Commission.

"While California tries to encourage the development of renewable sources of electricity, the current state of the art does not provide the modeling fidelity needed to optimally integrate all the photovoltaic capacity that will be deployed in California over the next decade," said Byron Washom, principal investigator of the DOE-funded project and director of Strategic Energy Initiatives at UC San Diego. "As more and more home owners, small businesses and other non-utility groups install photovoltaic systems and connect them to the energy grid, fluctuations in cloudiness over relatively small areas can potentially have significant negative impact on the associated electricity distribution system if not adequately addressed."

The university is an ideal place to analyze clouds because it is home to engineering and climate researchers, a 1.2-megawatt photovoltaic system, a self-contained energy grid and one of the world's densest collections of roof-mounted weather-monitoring stations that can be used to study meteorological effects on the electrical output of photovoltaic panels.

The variable effect of clouds on electricity distribution systems reminds Washom and Kleissl of the lyrics of "Clouds," a folk song made popular by Joni Mitchell: "we really don't know clouds at all."

But Kleissl is using a "total sky imager" to understand clouds much better. The imager records their movements across the entire sky throughout the day. "Some clouds grow or shrink and change shape, while others move across the sky without changing much," said Kleissl. "So far, we've found that cloud shape changes are difficult to predict, but we will be able to model the cloud movement and its impact on shading of photovoltaic systems with 90 percent accuracy." The sky above UC San Diego photographed by the imager can be viewed in real time during the daytime at http://maeresearch.ucsd.edu/kleissl/demroes/live/TSI.jpg.

Kleissl's experiences have calibrated the sudden, dramatic effects of clouds on the output of photovoltaic panels.

"Once a cloud arrives, the power output from our photovoltaic panels can decrease 40 to 80 percent within a few seconds, and when the cloud leaves the power output increases just as dramatically," said Kleissl. "Utilities and operators of large power plants want to be able to predict the timing of these transitions so that they can charge up energy storage systems in advance to 'smooth' the clear-cloudy transition or prepare other generation to make up for the lost solar power."

"In the future, electricity generators and energy storage facilities of all scales will likely be able to bid into an hourly market, and the ability to accurately forecast photovoltaic output 1 to 3 hours in advance, despite the variability of the solar resource, would be of immense economic, environmental and operational value," said Washom.

Governor Arnold Schwarzenegger in September 2009 signed an executive order directing the California Air Resources Board to adopt regulations increasing California's Renewable Portfolio Standard to 33 percent by 2020. At the same time, the DOE, California Energy Commission, CPUC and CAISO have recognized the need for sophisticated modeling tools to successfully integrate alternative energy sources into the grid.

The technology under development by Kleissl and Washom is expected to be integrated into the management of any grid, large or small, The UC San Diego's campus as a precursor to a smart grid since it already self generates 80 percent of its annual electricity demand with its "microgrid" that integrates 1.2 megawatts of solar, a 30-megawatt natural gas-fired cogeneration plant, energy stored in the form of 3.8 million gallons of chilled water, and a sophisticated energy management system that controls thermostats and heating and ventilation systems of 90 buildings.

The campus microgrid will grow in size and complexity with the planned completion of a 2.8-megawatt fuel cell that will use an electrochemical process to convert renewable methane gas that is currently being flared at the city of San Diego's Point Loma Wastewater Treatment Plant into electricity. Once in operation, the electrical output of the fuel cell will be used 20 hours a day to power the campus's grid, and four hours a day to charge batteries. The stored energy will be discharged the following afternoon during periods of highest electricity demand. Both the fuel cell and energy storage are enabled by the CPUC's Self Generation Incentive Program.

For more information about sustainability programs at UC San Diego, visit http://sustain.ucsd.edu

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