Energy Storage System Firms a Renewable Resource

Successes from PNM's Smart Grid Demonstration Project

Introduction

A photovoltaic (PV) plant's output varies widely between days, and even hours, depending on such factors as cloud cover and the sun's angle to the solar panels. These fluctuations present a problem: the source of the PV plant's energy is variable, yet the need to meet electricity demand and keep the grid stable is constant.

"On cloudy days, customers aren't changing their usage based on when the sun comes out," says Jon Hawkins of the Public Service Company of New Mexico (PNM). "As a utility, we are still required to give customers quality power."

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PNM is New Mexico's largest electricity provider, serving more than 500,000 customers. In 2009, PNM received a grant for $2.3 million from the U.S. Department of Energy's Smart Grid Demonstration Program to modernize electric distribution systems.

With this Recovery Act funding, PNM demonstrated that utility-scale battery systems can be used to firm PV energy. It also demonstrated how battery systems can smooth fluctuations in PV plant output and reduce peak power at the substation. The hybrid energy storage system at the heart of PNM's project encompassed two battery systems: a 0.25-MW "shifting" battery system that could store solar energy and discharge it later, when electricity demand was higher, and a 0.5-MW "smoothing" battery system that could lessen variations in the output of an adjacent 500-kW PV plant.

The project deployed a data acquisition system that collected sufficient data to inform system control algorithms. These algorithms, detailed in PNM's technical report, dictated how the batteries' actions could best augment the PV plant's output.

"Today there are not many software or control systems that support battery energy storage, and, to the extent that you use manual presets like a sprinkler timer does, you do not capture the value that could be obtained with price, weather, and local feeder loading information, etc.," says Hawkins, PNM's manager of advanced technology and strategy. "The ability to send the energy storage system multiple real-time data points and react to those inputs—things like prices or weather—all autonomously from the control center" set PNM's energy storage system apart from others. This ability helped PNM successfully demonstrate smoothing; capacity firming, or converting variable, power output to a sustained level; and peak shaving, which means to decrease the amount of energy purchased during peak hours.

Smoothing Fluctuations in Solar Energy Output

PNM showed that an energy storage system can dampen the daily spikes in electricity output from PV systems. PNM used output from a PV meter to fine tune the energy storage system's performance in flattening spikes and troughs in the energy system's total output. A control system algorithm instructed smoothing batteries to discharge a percentage of their energy to the grid to compensate for declines in PV output as well as recharging the battery during sharp increases in PV output. PNM's model suggests that as more intermittent resources are added to the grid, the smoothing batteries would have a more pronounced effect. Given New Mexico's Renewable Portfolio Standards, as well as the state's abundance of renewable resources, more intermittent, variable resources will be deployed in the years ahead. In fact, by 2020, 20 percent of the state's electricity will have to come from renewable sources[1], such as solar and wind.

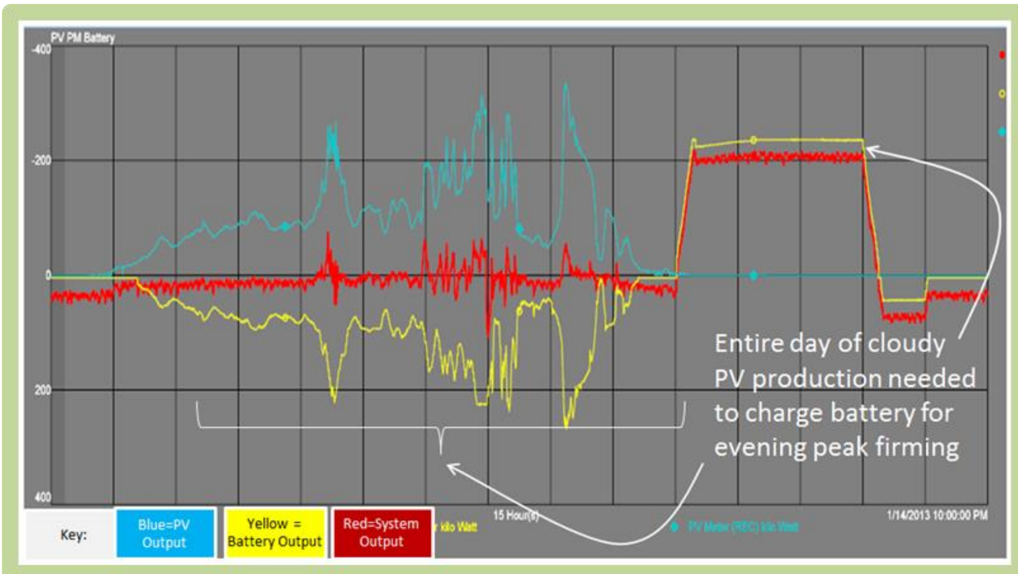

Figure 1. On January 13, 2014, cloud cover made the PV plant's output especially variable. Instead of sending this variable energy directly to the grid, PNM used it to charge batteries housed in the energy storage system. In the evening, when electricity demand rose and solar irradiance waned, PNM discharged the batteries to accomplish firming of the PV, as the graph below shows. *Image courtesy of PNM.*

"We wanted to do something in storage that supports a proactive approach to accommodating all of these renewable, variable resources that we will have to put into our system," Hawkins said.

Matching Electricity Output to Electricity Demand

In addition to smoothing the PV electricity, the PNM battery systems helped provide firm PV output. PNM utilized analytical models to estimate how the energy from the PV plant's peak output could be stored for use during periods of peak demand. The project demonstrated that a properly designed control system could reliably shift the peak in electricity output based on when electricity demand reached its highest point, which proved especially useful on a day Hawkins calls "super variable" (see graph). The energy storage system made it possible for PNM to shift discharge of electricity from batteries onto the grid to later in

[1] "IOU's now must have in their portfolio as a percentage of total retail sales to New Mexico customers, renewable energy of no less than 15% (by 2015) and 20% (by 2020)." Source: New Mexico Public Regulation Commission, http://www.nmprc.state.nm.us/utilities/renewable-energy.html

the evening, while also smoothing the variability of solar energy delivered to the grid. To do so, PNM spent the day "sinking all that intermittent energy right into the battery" instead of sending it onto the grid, explains Hawkins. At about 6 p.m., when solar energy waned, the utility smoothly dispatched the stored energy.

Hawkins describes the dispatch as "a block of power with definite amplitude and time duration. We took the problem of PV variability and created something very useful."

Reducing Peak Power Flow

The project showed that an energy storage system can be useful in lowering a substation circuit's peak power flow, as well. PNM developed an algorithm that predicted how much electricity would be delivered to a circuit throughout the next day, based on such variables as weather and the circuit's recent history. Accordingly, the algorithm dispatched battery resources to augment the PV plant's output. PNM was able to serve a portion of the residential and commercial customers' load from the PV/battery energy storage system, which reduced the load on the Studio Substation equipment by 15 percent (see diagram).

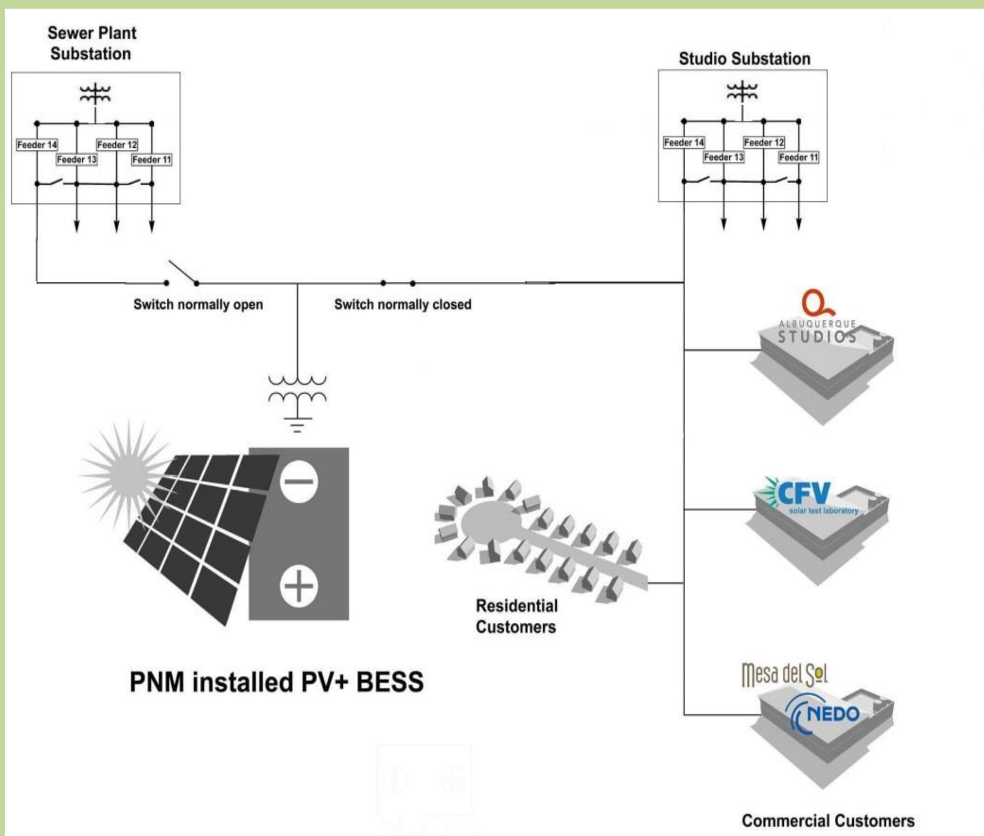

Figure 2. A feeder connected the PV plant and battery energy storage system to a nearby studio substation, which delivered power to both residential and commercial customers. This setup made it possible for the PV plant and battery energy storage system to relieve the studio substation of some of its load. *Image courtesy of PNM.*

As more variable energy resources are deployed on the grid, complementary energy systems can play a large role in peak shaving.

"If I turn off one air-conditioner during a peak event, that doesn't mean anything to the transmission level," says Hawkins, "but if I take 1,000 of them, all of a sudden, those little 5-KW [changes] mean something."

Similarly, by discharging multiple battery systems when demand peaks, a utility may be able to avoid accessing a peaking-generation resource.

Next Steps

By showing that batteries can be used for peak shaving, smoothing, and firming, as well as other purposes, PNM's project highlights how batteries can be valuable in multiple applications beyond current ones.

"The battery is one of the most flexible resources out there," says Hawkins. "It can look like a load; it can look like a dispatchable resource; it can firm up photovoltaics."

In the future, PNM plans to investigate how energy storage systems located at the distribution level can react to signals at the transmission level. They plan to investigate whether energy storage systems can be used to respond to area control errors or provide voltage support.

In addition, PNM intends to explore how energy storage systems can coordinate with micro grids, examine back-office coordination of distributed resources, and investigate how to develop a distributed energy resource management system that is based on smart grid technologies. Already, PNM is meeting with its project partners to determine how the demonstrated technologies could be deployed more efficiently and less expensively next time.

"What we've done here has, I think, advanced the industry," says Hawkins. "There's more work to be done, and we're trying to figure out what the applications are and where this can go from here. This is such a great system. It would be a shame to use it just for its intended purpose."

Further Reading

For more information about PNM's project, read its technology performance report, published on the SmartGrid.gov website. A more detailed description of SGDP can also be found at SmartGrid.gov.

Under the American Recovery and Reinvestment Act of 2009, the U.S. Department of Energy and the electricity industry have jointly invested over $1.5 billion in 32 cost-shared Smart Grid Demonstration Program projects to modernize the electric grid, strengthen cybersecurity, demonstrate energy storage, improve interoperability, and collect an unprecedented level of data on smart transmission, distribution operations, and customer behavior.