Energy Storage Evolution Continues

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Energy storage has been called a potential "silver bullet" for integrating large quantities of intermittent renewable (i.e., wind and solar) energy into the US electric grid. Let's take a look at how its evolution is going so far.

Renewable energy sources vary with weather and solar output. Even during an apparently sunny day, solar panel output can vary due to passing clouds. On the other hand, consumer electric demand occurs in largely predictable daily patterns but is generally intolerant of poor reliability. Renewables developers market their product for what it is: a clean, abundant, increasingly cost-effective energy resource that happens to have an attribute of intermittency.

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ENERGY STORAGE FOR INTEGRATION OF INTERMITTENT RENEWABLES

On the Distribution System

Most of the current popular discussion about storage focuses on applications on the utility distribution system, or "distributed" storage. Here, electric utility service is provided at retail, and its rules and rates are regulated by state utility commissions (for investor-owned utilities), city councils or utility boards (for municipal utilities), or member boards (for cooperatives).

Behind the Meter

Much of the current popular focus in distributed storage is "behind the (utility) meter." That is, the storage activity occurs within the customer's premises—not on the distribution grid. Essentially all of this storage involves various battery technologies and, while batteries can be charged from any electric energy source from the grid, this storage is often combined with solar photovoltaics (PV) also located within or on the customer's site.

Initial applications of behind the meter battery storage in commercial and industrial (C&I) facilities are appearing. While the highest-value product of a backup emergency energy source like storage is to ensure reliability (the cost of electric outages, called "unserved energy" in the utility industry, is very high and can range from $22 to $295 per kilowatt-hour (kWh) for large C&I to small C&I for a one-hour outage),[1] current applications may also involve energy price arbitrage (buy low, sell high), demand management for reduction in utility demand charges, and other value streams.

One interesting application is the use of battery storage to manage commercial customer peak demand charges. Most sizeable commercial customers are billed using separate demand (in kilowatts [kW]) and energy (in kWh) rates. Periods of high customer demand (say, during the business day) have a higher total cost per kWh because they have both demand and energy components. By storing energy during low demand periods (i.e., at night) and then using the battery output during day, the customers can affect their demand charges.

The key is to be smart about when the limited battery output duration will be used so as to hit (offset) the customer's highest peak demand periods. Customers with relatively short-lived peak demands are best suited to this approach. Customers with broad peak demand periods over time risk having the battery run out of power and be unable to offset all the peak loads—if they miss only one 15-minute peak period, they have missed for the entire month or more.[2]

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There is much discussion in the industry today about "microgrids". These are islands of customer loads with their own internal generation sources capable of disconnecting from the utility grid and operating independently of it for periods of time. Certain commercial and industrial customers with particularly high reliability requirements, such as hospitals, have had what are now called microgrids for decades. In the event of an electric service outage, they would separate their critical electric loads from non-critical ones (say, the surgical suite from the coffee shop), and use a local generator, usually driven by a gas or diesel engine, to serve it.

Storage batteries can serve a similar function.

SERVICE RELIABILITY REMAINS A PRIMARY DRIVER

Interest in microgrids and batteries to accomplish them has been stimulated by recent events like Hurricane Sandy on the East Coast in 2012, which resulted in widespread, long-lasting and costly electric outages.

Like the traditional use of backup power for hospitals, the batteries in such applications are intended to ensure service reliability. While the installation cost of batteries continues to decline, there is yet little evidence in the current literature that such installations pay for themselves economically beyond their inherent value in ensuring reliability of electric service to the customer. Even though severe events like Hurricane Sandy happen infrequently, peace of mind alone is a very valuable thing.

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Residential customer applications of rooftop solar PV with storage are a more visible application of batteries behind the meter. Residential customers can size their rooftop solar installation to provide electric energy in an amount up to the total their house uses.[3] To do this, the solar panels are sized to produce more energy than the house needs during the solar day. The excess is sold to the local utility. The utility provides the balance of the house's electricity needs when the sun doesn't (at night and on cloudy days). In this example, the utility grid is acting like a storage battery for the residential customer.

An average-sized home solar PV system, installed with a direct current to alternating current (DC to AC) invertor and associated hardware today has a net cost between $2,000 to $4,000 per kW of output, depending upon available rebates or tax credits.[4] Today, the simple payback of such a solar PV system without storage to a residential customer ranges from about four to seven years (in Hawaii) to about ten to 20 years in Georgia, with the variation depending upon location and local utility rates.[5] These payback periods are forecast to shorten as solar cell technology and manufacturing continue to improve.

Residential customers can combine their rooftop solar PV with batteries to form their own microgrid. Instead of selling their excess solar output during the solar day to the local utility, the excess is directed to the customer's own onsite battery instead. For example, one offering for residential use features storage capacity of 14 kWh per battery pack, with installed costs of about $7,000 (or $500 per kWh of storage capacity), in addition to the cost of the solar PV system.[6] Multiple batteries can be used for longer storage durations, at higher cost.[7]

The Libertarian consumer in all of us can enjoy the vision of using our own solar PV and storage system to go totally off the monopolistic utility grid, exercising our right of energy independence and thereby "Sticking it to The Man". And although current battery capabilities allow one to get close to this vision, more evolution is necessary.

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For a simple example, a typical house without electric space heating may use an average of about 24 kWh per 24-hour day, with 10 kWh of use during the solar day and 14 kWh at night. A 5 kW rooftop solar PV system can produce about 24 kWh each day the sun shines. Thus on a sunny day the battery needs to store about 24 – 10 = 14 kWh for use in the evening and at night when the sun is down. That all works.

However, the problem occurs when the sun does not shine, perhaps for one or more consecutive cloudy days. The battery runs out of energy, and we then have to depend on the utility again for back-up. Or worse, we run an extension cord to the neighbor's house, only to realize that in the process we have created a (gasp!) electric grid.

We will have become The Man.

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ECONOMICS BECOMES THE PROBLEM

The more difficult problem is economics.

One of the fundamental advantages of storage, whether for energy or other commodities like corn or soybeans, is the opportunity for price arbitrage, i.e., to buy at a low price and sell at a high price some time later. The difference between the purchase price and the sale price (called the "price spread") needs to be positive. That is, the sell price needs to be higher than the buy price. And unfortunately, such a positive price spread is not present over most of the United States today. Thus, regardless of the cost of the battery, it will lose money in every storage-operating cycle.

Many analyses of the economics of solar PV with storage assume that the energy stored in the battery (that is, the excess of solar PV output beyond what the customer's house uses during the solar day) is free. That's not true. The solar customer has an opportunity to sell that excess to the local utility for a price. And in a number of states that continue with net metering rules, that price is the full retail rate. Thus the customer who stores this surplus energy in a battery instead is foregoing payment they would otherwise get from the utility for it.

Now, when should the customer release the solar PV energy stored in the battery? That would be at night when the sun is down. And in most of the United States electric rates (that is, the value of the energy coming out of the battery) is lower at night than during the day.[8] Simply, the traditional daily human business cycle means electric consumption in most of the country, and thus the price for it, is higher during the day than at night.

This is a negative price spread which is detrimental to paying for the battery.

GRID INDEPENDENCE DOES NOT NECESSARILY MEAN FINANCIAL INDEPENDENCE

On the plus side, positive price spreads are happening in California, where levels of solar PV installations are high, thereby depressing market prices due to oversupply during the solar day and resulting in higher market prices in the evening and at night. California and probably Hawaii are the first emerging opportunities for solar with storage in the United States. In this manner, large-scale adoption of battery storage with solar PV in the rest of the United States depends largely on continuing trends in decreasing solar PV costs and resulting increasing levels of solar PV installations there to make the daytime market price lower than the nighttime price.

Front of the Meter

Batteries can also be installed on the distribution system in front of the customer meter. In some applications, utilities are now using battery storage to defer or avoid investment in distribution facilities that would otherwise be needed without the storage, or to improve reliability of service to distribution customers.

An example of this is the Consolidated Edison battery project in New York City, which aims to avoid a $1.2 billion substation investment.[9] Additional examples include large projects by San Diego Gas and Electric, Southern California Edison, and other investor-owned utilities in California.[10] These are being done in compliance with State of California mandates for storage installations and to address the issues related to the Aliso Canyon natural gas storage facility outage.

Oregon and Massachusetts also have state mandates for minimum levels of energy storage in an effort to gain experience with the technologies involved.

On the Transmission System

In addition to distribution, energy storage has applications in wholesale (i.e., sales for resale) markets and on the transmission grid. This storage can take the form of distributed storage gaining access to wholesale markets, or grid-level storage physically located on the transmission grid itself. The rules and tariffs here are regulated by the Federal Energy Regulatory Commission (FERC) via organized markets including Regional Transmission Organizations (RTOs), and Independent System Operators (ISOs) in their respective regions,[11] and through regulation of utility wholesale rates.

Although distributed storage is primarily done to serve the needs of its local host facility, once installed it is capable of also providing additional, so-called ancillary, services to the wholesale grid[12] and thereby conceptually receive additional revenue payments.

And current economics, including current battery costs, make sole dependence on distribution-level revenue opportunities alone problematic without such additional revenue streams. Unfortunately, current wholesale market rules, originally developed for conventional generation facilities that are typically larger in size and can operate for more hours than distributed storage, often block smaller, faster, modern devices with unique capabilities from access to participation at wholesale. And the offerings and rules for such things in the individual RTOs and ISOs are different, adding complexity.

In spring 2016, FERC initiated Docket No. AD16-20 titled "Electric Storage Participation in Regions with Organized Wholesale Electric Markets" to address current challenges to storage technologies accessing wholesale opportunities in the organized markets. After securing initial comments from the RTOs/ISOs and the public, FERC issued a Notice of Proposed Rulemaking (NOPR) on November 17, 2016. The 142-page NOPR, comments on which were due back to FERC by February 13, primarily addresses the ability of distributed storage to access wholesale markets and to fairly compete for ancillary services and other revenue opportunities with other resources that can provide similar service. The NOPR also addresses enabling aggregators of numerous, relatively small, distributed storage systems to act as wholesale market participants.

These issues will be developed further during 2017.

FERC PLAYING A KEY ROLE

FERC also initiated Docket No. RM17-8, "Reform of Generator Interconnection Agreements and Procedures," to address issues related to generation sources of all types, including storage, making application to the organized markets for interconnection to the transmission grid. Many of the issues here are similar to those in Docket AD16-20, as the current rules are based on conventional generation facilities, not storage. FERC subsequently issued a 181-page NOPR in the Docket on December 15, 2016, with comments due back to FERC in March. Many of the NOPR's proposed changes would address and benefit storage.

These issues will also be developed further during 2017.

GRID-LEVEL STORAGE

Finally, grid-level energy storage on the transmission system can include multiple technologies such as pumped-hydro storage, compressed air energy storage (CAES), flywheels, or batteries, among others. Today, the United States has about 22,000 Megawatts of pumped-hydro storage facilities in operation. Most of these have been in operation for decades and were originally justified for reasons other than renewable energy such as providing load for then-new nuclear power plants.

Grid-level storage projects like pumped hydro or CAES offer larger capacity sizes, longer storage durations and lower capital costs per kWh of storage than batteries, but their locations are limited by geology and geography. Recent grid-level storage projects have been proposed specifically to enable additional renewable energy on the grid. They include the 1200 Megawatt Utah CAES facility (48 hours of storage) with 3000 Megawatts of Wyoming wind,[13] the 300 Megawatt Apex CAES facility in Texas (48 hours of storage),[14] and the 1200 Megawatt Gregory County pumped hydro storage project in South Dakota (26 hours of storage) with 2400 Megawatts of wind.[15] Each of these projects seeks to provide needed ancillary services for integrating renewables to the grid or to combine renewable energy with storage to produce fully dispatchable, near-baseload, primarily renewable resources as alternatives to conventional generation facilities as they are retired.

Like their distributed counterparts, grid-level storage projects also face challenges to monetizing the various benefits they can provide to the grid—particularly in the organized wholesale markets. Depending on their ownership, location on the grid, and other factors, their operation can be beneficial to regional renewable facilities by reducing their curtailment and providing a better market price, and to regional conventional generation facilities by increasing their load factors and decreasing their cycling. But without tariff changes in the wholesale markets, these benefits may accrue to the renewable and conventional generation facility owners as "free riders" in that they will receive the benefits but have no responsibility to pay for the storage.[16]

Grid-level storage needs innovative new market tariffs.

Additional challenges include the fact that the FERC processes in both Dockets address issues related to storage only as dispatchable generation. They do not yet address the benefits of storage acting as dispatchable load, or "demand-side management in reverse". Schulte Associates LLC has outlined these issues and potential solutions to them in comments to FERC in the Docket AD16-20 and RM17-8 proceedings. The viability of grid-level storage in the organized markets will likely depend on FERC's response to them.

EVOLUTION CONTINUES

Whether distributed storage behind-the-meter or in front of the meter, or distributed storage seeking access to wholesale markets via FERC, or grid-level storage seeking new market treatments and tariffs at FERC and in the organized markets, modern energy storage has a potentially very large role to play as it evolves in enabling the clean energy future.

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In addition to storage, other complementary resources such as fast-ramping, natural gas-fired generation facilities and interregional high voltage direct current (HVDC) transmission lines will help integrate wind and solar energy and take advantage of their temporal diversity across large distances to make large quantities of additional renewables available, cost-effective and reliable. It will be a very interesting ride.

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NOTES

[1] Sullivan, J., Shellenberg, J., & Blundell, M. (2015, January). *Updated value of service reliability estimates for electric utility customers in the United States*. Ernest Orlando Lawrence Berkley National Laboratory, Table ES-1 at xii. One kilowatt-hour (kWh) of unserved energy is equivalent to one kW of electric load experiencing a service outage one hour in duration.

[2] Most utilities have a "ratchet" clause in their rates that use the highest peak demand in the prior few months as a minimum demand charge for the current month. Thus one-15 minute miss can penalize for many months.

[3] Current utility rate and service policies typically limit the output of residential solar installations to no more than the customer's own electric use each year.

[4] National average installed cost in Q1 2016 for residential applications was $2,930/kW. Fu. R., Chung, D., Lowder, T., Feldman, T., Ardani, K., & Margolis, R. (2016, September). *U.S. solar photovoltaic system cost benchmark: Q1 2016*, National Renewable Energy Laboratory Technical Report #NREL/TP-6A20-66532, p. 17. Retrieved from http://www.nrel.gov/docs/fy16osti/66532.pdf.

[5] Annual savings based on solar calculator at pvwatts.nrel.gov. Locations with higher amounts of annual solar insolation and higher utility rates offer lower simple payback times.

[6] Costs shown for 14 kWh Tesla Powerwall with invertor and installation. *See* https://www.tesla.com/powerwall.

[7] A commercial-sized, 500 kW, 3000 kWh Tesla Power Pack costs about $1.2 million, or $400/kWh, plus installation. *See* https://www.tesla.com/powerpack/design#/

[8] This assumes use of time-of-use rates, which are the best opportunity for storage arbitrage benefits.

[9] Eckhouse, B. (2016, August 8). Stem to provide battery storage for Con Ed in New York. *Bloomberg*.

[10] Cardwell, D., & Kraus, C. (2017, January 14). Big test for big batteries. *New York Times*.

[11] FERC does not regulate the Electric Reliability Council of Texas, because it is not interstate.

[12] Such ancillary services include supplemental and spinning generation reserves and regulation services used to operate the electric system.

[13] Miser, T. (2016, April 19). The Intermountain Energy Storage Project. *Power Engineering*.

[14] APEX CAES. (2016, April 27). Presentation at Energy Storage Association Conference and Expo, Charlotte, NC.

[15] Schulte, R. (2013, October 16). *Gregory County Pumped Hydro Storage Project Feasibility Study*. Retrieved from schulteassociates.com. Also: *Application for Preliminary Permit for Gregory County Pump Storage Project*. (2016, November 30). Missouri River Energy Services, application to FERC for preliminary permit.

[16] Schulte, R. & Bjorklund, I. (2015, December 4). *Market and tariff challenges to grid-level energy storage enabling renewable energy in RTO/ISO Markets.* Retrieved from schulteassociates.com and bjorklundlaw.com.