Girding the U.S. Electric Grid with Community Energy Storage

By Ben Bovarnick July 13, 2016

The U.S. electricity grid is vulnerable to natural disasters, including hurricanes, drought, wildfires, flooding, and extreme temperatures. The U.S. Department of Energy, or DOE, identifies weather-related outages as the single greatest cause of interrupted hours to electric customer service—more than 4 billion hours from 2011 to 2014.[1] As a result of worsening climate change, experts expect these threats to electric grid reliability to grow in the coming years.[2]

Aging electricity grids will require additional investments in climate resilience to provide customers with reliable service.[3] Energy storage offers an innovative opportunity for utilities to modernize their electric grids, improve efficiency, and reduce vulnerability to extreme weather—preserving and conferring numerous benefits to customers. Specifically, energy storage technologies—such as batteries, flywheels, pumped hydropower, and compressed air storage—can provide states and utilities with additional means to support electric grids and services. In particular, it will be important that utilities and grid operators consider using battery storage systems to augment grid resilience in the coming decades. These systems can take excess electricity off of the grid and reinsert it when necessary, allowing grid operators to efficiently manage fluctuations in the grid and direct electricity where it is most needed in times of crisis.

Energy resilience is a key component of emergency response, and the preservation of electric services is necessary for a properly functioning emergency infrastructure. Many pieces of vital infrastructure, from hospitals to cell phone towers to gas stations, all require electricity to operate during emergencies. Historically, backup internal combustion generators have been the predominant source of electricity when electric grids fail, but while these generators can be cheap to operate, they require fuel reserves, can be vulnerable to flooding during storms, are inefficient, and have relatively high emissions.[4] By contrast, batteries and small-scale energy storage systems can dispatch electricity efficiently, have no direct emissions, and can be flexibly placed elsewhere in buildings to ensure their continued operation during floods.

Although energy storage technologies are not yet affordable enough to encourage wide deployment, their costs—particularly for battery technologies—are projected to fall considerably in the next 5 to 10 years.[5] As costs fall, public programs to support infrastructure resilience could promote the use of energy storage in collaborative public-private partnerships with utilities to strengthen electric grids and increase their efficiency.

One innovative strategy for incorporating energy storage systems into the electric grid is through community energy storage, which uses many small-scale battery storage units to collectively aggregate their distributed capacity to improve electric grid flexibility. Recent energy storage software advances are helping energy storage companies remotely combine small energy storage systems for substantial amounts of aggregate capacity. These distributed systems are beginning to compete in electricity markets, where they can yield revenue while also serving as backup assets for emergency use.[6] In the coming years, as energy storage systems fall in price, community energy storage systems offer utilities and customers a new tool to bolster electric grid resilience and grid stability.

Mitigating the vulnerability of the electric grid to extreme weather

Electricity grid failures caused by extreme weather impose a substantial cost on the U.S. economy. From 2008 to 2012, weather-related power outages were estimated to cost between $107 billion and $202 billion annually.[7] And climate change is only projected to increase the severity of extreme weather events and the costs from damages that result. A study of urban vulnerability to climate change-related extreme weather found that cities from New York and Philadelphia to Jacksonville and Virginia Beach will become increasingly susceptible to blackouts in the coming decades.[8] Rising sea levels will expose an increasing amount of critical electric infrastructure along the East Coast and Gulf Coast to flooding, while droughts and heatwaves will increase the likelihood that wildfires will disrupt and damage electricity infrastructure around the country.[9]

The electric grid serves more than 144 million end-use customers in the United States. Much of it, however, is extremely old and vulnerable to failure.[10] When portions of the grid fail due to extreme weather or daily wear and tear, or need to be shut down to allow for maintenance, homes and businesses are at risk of plunging into darkness. Businesses can suffer lost output and revenue, delayed operations, and loss of goods during these outages. To avert these threats, the DOE recently launched a $220 million Grid Modernization Initiative and is working with electric utilities to strengthen the electric grid against extreme weather, physical attacks, and cyberattacks.[11] This initiative will support a more resilient grid by studying the integration and optimization of advanced storage technologies and clean energy generation.

In recent years, the DOE has directed significant grid resiliency resources toward smart grid projects.[12] Smart grids incorporate digital communications technologies into electric meters and critical juncture points, such as transformers, to help electric grid operators detect and respond faster to power outages and increase grid efficiency.[13] These investments have demonstrated their value in times of crisis. In 2012, half of the 170,000 customers who received smart meters through a partnership between the DOE and the Electric Power Board, or ERB, in Chattanooga, Tennessee, were spared power outages after a derecho swept through the area.[14] Similarly, the DOE and Florida Power and Light, or FPL, financed a $579 million project to install 4.6 million smart meters, distribution automation systems, and advanced transmission systems to improve operational efficiency and reduce electric bills. These system improvements helped FPL avoid 9,000 customer outages when Tropical Storm Isaac passed through Florida in 2012.[15]

While smart meters can help pinpoint the location of electric grid disruptions so that electric repairs can be completed faster, they cannot restart electric services after an outage. But energy storage units, such as batteries, can be placed at strategic points throughout electric distribution networks to restart electric grids when power generation fails. Distributed energy storage units also include digital communications technologies that can similarly inform grid operators of disruptions to the grid. These capabilities can help utilities further reduce disruptions and limit the amount of time that homes are left without power.

Energy storage systems can also be incorporated into microgrids at critical emergency centers, such as police stations and hospitals, to preserve electricity flow when it is most needed. Microgrids are small electric grids that contain their own generation capacity, distribution systems, and often storage capacity. The market for community resilience microgrids, which either can operate in sync with the broader electric grid or provide electricity independently during power outages, is poised to grow rapidly, from $162.9 million in 2015 to $1.4 billion by 2024.[16] The United States commissioned 13 microgrid projects in the first half of 2016 alone, and microgrid deployment is expected to grow 30 percent through 2020, to more than 3.7 gigawatts of capacity.[17]

Community energy storage for grid resilience

The term energy storage is used to refer to a variety of technologies that primarily store electrical energy for later use when it is most needed. These technologies range from fast-response energy storage, such as lithium-ion batteries, that can help electric grid operators and utilities manage electricity distribution, provide backup power to homeowners and commercial customers, and power electric vehicles, to bulk energy storage systems, such as pumped hydroelectric facilities and flow batteries, that can provide electricity to meet substantial demand over time.

Energy storage systems intended for resilience purposes must be designed to provide electricity fast and reliably when parts of the electric grid fail. Lithium-ion batteries can respond to demand in timeframes of milliseconds to seconds and provide energy for up to multiple hours, depending on their size. They have the versatility to provide services to the electric grid that increase efficiency and reliability; these include frequency regulation and peak shaving, which reduce the risk of grid failures. These services, and other ancillary services such as voltage support, are valuable to electric grid operators, and storage system owners can use energy storage to earn revenue through ancillary service markets. Other types of batteries, such as advanced-lead acid batteries, also can provide electricity at a moment's notice to displace diesel generation for backup power while at the same time serving the grid through voltage regulation and other ancillary services.[18]

When a portion of the electric grid fails, be it through an overloaded circuit or a downed power line, utility operators must isolate the failure and dispatch workers to repair it. The electric distributor, meanwhile, has to reroute electricity around the damaged circuit until it can be repaired. When distributed energy storage systems are placed at strategic points in the electric grid, they can communicate with the grid operator to help pinpoint the location of grid failures, absorb unexpected fluctuations in electricity levels, and temporarily compensate for losses in electric generation. These abilities can make energy storage systems a valuable tool for improving the resiliency of electricity grids.

Energy storage is a relatively new entrant in discussions of resilience. While energy storage has the potential to improve electric grid stability and reliability, these systems historically have not been incorporated into electric grids or utility resilience strategies. A major reason for this is that, until recently, many energy storage systems were too costly to warrant investment. However, between 2010 to 2015, costs for battery storage fell 50 percent.[19] This trend is expected to continue, and energy storage systems are expected to fall an additional 40 percent to 60 percent by 2020, from the 2015 price point of between $350 and $700 per kilowatt hour.[20]

As energy storage costs continue to fall, the economics for employing these systems to bolster grid stability and relieve grid strain during periods of high demand—as well as incorporate them into microgrid systems that allow local electric grids to "island," or provide power when the main electric grid fails during extreme weather events—will become more compelling. By deploying energy storage for microgrids and community energy storage projects, utilities can equip portions of the grid with the means to provide uninterrupted electricity access during natural disasters that in the past would have caused widespread outages.[21]

A University of California study evaluated the placement and operation of distributed storage systems, and found that with accurate network models, energy storage units located near electrical substations could be optimized to provide resilience benefits and earn revenue through the sale of excess capacity. By evaluating the peak load conditions of specific grid sections, utilities could program the systems to store enough energy to meet demand in the event of a power outage, while retaining the rest of the battery's capacity for ancillary services. The study concluded that storage system operators would need to determine the value of resilience relative to potential sales to transmission markets, since profits are maximized when the full system capacity is made available for ancillary services.[22]

With the falling cost of battery technology and improvements to battery management systems, community storage projects offer renewed potential to strengthen electric grids and increase their efficiency. By deploying small energy storage systems across a utility service area at critical junction points such as transformers, utilities and energy storage companies can bolster electric grid resilience while selling the aggregate capacity of the systems in regional transmission capacity markets.[23]

The evolution of aggregate storage

Recent advances in the energy storage industry suggest that the market is on the verge of successfully accommodating the infrastructure necessary for community energy storage. Companies such as Stem Inc. in California, and Sonnen in Germany, are employing new battery management systems to aggregate storage and serve conventional electricity markets. These systems allow energy storage companies and utilities to combine individual batteries into large virtual storage apparatuses to provide ancillary services for electric grids.

In Northern California, Stem Inc. became the first storage company to aggregate capacity of its individual units in September 2015. In order to participate in the ancillary services market of the California electric grid, Stem has partnered with the Pacific Gas and Electric Company to virtually manages the total capacity of the individual distributed storage units it provides to commercial customers. This allows the company to earn an additional return on investment that it can pass on in cost savings to customers.[24]

Similarly, Sonnen announced a program in 2015 for owners of its sonnenBatterie storage system to sell aggregated energy storage capacity through its sonnenCommunity program. The sonnenCommunity program establishes a virtual network that connects homeowners' residential rooftop solar panels and sonnenBatterie storage to share excess electricity generated within individual communities at lower prices than utility-supplied electricity.[25] Since Sonnen entered American markets in December 2015,[26] recent improvements to these systems' economics have allowed the company to project a 6.5 year payback on its battery systems in Hawaii.[27]

Stem and Sonnen have succeeded in aggregating their units in part due to recent advances in the software needed to support distributed energy storage integration. The important role that energy storage software plays in integration and aggregation of batteries is attracting growing interest from major energy companies, such as Royal Dutch Shell,[28] suggesting future opportunities for aggregating distributed energy storage systems just as customer-sited "behind-the-meter" storage capacity is growing.[29]

In the first quarter of 2016, customers added 8.9 megawatts of behind-the-meter storage capacity to the U.S. electric grid. This added capacity came in part from distributed residential battery storage systems—such as the SonnenBatterie, the Tesla PowerWall, and Sunverge Solar Integration System—which were marketed as backup generators in the event of power failures or as ways to stockpile solar energy for use after dark by coupling the systems with rooftop solar panels.[30] Through aggregate storage programs, these residential and commercial storage systems could be networked to bolster resilience not just for the homes they are situated in but also for the grid at large.[31] Energy storage company Advanced Microgrid Solutions recently secured a $200 million investment to build and operate distributed energy storage projects throughout Southern California.[32] However, aggregated energy storage programs have not yet been targeted to support broader electricity resilience goals.

Piloting community energy storage

In 2010, Detroit Edison electric company developed a community energy storage pilot in Michigan to strengthen the local electric grid and integrate a 500 kW solar power system. The utility installed a 500 kW lithium-ion battery integrated with the solar generator, as well as 20 individual 25 kW community energy storage units throughout the service territory that were integrated with residential transformers.[33] This pilot project successfully demonstrated that the aggregated community energy storage system could improve power quality, increase the security of emergency response infrastructure, and support integration for renewable energy.[34]

In a follow-up study, Detroit Edison reported that community energy storage projects could provide layered benefits to utilities, and that "in the right situation, energy storage is a tool that can be justified on economics."[35] Although the program concluded that batteries would have to cost less than $705 per kWh in order to be economical, cutting costs by relying on repurposed electric vehicle batteries was ill-advised due to their higher failure rate.[36] The $10.88 million project cost was split between an almost $5 million DOE grant and investments from private sector partners; the early development battery system the project relied on cost $2,000 per kWh.[37]

Building on the community energy storage concept, this June, Consolidated Edison, SunPower, and Sunverge announced a $15 million "virtual power plant pilot" to serve 300 households in the New York City boroughs of Brooklyn and Queens. The project, which is part of New York's Reforming the Energy Vision initiative, will install a 7 to 9 kilowatt rooftop solar system and a 6 kilowatt lithium-ion battery storage system in each home. The project is designed to operate as a "clean virtual power plant" and to primarily serve as an asset to the electric grid. This means that although deployed in residential homes, the power systems will be operated remotely. The systems' electricity generation and storage capabilities will be aggregated in real time, and the companies hope to use the data collected to understand the specific operational characteristics of battery storage and the value consumers place on backup power.[38]

State energy resilience programs

As discussed above, New York has begun to support energy storage projects through its Reforming the Energy Vision, or REV, process, in addition to the Consolidated Edison virtual power plant pilot. The state is funding battery storage companies and projects such as the VARTA Microbattery, which will pilot a solar-plus-storage microgrid that can switch easily between on-grid and off-grid power.[39] More recently, in May 2016, the New York Public Service Commission approved reforms to the model that utilities use to generate revenue. The new revenue generation model will allow utilities to earn returns on cost-of-service investments; market-based platform services; the deferment of capital investments through innovative strategies; and market-based performance measures. The opportunity to earn revenue through the latter two options creates new market opportunities for community energy storage projects. By incentivizing utilities to invest in unique solutions to defer capital expenditures, New York can encourage utilities to invest in lower-cost demand-side management and distributed energy storage programs rather than expensive new upgrades, as Consolidated Edison recently did, saving $500 million in the process.[40] Furthermore, allowing utilities to earn revenue through market-based performance measures—essentially, allowing them to earn more money if grids perform better for customers—can reward utilities for investments to improve grid resilience.

After Superstorm Sandy exposed the vulnerability of electric grids throughout the Northeast and an estimated 8.5 million homes lost power across 17 states, many of the affected states launched efforts to spur new investment in electric grid resilience and committed more than $400 million in state funds toward micro-grid, energy storage, and community resilience projects.[41] New Jersey established a state Energy Resilience Bank, or ERB, to finance infrastructure resilience projects. The bank was financed with $200 million allocated for Community Development Block Grant-Disaster Recovery to "support distributed energy resources at critical facilities throughout the state that will enable them to remain operational during future outages."[42] The ERB will provide grants and loans to projects that can operate independently of the grid and operate when the grid fails, as well as to projects that were affected by Superstorm Sandy. The bank has an available budget of $5 million for electricity storage equipment, with each project eligible for up to $500,000 in financing.[43]

In Oregon, the Eugene Water and Electric Board has begun a two-year $1 million project to pilot the use of microgrids to enhance grid resilience and disaster management.[44] The program is partially funded with a $295,000 grant from the U.S. DOE and the Oregon Department of Energy.[45] The project incorporates a 500 kW lithium-ion battery system and is networked with electric vehicle charging stations and a community solar installation.[46]

Finally, a 2014 report issued by the Maryland Energy Administration, or MEA, concluded that as distributed renewable energy is increasingly deployed throughout the state's electric grid, "even relatively small energy storage systems can provide resiliency and grid system benefits that make projects more economical and improve power quality to the entire electric grid." The report recommended the MEA provide grants to encourage energy storage integration and promote distributed energy storage projects that could make the Maryland electric grid "more economical and resilient."[47] It stands to reason that distributed energy storage can provide similar benefits to other states as well.

These state-directed projects can provide valuable insight into best practices and potential pitfalls for utilities seeking to strengthen their electric distribution networks with distributed energy storage systems.

Next steps

As utilities and electric grid operators become more familiar with distributed energy storage applications and as these technologies enjoy broader usage, policymakers will also have to consider how these technologies can be integrated with other resilience strategies, including physical infrastructure investments and cybersecurity programs. Community energy storage offers utilities and policymakers an innovative strategy for integrating energy storage systems into the 21st-century electric grid. By incorporating future low-cost energy storage systems into electric grid resilience strategies, utilities can leverage investments in aggregated community storage projects to enhance local resilience investments and improve electric services for businesses and communities.

However, while distributed energy storage is a new tool for states to improve emergency services and utilities to strengthen their electric infrastructure, the value of such systems is not yet well defined. This can lead to hesitation or reluctance to invest in these technologies. Therefore, state directed public-private partnerships, like those underway in the Northeast, and other financial incentives to spur investment in storage for electric grid resilience are invaluable policies to bolster investment in energy storage for resilience purposes. These programs can help utilities collect valuable data to better assess the role of distributed energy storage in the future, as well as how to optimize resilience investments in the long-term.

In addition, states can consider regulatory policies to promote resilient electric grids such as performance-based rates, which compensate electric utilities for service reliability, rather than simply electric generation, to incentivize widespread investments in resilient technologies.[48]

Community energy storage is a tool for utilities and grid operators to pursue as they consider innovative strategies to increase electric grid resilience in the face of climate change. Small-scale, aggregated energy storage systems can benefit future resilience strategies by supporting a flexible grid that can respond to strains during extreme weather events and improve operational efficiencies during times of calm. As costs for batteries and other energy storage systems continue to fall in the coming years, utilities and companies can build on the lessons learned from early pilot programs to bolster their grid services and protect consumer electricity access in times of need.

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