WHITE PAPER

Improving Smart Grid ROI with distributed energy resources

The long-term objectives of the smart grid are to dramatically increase grid utilization, reliability, and efficiency; to provide customers with the means to respond to economic and environmental signals in their consumption of electricity; and to help utilities become nimble enough to thrive amid the volatility of a market in which customers become suppliers too.

In such a world, Distributed Energy Resources (DERs) represent a vital set of assets that allow power to be:

- controlled and managed at the customer level;
- generated using local distributed capacity;
- locally stored, which decouples generation from consumption; and
- transformed for electrification of transportation.

Four primary resources comprise the DERs that can represent capacity for a utility: demand response (DR); distributed generation (DG); distributed energy storage (DES) and electric vehicle (EV) charging.

By reducing peak load consumption, DR represents released capacity. DG is new capacity – often from renewable energy sources – that comes without the cost of transmitting the power through the electrical grid. DES is energy that has been "moved in time" to when it's most needed. EV charging is a category unto itself, a technical challenge for distribution networks particularly if there is local clustering or charging during peak demand, but a potential node for DES in the longer term.

Taken together, DERs can play a meaningful role for utilities in helping to increase the percentage of renewable energy on the grid; providing short-term reserve power; addressing grid reliability issues; and avoiding the need for capital investment in new generating capacity.

According to the Brattle Group, over the next few decades, DERs represent the potential of more than $23 billion in avoided costs. Fully applied, DERs can be used by a range of stakeholders at different levels in the power system to reap the kind of transformational benefits that their smart grid investments are supposed to foster.

In its report, "Reforming the Energy Vision," the New York State Department of Public Service looks at the benefits of this approach at the distribution level: "The intelligent integration of DER can solve distribution system planning challenges and improve the resilience of distribution systems. For example, installation of distributed generation (DG) could potentially increase the useful life of existing feeders by reducing their loading… and accommodate localized load growth without the need to upgrade feeders."

Currently, though, utilities struggle to find the economic value in DER. As new capacity, DERs can be both expensive and difficult to manage. Further, in an industry that was designed around a unidirectional flow of power (i.e., from generation to transmission to distribution to end-use) DERs put the utility at the hub of a more complicated, multi-directional supply chain.

As a result, DER applications have been largely limited to demand response in the form of direct load control. Under these programs, utilities can directly control consumer loads to reduce peak demand and avoid generation capacity costs. DR delivers immediate economic value, but there is far more potential value in DERs than that, according to Gary Rackliffe, Vice President of Smart Grid Development at ABB.

"If you have a demand response program, that's great," he offers. "You will be able to reduce peak load. But if you don't have that integrated into your generation portfolio and how you manage your grid, you won't capture the full benefit that DERs represent."

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Why hasn't the full impact of DERs been realized?

First, DER capacity is expensive, and in the case of renewable generation, intermittent and difficult to forecast. Second, some resources like DG can also create new problems, such as high voltages on distribution feeders. Storage, in meaningful amounts, has also been both expensive and difficult to integrate. But the technology exists today to address all of the major challenges that DERs represent, allowing utilities to unlock even greater value by managing them as an integrated and transformative resource across the grid.

Demand response

Demand response, the ongoing effort to manage consumption of electricity in response to levels of demand, has enjoyed the most success among DER technologies. The direct load control form of DR has predominated because it requires only a one-way flow of information.

This can be hard on customers, who have little control over when their power supply is curtailed, but for utilities these programs can be attractive as a way to reduce peak load when generation capacity is tight. Increasing investments in DR technology and AMI (advanced metering infrastructure) are enabling customers to get more involved and reap more rewards. Customers can use programmable communicating thermostats or customer portals to program usage preferences and thresholds for control program opt-outs. The technology can also be coupled with time-of-use rates to further incentivize customer behavior.

In a fully connected smart grid, this new capacity can – and is – being sold in an open market. Peak pricing programs have achieved reductions in peak demand of up to 20%, and as more smart meters are deployed, that figure is likely to increase. (There were 64 million smart meters deployed in the US in 2015, according to the US Energy Information Administration.) The continued propagation of AMI and related technologies will encourage broader participation in wholesale electricity markets; increase the variety of solutions utilities have to provide ancillary services; and eventually change the economics of the industry itself.

Distributed generation
Distributed Generation (DG) is power produced by small-scale sources at various points throughout the grid. The category includes wind turbines, solar/photovoltaic cells, geothermal, micro turbines and backup diesel generators. Often, the generation source is located on-site at the point of use.

Growth in DG has been supported by regulatory policy, and embraced as a revenue model by independent generation ventures. The most common sources of DG are small-scale installations of a few kW to perhaps 10,000 kW such as rooftop solar panels or backup diesel generation. But a growing number of commercial facilities are appearing. For example, business software developer SAS now operates a pair of solar farms near its North Carolina headquarters, supplying up to 2.2 MW for its own use as well as the surrounding grid.

Managing power flows from so many small sources is challenging. There are technical issues such as voltage support, power quality and safety that must be handled at the point where each DG node connects to the grid. There are capacity issues, too. A cluster of DG sources can put strain on aging distribution systems, requiring upgrades in substations, transformers, switchgear, cables and other field assets.

Timing is also an issue. Solar generation, for example, can suddenly drop when a cloud passes overhead, and it tends to hit its daily peak several hours before demand does. Wind generation is often greater at night when demand is low. Forecasting is another challenge. Projecting the output a few large generation sources – usually fossil, hydro, or nuclear – is easier than that of hundreds of independent sources.

Finally there is the issue of cost. The sources of DG tend to be more expensive per kWh than electricity from a central generation facility. So while utilities are required to accept DG capacity, they often don't have a market for it. On the other hand, DG tends to be renewable and carbon-offsetting (though some sources do use carbon-based fuel) and it is local, reducing transmission losses and providing reserve power for improved reliability at the distribution level.

Distributed energy storage
Distributed energy storage is energy from batteries and other storage technologies installed at various locations on and off the grid. Its value lies in the ability to unlink generation from demand. For example, in 2009 Long Island's Nassau Inter County-Express (an arm of the Metropolitan Transit Authority now called NICE) installed a sodium sulfur battery energy storage system (BESS) to run compressors used to refuel its fleet of natural gas buses.

The idea was to charge the BESS system at night when electrical rates are low, and use it to fill buses during the day. Because NICE was already filling buses at night to exploit the lowest electrical rates, the savings on electrical costs were small. But by moving the work to daytime, the agency saved $220,000 in third-shift labor costs.

This example of load-shifting/peak shaving is only one application of DES technology. Other key applications include:

- Renewable energy capacity firming: Storing energy from wind, solar or other renewable sources to provide a smooth flow of energy. As renewable sources (wind and solar) continue to proliferate and the cost of batteries declines (McKinsey estimates $200 per kWh in 2020, half today's price), these applications will likely become a key component in the electrical grid.
- Investment Deferral: DES modules placed downstream from the congested portion of a transmission or distribution system can provide power at peak times, helping to prevent overloads and defer line upgrades.
- Power Quality: DES devices can protect loads against short-duration disturbances that affect the quality of power being delivered.
- Voltage support: DES with reactive power capability can provide voltage support and respond quickly to voltage control signals.
- Outage management: DES can provide short-term power to a network, thus mitigating the effect of any kind of temporary fault.

Another important application of DES is for high-value ancillary services, such as spinning reserve. Fairbanks, Alaska, for example, is at the end of a long, remote power corridor and is subject to frequent power disruptions. With winter temperatures hitting 30 degrees below zero, traditional means of spinning reserve were either too costly or unreliable and they increased emissions. Since 2003, spinning reserve has been maintained with what at the time was the world's largest battery energy storage system (BESS), which can provide 27MW for 15 minutes, enough time to spin up longer-term reserve sources.

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02 The World's largest Battery Energy Storage System is located in Fairbanks, Alaska and serves 90,000 residents, spread over 2,200 square miles.

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03 ABB fast charger technology only takes 15-30 minutes to fully charge a vehicle.

Electrical vehicle charging

Electrical vehicle charging today is essentially a demand response/load leveling issue, but it is often separated from DR because of the scale of impact that an EV can have on an individual's residential load. A small cluster of EVs can also impact the local distribution system, especially distribution transformers. Today's control systems for EV charging can control when EVs are charged and the rate of charging to efficiently support demand response and grid services. Looking further ahead, EVs are appealing for their storage potential through vehicle-to-grid (V2G) technology. V2G works by using smart-charging stations to draw energy from the grid to charge the vehicle's battery when demand is low and feed that energy back into the grid during peak demand. This application is not currently supported by auto manufacturers and, with relatively few EVs on the road at this time, remains a speculative application.

Unlocking the value in DER

There is far more economic value in DERs than is currently being extracted. And the benefits accrue to every level of the electric-generating industry by helping to fulfill the core promises of the smart grid: improved grid utilization, customers enabled to make usage decisions, and flexibility for providers through creation of robust energy markets.

In a mature DER environment, power would flow seamlessly onto the grid from DG sources, while demand is managed effectively through DR. Trouble spots – such as where aging infrastructure gets overwhelmed by peak load – would be supported by strategic DES installations and highly localized DG. Microgrids and islands could be established using all the technologies of DERs to protect sensitive or critical loads from outside grid disturbances.

In short, DERs make electric capacity more fluid, which increases flexibility to participate in wholesale markets from both the buy and sell sides. That, in turn, benefits not only T&D operations, but also wholesalers, retailers and bulk generators.

Gaining visibility and control

Favorable public policy and rates, ongoing investments in AMI, and improved monitoring of grid assets are helping to enable wider adoption of DER. Meanwhile, utilities are left with a dizzying range of questions:

- How can all the EV chargers and load controllers for AC units, for example, be modeled as sources of demand, and used to accurately forecast capacity requirements?
- How can demand reductions across a few hundred thousand customers be aggregated as a single source of capacity?
- How can DG sources be understood as a predictable pool of power to be bought, sold and used?

There is a need to understand DER at the local distribution level for voltage optimization, protection and control, and capacity management. Utilities also need to address the impact of aggregated DER on the transmission grid and centralized generation. "As essentially another central generating plant, DER must be modeled and forecasted to coordinate these resources," says ABB's Gary Rackliffe. "It's a management issue that did not exist until recently."

A word about IEEE Standard 1547

IEEE Standard 1547 is the de facto interconnection standard for DER in North America. It establishes maximum DER disconnect times for abnormal voltage and frequency.

While it's understood that a high penetration of distribution connected DER may have a significant effect on the reliability of the bulk power system (BPS), those effects were not addressed in 1547, according to NERC.

"Of particular concern to [grid] reliability," the agency notes, "is the lack of disturbance tolerance, which entails voltage ride through (VRT) and frequency ride through (FRT) capability. Under high penetration scenarios, it is possible for a large amount of DER to trip on voltage or frequency due to a transmission contin-gency, which could potentially affect bulk power system stability."

In September 2013, IEEE modified Standard 1547 to permit both VRT and FRT. The standard continues to evolve to reflect how DERs are being used and their impact on the grid.

Making DERs work at a physical level isn't enough; they also have to work at a financial level. That requires a connection between operations technology (e.g., advanced meters, DG controllers, grid automation) and the systems that manage demand response, generation portfolios and the distribution grid itself.

That's the role of the virtual power plant (VPP), a critical technology in making economic sense of DERs. A VPP aggregates DERs based on location, pricing plans and operational characteristics in order to characterize, forecast and utilize the capacity they represent. It allows a utility to manage DERs in real time in such a way that they appear to market and grid operators as just another generation plant.

"If you can model and aggregate DERs as a virtual power plant, you gain the ability to dispatch that VPP as part of your supply portfolio," Rackliffe explains. So, the VPP is essentially an enabling technology.

"If we're trying to utilize DERs at the same level as traditional generation," Rackliffe adds, "the role of these systems is to create that equivalency. They allow the demand side to be valued at the same level as generation. This is one of the higher purposes of the smart grid, and we can do it right now."

Conclusion

DERs are vital tools for unlocking the benefits expected from the industry's smart grid investments. Utilizing technologies that are already being implemented, DERs can improve grid utilization and efficiency; provide customers with the means to respond to economic and environmental signals; and help utilities become nimble enough to thrive among the increasing volatility that the smart grid introduces.

When managed at an integrated level, DERs provide economic value by creating new opportunities for utilities to provide such ancillary services as spinning and other types of reserve energy. They also facilitate customers' access to commercial electrical markets on both the buy and sell sides. The impact of DERs today may be limited, but as use of virtual power plants and other enabling tools increases, the importance of DERs will continue to grow.

There are numerous reasons for utilities to begin or expand the process of developing a smarter grid no matter what their level of DER penetration. Certainly, a smarter grid will mitigate the variable nature of solar and wind DERs, but it will also support overall grid stability and reliability. And while there is still work to be done on universal standards to make DER integration easier, the work done now to make electric grids smarter overall is an investment that will offer immediate returns.

ABB Inc.
Smart Grid
1021 Main Campus Drive
Raleigh, NC 27606, U.S.A

new.abb.com/smartgrids

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