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 among 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 transportation applications.

These capabilities represent a return on investments that power companies have been making in the smart grid. They behave like new capacity, and are fundamental to the promise that smart grid initiatives offer.

Four primary resources comprise the Distributed Energy Resources (DERs) that can represent capacity for a utility: Demand Response (DR); Distributed Generation (DG); Distributed Energy Storage (DES) and Electric Vehicle charging (EV).

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 is a category unto itself – a technical challenge for distribution networks today if there is local clustering, but eventually a possible node for DES.

Taken together, Distributed Energy Resources can play a meaningful role for utilities in such strategic imperatives as helping to increase the percentage of renewable energy on the grid; providing various types of short-term reserve power; finding a solution for certain grid reliability issues; and avoiding the need for capital investment in large sources of new generating capacity.

Over the next few decades, DERs represent potential of more than $23 billion in avoided costs alone[1].

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.

But utilities struggle to find the economic value in DERs – and for good reason. As new capacity, DERs can be both expensive and difficult to manage. Further, in an industry that has had a uni-direction flow of product – from generation to transmission to distribution to end-user – DERs put the utility at the hub of a much more complicated supply chain, a position few utilities are prepared to occupy.

As a result, DER applications have been largely limited to demand response in the form of direct load control. Utilities can directly control consumer loads to reduce peak load and avoid generation capacity costs. Immediate economic value is recognized and the utility typically controls these programs.

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 don’t capture the full benefit of the capacity that DER represents.”

There are a few reasons the impact of DERs has been limited to date. DER capacity is, firstly, expensive. Renewable generation is also intermittent and can be difficult to forecast. DG can also create new problems, such as high voltages on distribution feeders. Finally, storing adequate amounts of energy has been both difficult and cost prohibitive.

But the technology exists today to address all of the major challenges that DERs represent, allowing utilities to unlock an even greater value by managing DERs not in silos, but as an integrated and transformative strategy across the smart grid.

Demand Response

If there is one facet of DERs that has seen consistent application, it is demand response – the ongoing effort to manage consumption of electricity in response to levels of demand.

The direct load control form of DR has predominated because it requires only one-way flow of information.

It can be hard on customers, who have little control over when their power supply is curtailed once they are signed up for a load control program. But for utilities these programs can be attractive as a way to reduce peak load when generation capacity is tight.

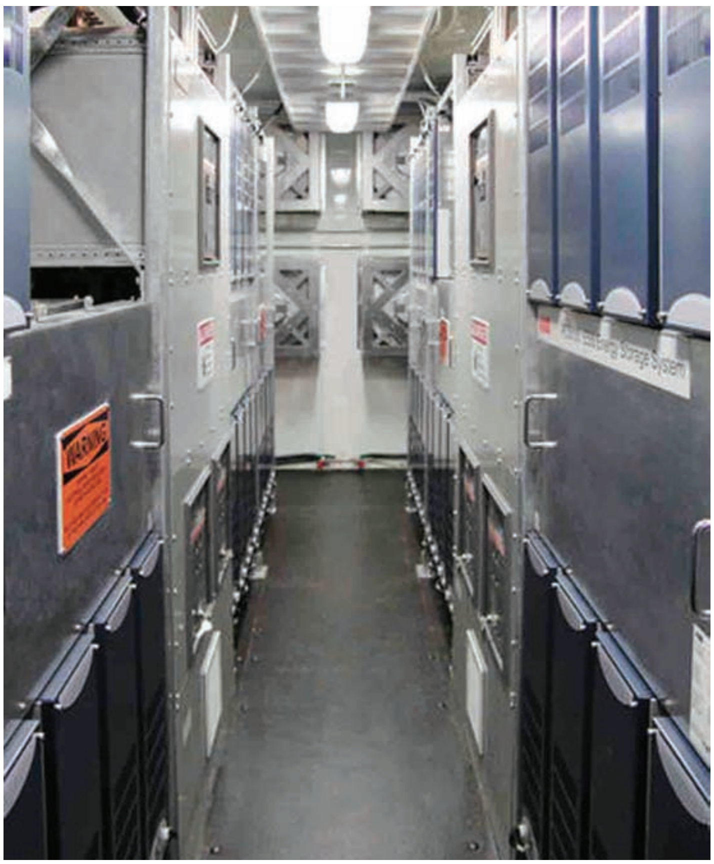
But if direct load control effectively caps energy use, it doesn’t reduce demand. That can only occur when end-users have the information and tools they need to make proactive decisions about how and when they use electricity.

Increasing investments in DR technology and AMI (Advanced Metering Infrastructure) are enabling customers to do just that. Customers can use programmable communicating thermostats or customer portals to program usage preferences and thresholds for control program opt-outs. The technology can be coupled with time-of-use rates to further incentivize customer behavior. Utilities are able to go beyond the peak-load reduction of direct load control – actually allowing customers to create generation capacity through managed demand.

In a fully connected smart grid, this new capacity can – and is – being sold in an open market. The DR contribution to peak load reduction within the U.S. ISO/wholesale market has increased 10 percent in the last five years, according to *Unlocking Customer Value: The Virtual Power Plant* – an article in *WorldPower* magazine in 2010 by Aaron Zurborg – formerly of Ventyx and now Senior Director of Energy Supply Technologies at Pacific Gas & Electric Co. That growth is meaningful, but it’s still incremental.

1. The Tao of the Smart Grid, a 2011 presentation by Dr. Ahmad Faruqui, a principal of The Brattle Group.

However, according to a Brattle Group study, *Unlocking the 53 Billion Savings from Smart Meters in EU*, a peak pricing program can achieve a reduction in peak demand by 13%-20%. So as more smart meters are deployed, that gradual curve is likely to accelerate. While there were about 13 million smart meters in use across the country at the end of 2011, that number is expected to quintuple, to 65 million, by 2015, according to the 2011 FERC *Assessment of Demand Response and Smart Metering*. The amount of recovered capacity this represents will encourage broad participation in wholesale electricity markets; increase the variety of solutions utilities have to provide ancillary services such as spinning reserve; and may change the economics of the industry.



Distributed Generation

Distributed Generation (DG) is power produced by small-scale sources at various points throughout the grid. Examples of DG sources include wind turbines, solar/photovoltaic cells, geothermal, micro turbines and backup diesel generators.

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 back-up diesel generation. But a growing number of commercial generating 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 the commercial grid.

Bringing energy onto the grid from so many small sources is difficult. There are technical issues such as voltage support, power quality, and safety which 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 investment in substations, transformers, switch gear, cables and other field assets.

The intermittency of renewable energy sources can create operational issues; solar generation, for example, can suddenly drop when a cloud passes overhead. Matching output capacity to demand can also be problematic; solar generation tends to hit its daily peak several hours before demand does and wind generation is often higher at night. Forecasting is another challenge. Supply of power from a few large generation sources – usually fossil, hydro, or nuclear – is easier to project than from hundreds of tiny independent renewable generating 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.

But the energy from DG is not without value. It tends to be renewable and carbon-offsetting (though some DG sources do use carbon-based fuel). It also tends to be very local – reducing transmission losses and providing a potential source of reserve power for improved reliability at the distribution level.

Distributed Energy Storage

Distributed Energy Storage is storage capacity from batteries and other storage technologies which are installed at various locations on and off the grid. Its value is 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 that are used to fill its fleet of natural gas buses.

The idea was to charge the BESS system – a DES technology – 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 but one application of DES technology. Other key applications include:

– Renewable energy capacity firming: Storing energy from wind, solar or other renewable DG to provide a smooth flow of energy when production is intermittent. As the penetration of intermittent renewable sources (wind and solar) continues to increase and the cost of batteries declines, it is expected that these applications will 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 loads – helping to prevent overloads and delay potential line upgrades.
– Power Quality: Power quality applications involve using DES to protect loads further downstream against short-duration events that affect the quality of power being delivered.
– Voltage support: Energy storage 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 increased emissions. Since 2003, spinning reserve has been maintained with what at the time was the worlds' largest battery system – a 1,500-ton Ni-Cd BESS that can provide 27mW for 15 minutes – enough time and power to spin up longer-term reserves from another source.

"As of today, the available commercial solutions in energy storage can offer better capabilities at a considerably lower cost than just 10 years ago," says Pablo Rosenfeld, Distributed Energy Storage Project Manager at ABB. "As the price for capacity (megawatt) and energy (megawatt-hour) continue to come down, Battery Energy Storage Systems will have a larger and larger role in the smart grid."

Electrical Vehicle Charging

Electrical vehicle charging today is essentially a demand response/load leveling issue, but it is often separated from DR in a discussion of DER 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. Looking further ahead, EVs are also considered for their potential as DES devices through Vehicle-to-Grid (V2G) technology. V2G works by using smart-charging stations to draw energy from the grid when demand is low and storing it in the vehicles' batteries, and feeding that energy back into the grid at 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

So 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. All of this would provide direct benefit to distribution grid operators.

Transmission operators would benefit as well. DG at the local level reduces average demand on transmission corridors that are already working at capacity, and provides new options to meet required levels for operating reserves and other ancillary services— effectively improving reliability and helping to avoid or delay capital investments in new transmission capacity.

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

Gaining visibility and control

DERs are both disruptive and transformative. While they make the grid smarter and more responsive, they also add complexity and volatility.

Ongoing investments in AMI, and improved monitoring of distribution and transmission assets, are helping to enable that transformation. But today, the economic benefit of DERs is merely implied – a peak-load reduction multiplied by wholesale rate per kWh to calculate the amount of electricity not purchased.

Meanwhile, utilities are left with a dizzying range of questions to answer:
– 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 reductions in peak-demand across a few hundred-thousand small 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 the wide-ranging impact DERs have on the grid just like they are another central generating plant," says Clinton Davis, Director of Product Strategy for Smart Grid at Ventyx, an ABB company. "It's a modeling task, a forecasting task and a management issue of the kind that was never required before."

In other words, 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 (such as advanced meters, distributed generation controllers, load

control devices, and transmission and distribution hardware and automation) with information technology (such as Demand Response Management, Portfolio Management, and Network Management systems).

That's the role of Virtual Power Plants (VPP), a critical technology in making economic sense of DERs.

A VPP aggregates customers based on their location, pricing plans and other characteristics to provide a means to understand, forecast and utilize the electric capacity they represent through DERs. It allows a utility to "tap resources in real time, and with enough granularity, to control the load profiles of customers, aggregate these resources, and put them up on a trader's desk," according to a 2011 Pike Research Report, *Virtual Power Plants*.

While VPPs can be used to manage DR and DG resources to provide reliable and high-quality power at the distribution level, they also can be used to aggregate available capacity for sale in retail and wholesale markets.

"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," Davis offers. "So your collection of DERs has operational characteristics that you define, costs associated with it, and benefits in terms of offsetting supply costs or addressing a network issue."

The VPP, in other words, provides sophisticated tools to allow the hundreds of thousands of capacity resources that exist under the DER umbrella to be viewed as a central generation plant. With this view any player in the utility landscape – retailers, wholesalers, transmission system operators and distribution system operators – can manage DER capacity with the increased flexibility required for the changing environment.

"This technology is the glue that connects DERs to the systems that analyze them and make use of them," says ABB's Rackliffe. "If we're trying to utilize DERs at the same level as traditional generation, the role of these technology systems is to create that equivalency. They allow the demand side to be valued at the same level as generation. It's a true balancing of supply and demand. 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 in their consumption of electricity; and help utilities become nimble enough to thrive among the increasing volatility that the smart grid introduces.

Most DER initiatives today are limited to DR. While DR is an important tool for managing overworked distribution grids, its application in a functional silo limits the potential financial benefit to the amount of electricity users choose not to draw. But when DR is combined into a suite of resources – through skillful management of DG, DES, and EV charging – it has potential to provide dramatic benefit across all utility operations.

This level of integration has only recently become technically feasible, due to improvements in energy storage technology and development of software solutions that can aggregate widely distributed energy resources into a unified source of capacity.

The result of this new capability is continued acceleration of the impact that DR programs offer, improved reliability, and increased availability of new capacity from renewable generation sources – thus improving compliance with clean-energy regulations.

When managed at an integrated level, DERs also provide economic value by creating new opportunities for utilities to provide such ancillary services as spinning and other types of reserve energy. Further, it improves the ability to participate in 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. It will help utilities improve their flexibility to compete in an increasingly volatile marketplace, and it will support them in achieving the full promise of the smart grid itself.

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