RESEARCH REPORT

Maximizing the Locational Value of Distributed Energy Resources

How Three Utilities Are Using Software to Overcome Distributed Energy Resource Integration Challenges

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Section 1
INTRODUCTION

1.1 Distributed Energy Resource Market Overview

The growth of distributed energy resources (DERs) is one of the most complex and disruptive trends to hit the electric power industry in the past several decades. And it's only going to get more complex: Navigant Research estimates 130 GW of cumulative DER capacity will be on the U.S. grid by 2021.

DERs encompass a broad set of solutions, including systems and technologies designed to operate closer to customers on the electricity grid. Rapidly expanding investment in DERs represents a major shift away from the centralized, one-way electrical grid that has been the status quo for the past century. Perhaps the most impactful new technology has been the growing distributed solar PV, which has now been installed by 4 percent of U.S. homeowners and has been considered by a further 40 percent.[1] This growth has generated concern and optimism throughout the power industry as regulators and grid operators work to understand the evolving landscape that is redefining the relationship between utilities and their customers.

The specific drivers of DER growth—including technology advances, business model innovation, and changing regulations, as well as sustainability and resilience concerns—vary from region to region. From the perspective of a grid operator and utility, the overarching goal of DER deployments is to integrate these resources effectively so that the electricity grid becomes more efficient, resilient, cost-effective, and sustainable. Most end-use customers, however, are only concerned with securing more cost-effective and reliable onsite power. While these goals can be complementary, the desired pace and scale of DER deployments differ among stakeholders. The forms of DERs most commonly referred to throughout the industry include:

Table 1.1 Distributed Energy Resource Technologies

Distributed Generation *(including solar PV, small and medium wind turbines, micro turbines, fuel cells, and diesel/gas generators)*	
Distributed Energy Storage Systems (DESSs)	Electric Vehicle Charging Systems
Microgrids	Demand Response (DR)

[1] Pew Research Center, *The Politics of Climate,* October 2016.

Several of these technologies (e.g., generator sets and DR) have been widely used for decades. Others, however, notably solar PV and DESSs, are now changing the way energy is delivered to customers. These technologies change the dynamics and the physical operation of the grid, as well as the relationship between utilities and their customers. These technologies also require greater levels of intelligence and control to realize maximum overall benefits while minimizing any negative effects. Companies throughout the industry are responding to this challenge by deploying innovative software platforms that examine ways to reduce utility and customer costs—all while improving the efficiency and reliability of the grid.

DESSs refer to systems installed behind a customer's utility meter in either residential or commercial and industrial (C&I) buildings. Recent cost-reductions, along with innovative business models, have made these systems an economical investment for a growing number of customers. Numerous factors drive these markets worldwide, including the rapidly growing solar PV industry, falling system costs, a need to improve resilience, increasing awareness of energy consumption, and the desire to use clean and locally generated electricity.

Pairing distributed generation and energy storage to form building-level nanogrids is one of the key long-term visions of the DER evolution. When properly designed and coordinated, these distributed grid systems can generate significant cost savings for customers while providing backup power indefinitely in the event of a grid outage. As the penetration of distributed and variable generation continues to increase, paring these systems with energy storage may be essential for maintaining grid stability and efficiency. By providing flexibility on both the supply and demand sides of the grid to eliminate wasted resources and inefficiency, DESSs can in many ways provide the missing link that will enable the optimal smart grid and DER vision.

According to a recent survey of utility-industry executives, 40 percent of respondents at regulated utilities indicate that their companies are pursuing distributed energy storage deployments as a new revenue stream.
Utility Dive, 2016 State of the Electric Utility Survey

Forward-looking utilities are working to integrate DERs into their grids, both in response to changing customer demand and as an extension of their current businesses. According to a recent survey of utility-industry executives, 40 percent of respondents at regulated utilities indicate that their companies are pursuing distributed energy storage deployments as a new revenue stream.[2] However, to fully realize the benefits of this new technology grid, operators must incorporate advanced software platforms that analyze their networks

[2] Utility Dive, *2016 State of the Electric Utility Survey*, 2016.

to identify locations in which DERs can provide the most value and ensure the proper management of these systems.

While a number of elements dictate the value and the challenges for DERs on the grid, physical location is likely the most important single factor. This study will explore the specific factors that determine the value of DERs in a given location, the challenges facing greater deployment, and how three leading utilities are approaching DER integration to overcome these challenges.

Section 2
DISTRIBUTED ENERGY STORAGE SOFTWARE

2.1 Key Software Capabilities and Functionality

Energy storage software platforms are becoming increasingly complex in response to the industry's demand for more flexible, cost-effective, and multifunctional storage systems. Although the exact requirements and operation of a software platform will vary depending on the specifics of each project, the three primary functions for storage software are:

- **Project analysis:** This function includes the modeling of ideal technology components, system sizing, operating parameters, and return on investment (ROI), and determines the most effective services a system should provide, based on utility/wholesale market rate structures and regulations.
- **System control and operation:** This function involves integrating the system with grid communication networks and determining the most economical operation based on market and system conditions.
- **System optimization:** This function focuses on maximizing the lifetime and condition of battery systems, maximizing revenue and ROI, and predicting system degradation and replenishment needs.

The value of DESS software lies in its cost management applications and services for host customers and in its ability to add flexibility to load in areas with capacity constraints or other locational issues. A number of forward-thinking utilities have calculated and published data on the cost differences of delivering energy at certain points of the grid at different times, reflecting the reality that the cost of serving customers varies over time and by location. When properly coordinated with advanced software, a DESS can resolve many of the issues that lead to high locational marginal prices and act as a part of the distribution grid itself rather than as a customer-centric addition.

The increasing capabilities of DESS software are beginning to blur the lines between distributed and large- or utility-scale energy storage systems. While a DESS is often designed only to generate cost savings for host customers, these systems may sit idle for long periods. Technically speaking, there are few constraints limiting the ability of distributed storage to provide the same services offered by utility-scale systems; doing so, however, requires the precise control and coordination of many individual systems. The ability to aggregate DESSs into a virtual power plant (VPP) using software is proving to be a major technological breakthrough in the industry.

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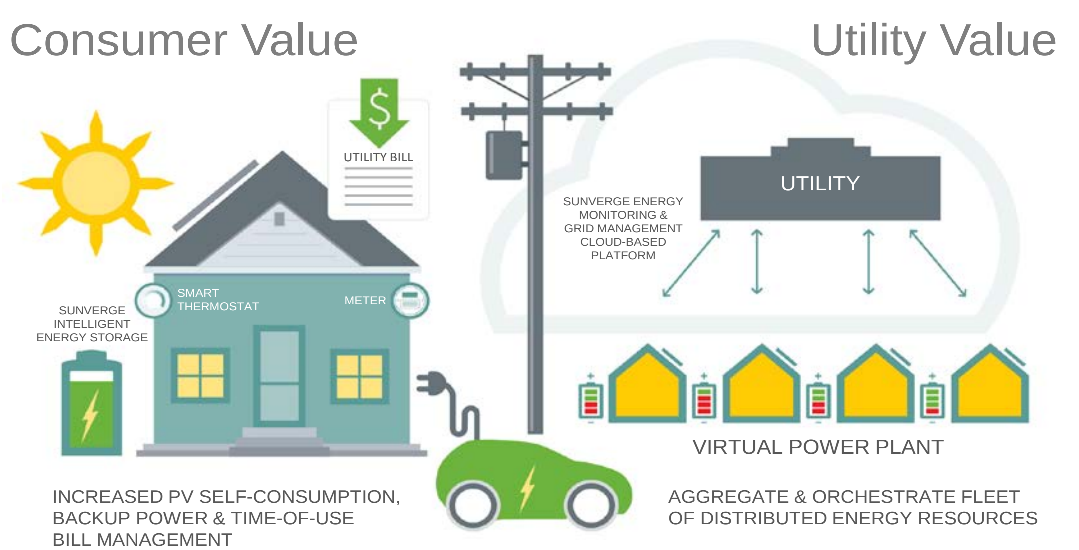
A VPP is a smart grid network that links retail markets to wholesale markets. The primary goal of a VPP is to maximize profitability for DER asset owners while maintaining the proper balance of the electricity grid at the lowest possible economic and environmental cost. Energy storage-enabled VPPs are being developed by both utilities and third parties. These VPPs allow owner-operators to monetize aggregated storage units, redistribute that revenue to individual owners, and quickly improve grid reliability. In essence, the energy storage-enabled VPP lets a utility add the flexibility of a power plant to its system without investing in a new physical plant. The capital costs are shared with end users and the benefits are transparently accrued by both customers and the utility (Figure 2.1).

Figure 2.1 The Coupling of Consumer and Utility Value via VPPs



(Source: Sunverge Energy, Inc.)

2.2 Differentiation in the Market

A number of companies are emerging as leaders in the rapidly growing market for DESS and DER optimization software, which in its most sophisticated form, can create a VPP. While many vendors offer similar platforms at this early stage in the VPP market, several key differentiating factors are becoming apparent, including:

- **Flexibility in platform services:** This flexibility includes the ability to provide multiple services depending on customer needs, including demand charge management, backup power, wind/solar integration, transmission and distribution (T&D) upgrade deferral, energy pricing arbitrage, frequency and voltage support, etc.

- **Offerings for multiple customer types:** These offerings include end-use storage customers (home and building owners), utilities, and channel partners, including solar PV providers.
- **Fleet aggregation capabilities:** Many of the valuable services provided by distributed storage require the ability to aggregate numerous systems virtually so that they can act as a single grid resource.
- **Data management and platform optimization:** Collecting and effectively using data to continually improve platforms is key—including data to analyze the performance of system components, analyze home/building load data, maximize the value of solar PV generation, and capitalize on changing rate structures. The value of data will only increase as DERs and the digitization of the grid continue to transform the power system.

Given the nascent stage of the VPP market, the level of experience of a vendor and the strength of its platform are major considerations for potential customers. Utilities looking to procure DER platforms will likely give preference to vendors offering solutions that are easy to use and integrate with existing grid systems. As many customers have limited experience with these solutions, leading platforms are often those that have pre-defined applications and grid scenarios, allowing utilities to deploy new services quickly so they can realize immediate benefits while they determine the optimal operating parameters for new DERs offering upstream value on their grids.

An important differentiator for leading platforms in this market, as noted above, is the ability to collect and use data comprehensively down to the individual device level, as the effective use of data can help utilities and other customers understand how to best utilize DERs. Valuable insights to improve both hardware and software platform performance can be gained from the various streams of data available. These may include battery and inverter performance, the interaction between hardware components in a system, building energy load profiles, solar PV generation profiles, and the overall impact of a system's operating parameters on customer energy costs and grid performance.

The effective collection and use of data can also allow vendors to expand their offerings to include other DERs and solutions for customers. Leading DER platforms that enable VPPs leverage all available data to create holistic home energy management solutions capable of minimizing customer bills whenever possible by coordinating systems, including thermostats, smart appliances, water heaters, and smart plugs. The effective optimization of all loads in a home along with solar PV generation, EV charging, and energy storage can provide substantial cost savings to customers and a reduction in overall grid peak demand.

Section 3
UTILITY CASE STUDIES

3.1 Introduction

Dozens of utilities have partnered with Sunverge and other platform providers to deploy pilot projects that integrate DERs—including energy storage—effectively into the grid. Navigant Research has described these projects as “mixed asset VPPs” by virtue of their ability to integrate generation, storage, and load into a single aggregated resource. The sum of the parts equates to better value for both asset owner and host utility. The following section highlights three utility VPP pilot projects, the goals and motivations of each, and how each utility sees the VPP market evolving.

3.2 Xcel Energy

Headquartered in Minneapolis, Minnesota, Xcel Energy services more than 3.3 million electricity and natural gas customers across eight states in the Midwest. The utility is a recognized industry leader in delivering renewable energy and reducing greenhouse gas (GHG) emissions. In Colorado, Xcel Energy established its Innovative Clean Technology (ICT) program in 2009, which enables the testing of emerging energy technologies that could lower GHG emissions and offer other environmental benefits. The ICT serves as a vehicle by which Xcel Energy can test new technologies and evaluate associated costs, reliability, and performance on a small scale before determining whether to deploy the technologies to its larger customer base.

Approved by the Colorado Public Utilities Commission under the ICT program, Xcel Energy announced in March 2016 that it would partner with Northern Reliability, Inc. (NRI) and Sunverge for its $4 million Stapleton Battery Storage project in Denver, Colorado. Customer demand for rooftop solar PV was increasing in the city, so the company wanted to examine how battery storage would facilitate higher concentrations of PV onto the Stapleton neighborhood’s distribution grid, creating a VPP that would provide bidirectional value. The company chose the Stapleton neighborhood because it has one of the highest concentrations of rooftop solar PV installations in the Denver metropolitan area; Xcel Energy sees the most promising opportunities for battery storage in areas with high PV penetration.

Xcel Energy’s primary goals are to:

- Increase the ability to accommodate more solar PV onto the local distribution grid
- Manage local grid issues such as voltage regulation and peak demand
- Assess the potential for battery storage systems to provide multiple benefits to the local and regional power grid

- Examine how to integrate battery systems with the grid effectively, especially in addressing communications and cybersecurity concerns for both customer and utility
- Understand costs, capabilities, and overall benefits

The Stapleton project includes six utility-scale batteries (two 18 kW batteries, two 36 kW batteries, and two 54 kW batteries, each with four hours of storage) placed in strategic locations along the distribution feeder system where reverse power flow occurs. Six additional battery units are to be installed at customer residences and begin operation in April 2017. The objective of deploying the battery systems in this manner is to mitigate the flicker and high voltage issues that a high penetration of solar PV (greater than 15 percent) causes on the grid.

NRI will be providing the large-scale batteries, while Sunverge will provide the home battery hardware and software. Participants will be able to keep the home battery system at no cost upon completion of the pilot. Xcel Energy plans to leverage Sunverge's cloud-based software platform so that it can aggregate the batteries to provide system benefits and operate each unit individually to address local grid issues. Xcel Energy expects to see how battery systems deployed within a VPP can mitigate the impacts of peak solar PV generation on the feeder. Deployed this way, the batteries could potentially increase the amount of solar energy the feeder can accommodate, while leveraging the advantage a VPP configuration can provide. The software helps mitigate local nodal issues that occur during periods of high renewable generation as well as rapid fluctuations in solar output than can occur throughout the day. Xcel Energy values the experience Sunverge brings in addressing these issues in diverse markets under different market conditions worldwide. In addition, Sunverge offers an intuitive dashboard, which makes it easier for customers to understand how the system is operating. Other benefits of the Stapleton project include providing backup power in the case of a grid outage and cost savings for customers.

As the project progresses, Xcel Energy anticipates learning about other grid service benefits the Sunverge VPP software can provide, which in the end could make the battery systems more cost-effective. For example, in addition to solar integration, backup power, and cost savings, battery systems could defer distribution grid upgrades for the utility while allowing customers to engage in energy cost arbitrage, lowering their monthly bills. Integrating behind-the-meter DERs with utility-scale energy storage allows Xcel Energy to understand how these resources integrated into a VPP can provide mutual benefits to the utility and customer alike. The Sunverge software's ability to optimize different VPP use cases will be an important component to monitor as this project continues.

3.3 AGL Energy

Energy retailer AGL is one of Australia's leading integrated energy companies and one of the largest owners, operators, and developers of renewable power generation in the country. The company's power generation portfolio includes base, peaking, and intermediate generation plants spread across traditional thermal generation and renewable sources such as pumped hydro, wind, landfill gas, biomass, and solar. With a service territory running through Queensland, New South Wales, Victoria, and South Australia, AGL services more than 3.7 million customers.

Partnering with the federal government's Australian Renewable Energy Agency (ARENA) and Sunverge, AGL launched what will be the largest residential VPP pilot project in the world in December 2016, dubbed Power in Numbers. Operating in Adelaide, South Australia, Sunverge's cloud-connected software will aggregate storage units to operate in unison, helping participants leverage their locally generated rooftop solar and provide grid stability. In a power market subject to intense retail competition, AGL benefits from offering customers an intelligent energy storage solution. The assets that underpin this VPP serve as an impactful, long-term investment that improves customer engagement. This will benefit both the customer and broader community to manage peak electricity demand and, perhaps more importantly, demonstrate an ability to utilize DER for resolving network constraints in transmission and distribution assets.

With a total cost of approximately AUS $20 million, AGL sees this project as central to its strategy of being a manager of DER while leveraging its investment in Sunverge[3], helping to improve the customer experience and enable long-term success in the VPP space. Major objectives of this pilot project include:

- Demonstrating an ability to ease capacity constraints on local South Australian networks by displacing conventional fossil fuel generation
- Participating in wholesale markets, leveraging local capacity and electricity network data
- Providing AGL customers with an innovative solution that autonomously optimizes clean energy for their homes
- Demonstrating how relationships between electricity networks, retailers, consumers, and the market operator can create new sources of value and stability in a renewable energy future

The Power in Numbers project is being rolled out in three phases over a period of 18 months. In phase one, which was finished in mid-December 2016, 150 qualifying customers in metropolitan Adelaide purchased the 5 kW/7.7 kWh Sunverge system for AUS $3,500; this includes hardware, software, and installation costs. AGL estimates the

[3] Energy Storage Leader Sunverge Energy Closes $36.5 Million Series C Funding, February 9, 2016. http://www.sunverge.com/energy-storage-leader-sunverge-energy-closes-36-5-million-series-c-funding/

expected payback time for this system to be approximately 7 years. Phases two and three will see a similar offering to narrower zones within metropolitan Adelaide; 350 eligible customers will be able to purchase a 6.5 kW/11.6 kWh battery system for AUS $3,849. Collectively, the VPP will aggregate 7+ MWh of total energy capacity across 1,000 controllable DER assets.

The company cites that virtual aggregation of DERs is crucial to the evolution of utilities over the next several years and foresees several benefits embedded within the VPP model, including its ability to:

- Reserve stored energy across a portfolio of DERs and bid power into wholesale markets
- Gain market share by providing customers with choice, savings, and backup power
- Track sub-minute fluctuations in system load and correct for unintended changes in generator output
- Reduce the need for investment in T&D infrastructure

Through the software aggregation platform, AGL can provide coordinated energy dispatch for market-driven energy supply. Recent testing shows that using a VPP aggregation platform such as Sunverge's allows a utility to dispatch reliable power on a moment's notice to portions of the grid experiencing locational issues. Furthermore, the utility can determine on a moment-by-moment basis if the energy available through the VPP should be bid into wholesale markets or used locally. Reviewing historical market prices can help identify expected durations and time periods for price-driven market dispatches and further testing for different durations, hours of the day, and times of the year will help characterize typical availability. This type of opportunity is a key value proposition for DER aggregation platforms such as VPPs, which can greatly improve the value of individual behind-the-meter systems on the grid.

Important considerations when choosing Sunverge for this project were: full visibility, control and the ability to stack benefits across the electricity market value chain. AGL vets potential customers of this pilot to estimate solar generation is sufficient to earn cost savings over the duration of the pilot, emphasizing that system location is a critical component in achieving these savings.

3.4 Alectra Utilities (formerly PowerStream)

Alectra is the second largest municipally owned local electricity distribution company in North America. In January 2017, PowerStream merged with Horizon Utilities and Enersource and now serves nearly one million customers throughout its service territory with more than one thousand employees. By 2020, Alectra plans to build on its core electricity distribution business to become Ontario's premier integrated energy services provider.

Alectra's residential solar plus storage pilot project, dubbed POWER.HOUSE, was partially funded by the Independent Electricity Supplier Operator (IESO) in Ontario. The goal of this pilot was to successfully deploy residential solar plus storage systems in 20 homes within Alectra's service territory. With Robertson Bright as the installation partner, each home was equipped with a 5 kW solar array and a 6.8 kW/11.6 kWh battery with Sunverge's energy management platform. Though the system is utility-owned and -operated, the customer can monitor the system and other loads in real-time with a web app downloadable via smartphone. The aggregation of DERs will essentially allow each home "nanogrid" to be part of a VPP. Key objectives of POWER.HOUSE are to:

- Determine which business model best fits this type of system (e.g., utility vs. customer-owned, optimal financing models)
- Tailor internal and external processes to support business model implementation
- Evaluate how the VPP for residential solar plus storage technology works on Canadian grounds
- Balance customer benefits (such as bill reduction and resilience) with system benefits (such as capital deferral, congestion management, and other ancillary services)

Alectra presents a three-pronged value proposition to POWER.HOUSE participants: save money on electricity bills by way of peak load reduction, receive protection against outages, and generate renewable power locally. From the utility's perspective, the POWER.HOUSE project is designed to reduce load on select parts of the distribution network during peak periods, resulting in the ability to defer distribution grid upgrades. An additional benefit leveraged from this project is to gain a better understanding of how best to allow greater amounts of solar PV to be effectively integrated on a feeder by virtue of VPP innovation.

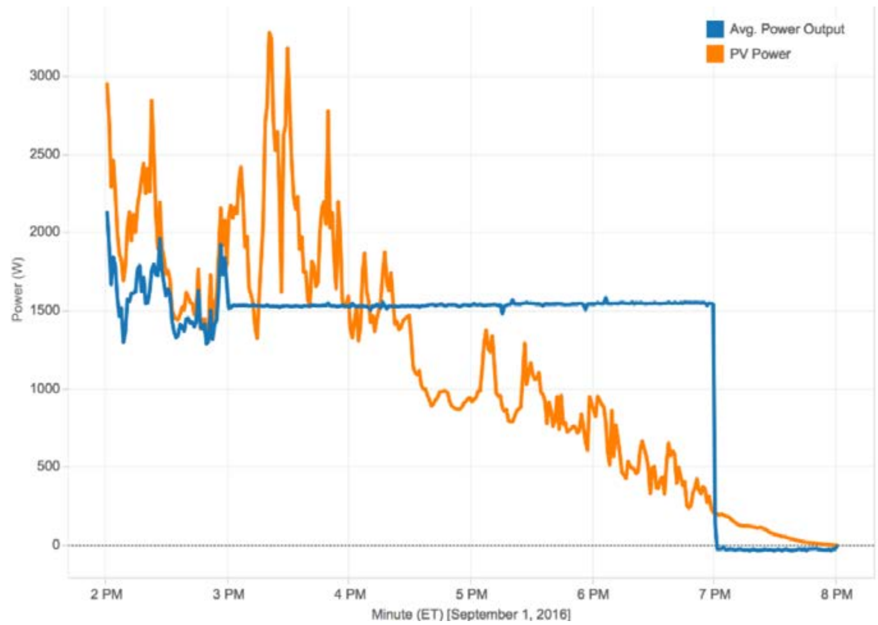
For the purposes of the pilot, a utility-owned asset model was evaluated. The pilot offering required the customer to pay an upfront fee of $3,500 for installation and thereafter, a monthly service fee of $20 over a five-year contract. Alectra reserves 50 percent of the battery for customer outage protection, while the remaining 50 percent is available for use by the utility. The company estimates that the system will reduce electricity bills by an average of $100 per month and provides a performance guarantee that ensures customers will recover the equivalent of their initial investment ($3,500+taxes) in the form of energy savings over the duration of the contract. If not, Alectra will pay the difference.

Though the POWER.HOUSE project is still underway, Alectra has already drawn several insights and important conclusions. Perhaps the most critical aspect of this project is the functionality of the software and its ability to sense and react to changing external conditions so that it can deliver a wide variety of energy services. The ability to adapt, change, and provide situational awareness is a key benefit. Alectra found that algorithms programmed to autonomously control loads and maximize the benefits of storage amid high solar production levels are important when defining the business case of VPPs. Likewise, strategic placement of these solar PV nanogrid systems in areas with high penetrations of renewable generation positions Sunverge's VPP software to offer additional value streams. Among these value streams are ancillary services that can be created by the cooptimization of assets, a fundamental value proposition attached to the VPP concept. Other key findings of the project thus far include using a fleet of systems to test a variety of value streams:

- **Net metering:** Successfully implemented Ontario's first net metering on a time-of-use (TOU) billing structure, providing a blueprint for future adoption throughout the territory
- **Insurance:** Created an awareness in the insurance industry of new ownership models for behind-the-meter renewable generating assets and identified key insurers that would be willing to take on new projects
- **Permitting:** Educated municipal planning departments, helping them establish new precedents and protocols
- **Site inspection:** Established best practices to accelerate installation and improve home qualification

For Alectra, the VPP is a flexible resource that can be controlled and aggregated to defer the need to upgrade transmission and distribution assets, while alleviating solar intermittency and back feeding issues. Discrete and aggregated data delivered to the utility improves the operation of the grid, maximizing power quality and minimizing power losses. The result is improved stability despite the growing number of PV systems. While system stability has been a major benefit of the program, the project's most important advance is gaining a better understanding of how coordinating DERs via the VPP platform can deliver a viable ROI by stacking a long list of value streams on top of each other. These value streams range from deferral on additional grid infrastructure investment to new sources of ancillary services. Despite being a small pilot program (20 homes), the POWER.HOUSE program has already saved customers collectively $13,476 and displaced 37,522 kWh of energy since last April. Figure 3.1 below illustrates the operation of the Sunverge battery network to provide firm capacity that can be used for demand response, as well as to mitigate the steep ramp down of solar PV production in the late afternoon, or to offset peak demand.

Figure 3.1 Demand Response Event, Alectra Utilities



(Source: Sunverge Energy, Inc.)

Section 4
DISTRIBUTED ENERGY RESOURCE VALUE AND CHALLENGES

4.1 Key Factors for the Locational Value of DER

DERs represent a transformational force for the power grid that will require an unprecedented level of planning and coordination among various stakeholders. While a number of elements dictate the value and challenges for DERs on the grid, physical location is likely the most important single factor. The following sections explore the specific factors that will determine the value of DER in a given location, the challenges facing greater DER deployment, and what will be needed to overcome these challenges for utilities and grid operators to realize maximum value.

4.1.1 Energy Cost Savings

DERs, particularly distributed energy storage, can allow utilities to take advantage of changing rates for wholesale energy to reduce overall costs, which are then passed onto ratepayers. The primary ways that distributed energy storage can be used by utilities to reduce costs are 1) lowering the overall peak load and associated demand or T&D network charges and 2) relying on stored energy rather than power purchases or imports when wholesale prices are highest. The specific opportunities for using storage and other DERs to reduce overall energy costs depend on several factors, including energy market structure, utility business models, and both wholesale energy and peak power rates.

Energy cost saving opportunities will be most lucrative for utilities in deregulated markets or cooperative and municipally owned power providers. These utilities often own limited generation assets themselves and therefore rely on wholesale electricity imports to provide the majority of their energy—so they are forced to pay higher prices when wholesale rates spike. Many of these smaller utilities must also pay a fixed rate based on their peak load and contribution to the overall peak capacity required by a regional system operator. Such charges can represent a significant expense for utilities and are already a target for energy efficiency, demand-side management, and energy storage initiatives. By using energy storage to reduce both high-priced energy imports and overall system peak demand, utilities can realize significant savings that can be passed onto customers. To effectively capitalize on these savings, grid operators must have a sophisticated software platform capable of monitoring and predicting both wholesale prices and grid usage and conditions to coordinate the operation of a large number of distributed systems for maximum savings.

4.1.2 Asset Upgrade/Investment Deferral

One of the primary potential benefits of energy storage and other DERs is the ability to defer or entirely avoid the need to upgrade existing grid infrastructure. This use for energy storage is driven by the fact that grid infrastructure is built to accommodate the maximum possible demand in a given area, although that level of demand may be approached only a few times per year, if ever. As electricity demand has grown over time, many grid assets, such as substations and T&D lines, are approaching their maximum capacity at times of peak demand. By coordinating the operation of DESSs during peak demand, the total capacity required at a given substation or power line can be greatly reduced and the need to upgrade or replace that asset can be avoided.

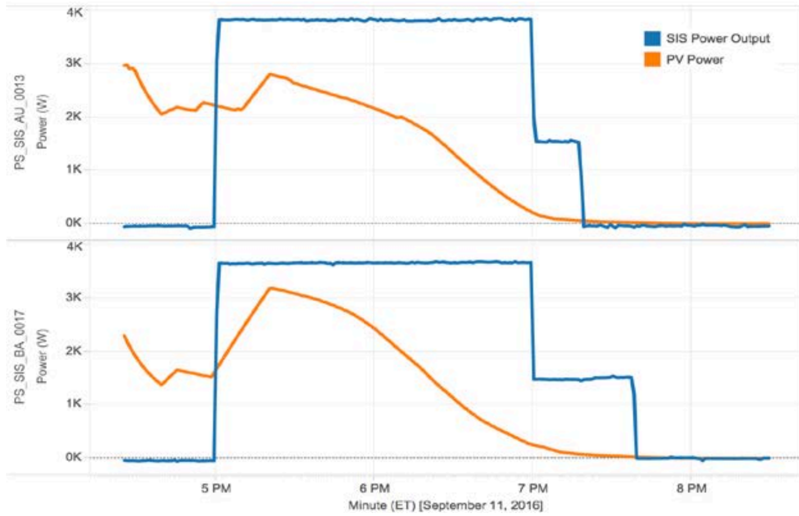
The ability to use energy storage to provide this service is dictated by locational factors such as the existing capacity of grid assets, local load growth, and the cost for infrastructure upgrades. Because peak load may rarely occur in a given area, storage may be required to provide this service only a few times per year. As a result, the ability to defer grid infrastructure upgrades is typically only one of a number of services that distributed energy storage will provide to utilities. However, as with most factors dictating the value of DERs, this service is highly location-dependent. Areas with older grid infrastructure, rapidly growing electricity demand, and more congested grids may be able to use storage for this purpose on a much more regular basis.

4.1.3 DG Integration

The increasing amounts of variable renewable generation—primarily solar PV and wind—are causing challenges to grid operators, as changing conditions can lead to dramatic swings in the amount of energy and voltage being fed onto the grid. These issues are particularly acute on the distribution grid, where growth in rooftop solar PV installations has resulted in utilities being forced to upgrade distribution infrastructure and in some cases entirely stop the installation of new PV systems. For many grid operators, distributed energy storage is an ideal solution to the challenges of distributed solar PV on the grid. Energy storage can facilitate the effective integration of DG in two primary ways: output smoothing/ramp control and energy time shifting.

Smoothing and ramp control refers to a relatively short duration application for energy storage that is used to control the output of variable generation. Smoothing helps ensure a stable output from a renewable plant if clouds pass overhead or wind speed changes; it protects grid infrastructure from damage due to fluctuations in voltage or energy output. Ramping refers to the controlled, measured reduction or increase in the output from a renewable plant while other generation sources can be brought on- or off-line to meet demand. Figure 4.1 illustrates the operation of an energy storage system used to provide solar smoothing and ramp control by mitigating the effects of changes in output throughout the day and reducing output when the sun goes down in a measured and predictable way.

Figure 4.1 PV Firming: Dispatch to Mitigate End of Day Ramp



(Source: Sunverge Energy, Inc. Data from actual utility customer)

Renewable energy time shifting refers to a longer duration application where several hours of energy is shifted to align with times of greatest overall grid demand. Time shifting solar PV is an increasingly attractive application for energy storage as peak solar production occurs midday, while in many areas, overall grid demand peaks in the evening. This has been an important focus of many utility-led DER programs to date. Properly coordinated, distributed storage and other DERs can absorb excess solar PV during the day to mitigate reverse power flows and align production with peak demand.

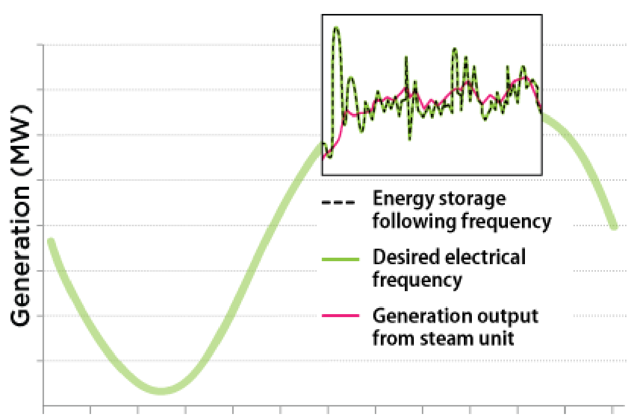
The ability of energy storage to facilitate the integration of distributed renewable generation is a key factor in determining the locational value of these systems and other DERs. Utilities in regions experiencing high levels of distributed solar PV penetration have recognized the growing value of DERs to ensure the stability of their grids as increasing amounts of DG continue to be added. Unlike large conventional generators and other grid infrastructure, DERs allow utilities to target the specific areas of the grid experiencing issues with DG integration in a scalable and cost-effective way. For fully capturing these benefits, however, a software platform capable of managing not only the status and operation of individual and aggregated DERs, but also the expected output of renewable generation, real-time grid conditions, and electricity prices is imperative. Efforts are underway by utilities and regulators working to quantify the value of DG integration to develop frameworks that can guide compensation for these services.

One issue currently limiting the adoption of energy storage and other DERs is the compensation structures for DG, specifically rooftop solar PV. Because most customers are still guaranteed compensation at or near retail rates for any excess solar PV through net metering or feed-in-tariffs, there is a disincentive to invest in energy storage or other technologies that can maximize DG self-consumption. As compensation rates through these programs are reduced or eliminated entirely, energy storage will emerge as an economical investment for PV system owners. However, customers need certainty that these technologies are working on their behalf and saving them the most money possible. While solar PV support programs have successfully driven the growing PV industry, they have not resulted in the most efficient deployments from a grid-integration perspective. To fully realize the maximum value of onsite solar PV and other DERs for both customers and utilities as rate structures evolve, utilizing advanced software platforms capable of evaluating changing rate structures to optimize storage system operation is important.

4.1.4 Grid Stability and Resiliency

The ability to respond to signals that help maintain grid stability rapidly and accurately is a key advantage for energy storage and other DERs. Compared to the relatively slow response of large conventional fossil fuel generators, energy storage and DERs can respond to changing grid conditions almost instantaneously. DERs can provide two primary services to improve the stability and resilience of the grid: voltage support and frequency regulation. Voltage support is used for managing reactive power to hold the grid's voltage at acceptable ranges given the operating conditions it is likely to face. Frequency regulation balances the fluctuations between electricity generation and electrical load, manages the variability in the grid's frequency, and maintains the frequency of the current on power lines within safe ranges by pulsing large bursts of power on and off the grid. Figure 4.2 shows the signal from an energy storage unit matching the desired electrical frequency of the system when conventional generator output follows a different (less accurate) response pattern.

Figure 4.2 Depiction of Frequency Regulation



(Source: PJM Interconnection)

Traditionally, conventional generators have provided frequency regulation, voltage support, and other ancillary services as a requirement of their contracts with utilities. The current falling costs for DERs, combined with the ability to respond to grid disturbances more quickly and accurately, is leading to competition for the provision of these ancillary services in many markets. As the penetration of variable renewable power generation increases, the grid is requiring greater levels of frequency and voltage support to ensure that rapid changes in generation output do not adversely affect the grid's stability. This dynamic is particularly prevalent on distribution circuits where increasing rooftop solar PV deployments are challenging stability. Many solar PV integration issues are due to over-generation during daytime hours that can cause voltage spikes and sags as PV output changes, potentially damaging or tripping other grid equipment offline.

> Compared to large, centralized generators, DERs can provide a more effective source of frequency and voltage support directly on distribution circuits and address issues before they affect other parts of the grid.

Compared to large, centralized generators, DERs can provide a more effective source of frequency and voltage support directly on distribution circuits where issues arise before spreading to other parts of the grid. These benefits of DERs can be magnified through the use of advanced software capable of responding to grid signals by dispatching aggregated DER almost instantaneously.

4.1.5 New Products and Services

At a time when the falling costs and growing sophistication of DERs are challenging incumbent business models and revenue streams for utilities and electricity retailers, the ability to offer customers new products and services may be key to future profitability of many utilities. This is a particular challenge for electricity providers in deregulated markets where retailers have few ways to differentiate from their competitors in the eyes of customers.

Though seen by many as a threat to existing utilities and energy retailers, DER technologies can also represent new products and services to offer customers in increasingly competitive markets. Working with DER vendors to offer solar PV, energy storage, and other technologies that customers are beginning to purchase on their own provides numerous benefits to utilities. A primary motivation for many of these utilities is to achieve greater levels of customer engagement and differentiation from competitors by offering the cutting-edge technologies that customers want at a lower cost. By deploying DERs on their own terms, utilities can also ensure that these systems are operated for the benefit of the overall grid in addition to reducing costs for customers.

Utilities are also able to use their fleets of aggregated DERs at customer sites to provide frequency regulation, reduce high-priced wholesale energy purchases, offer resilience and backup power as a service to customers, and facilitate greater levels of renewable energy integration. Utility-led DER deployments may prove more efficient and cost-effective as they are uniquely positioned to integrate DERs into billing and other backend operations. Furthermore, utilities benefit from easy access to customers and high brand recognition and confidence, which can help customers overcome concerns regarding the reliability of these new technologies.

4.2 DER Challenges

While DER deployments have increased considerably over the past several years, significant challenges remain in facing these technologies, many of which stem from the major differences in the needs and circumstances of DER customers, including both utilities and electricity consumers. These differences challenge DER providers to develop standard products and solutions that will apply to customers across numerous markets.

4.2.1 Regional Differences

To date, most DER deployments have taken place in select locations with the right conditions to make these systems an economical investment for both utilities and electricity customers. These markets are laying the foundation for a future grid that is much more reliant on DER. However, looking across different regions, countries, and even utility service territories, major differences in tariff/rate structures, utility business models, and grid conditions will affect the economics of DERs, making it difficult for vendors to translate success in one market to another.

One of the major obstacles facing DER growth is the wide variation in utility rate and tariff structures between different markets, even within a single state or province. Rate structures dictate the ROI of DERs to customers; in particular, the rates for demand charges, TOU pricing variations, feed-in tariffs/net metering, and overall electricity prices have a major impact on the economics of a DER installation. As the ideal conditions for many DERs exist only in select locations, widespread deployment across entire countries has been limited. However, recent policy updates around the country are shifting in favor of energy storage. According to the National Regulatory Research Institute (NRRI), 17 states are currently reviewing changes to net metering programs.[4] These changes may follow net metering updates recently enacted in Nevada and Hawaii that could reduce the compensation paid to solar PV owners and greatly improve the economics of behind-the-meter energy storage.

In addition to rate structures, the electricity market and utility regulations in a given area dictate the viability and business models for deploying DERs. For example, in deregulated electricity markets, utilities may be able to partner with vendors to offer DERs directly to

[4] National Regulatory Research Institute, *15-08 Rate Design for DER*, October 5, 2015.

customers, lowering overall costs for deployments and helping foster market growth. On the other hand, many vertically integrated and regulated utilities are not able to own generation assets, including DERs, and may be prohibited from exploring new technologies without regulatory approval. Numerous other types of regulatory and market structures dictate the level of involvement utilities can have in the DER space, further complicating vendor efforts to develop standard solutions.

The variations in rate structures, regulations, and utility business models across markets makes software critical for the effective integration of DERs. An essential characteristic of DER management software is its ability to process evolving rate structures and regulations specific for each market and determine how to optimize system performance to maximize value for customers and the grid.

4.2.2 Supporting Key Infrastructure

The opportunities for DERs to support key grid infrastructure and avoid the need for new investments also varies widely in different markets. Electricity distribution networks have distinct architectures that may influence how DERs are accommodated and utilized, including the number of customers per circuit, the distance between customers, DG penetration, peak demand, and load growth. These factors and their variation from one area to another make the impact of DERs difficult to generalize. Factors such as the age and condition of grid infrastructure, load growth, solar PV penetration rates, and overall grid stability dictate the ability of DERs to support infrastructure.

As these factors vary considerably even across a single utility's service territory, saying that any one-size-fits-all approach will work across different utilities or different circuits is difficult. Although the integration of DERs in certain situations can help support grid infrastructure, many DER technologies introduce new issues and challenges for the grid. This is particularly true for variable generation resources such as solar PV. While battery storage and other DERs can provide value and support for grid infrastructure, they are often made necessary only by the introduction of solar PV and other technologies onto the grid.

Furthermore, the operation of DERs often does not align with grid needs and cannot be coordinated with the level of reliability that grid operators require. To replace distribution assets effectively, DERs must achieve equivalent characteristics of availability, dependability, and durability compared to conventional systems. New DERs must also be able to integrate with existing utility systems effectively from a technical and operational perspective. Issues such as interoperability with existing assets and management systems, as well as flexibility and cybersecurity, are key considerations for utilities looking into DER integration.

This dynamic highlights the importance of sophisticated software that can effectively coordinate the operation of a variety of DERs to reliably perform the same services that grid operators expect from conventional assets. Given the core focus on ensuring safe and reliable service for all customers, utilities are often hesitant to integrate new technologies that are out of sync with their existing assets and systems. Therefore, it is critical for software vendors to develop platforms capable of integrating DERs with existing utility systems in a way that supports legacy infrastructure and fits with how the grid is typically managed.

4.2.3 Balancing Customer and Grid Needs

Perhaps the most transparent issue facing DER integration is the fact that the needs and desires of customers installing DERs often do not align with the needs of the grid. Many of the customers involved in the three utility DER projects outlined in this paper were motivated primarily by the potential for energy cost savings, resilience of supply, and the desire to use clean energy. For example, many customers installing DESSs do so in order to reduce their peak power consumption and associated demand charges. However, the peak demand for a given customer may not align with the overall grid demand. A commercial building's load commonly peaks in the early afternoon, while overall grid demand may not occur until the evening. As a result, these systems do not provide the type of grid support that utilities are looking for in order to defer infrastructure upgrades and investments.

Given the focus on customer cost savings, when modeling the locational value and impacts of DERs, the underlying assumption is that customers install and operate systems to realize private benefits. Therefore, their total capacity to provide grid support is not as reliable as a traditional asset's would be. To realize the maximum benefits of DERs on the grid, utilities must have the proper coordination and management software platforms to ensure that all potential grid support can be derived from DERs while constrained by the need to provide customer benefits first.

Section 5
CONCLUSION

5.1 Conclusions and Recommendations

DER technologies hold significant potential to transform and modernize the electrical grid for greater efficiency and resilience while reducing emissions by facilitating the integration of renewable generation. Despite the potential, several challenges facing the growth of DERs must be recognized and overcome for the transformational potential of these technologies to be realized. The specific challenges facing DERs and the value of these systems are based on a number of factors explored throughout this study and will vary around the world based on specific local considerations.

Globally, select utilities have begun exploring opportunities for optimally integrating DERs through a variety of programs. These utilities are paving the way for new solutions and have learned valuable lessons that all stakeholders should consider. Following are some of the key best practices highlighted by the utilities profiled in this report:

- **Ensure project specifications are well defined and planned:** This helps ensure that the best vendors and pricing are selected given the wide range of available solutions.
- **Plan to identify and implement lessons:** As many programs will be the first attempt at establishing new solutions and processes, it is important that these programs be designed to identify challenges and evolve the program.
- **Have pilots reflect full-scale market offerings:** Rather than pitching programs to customers solely as a pilot program, create participation agreements and establish revenue streams and payback targets.
- **Establish company-wide engagement:** DER integration will likely touch on many, if not all, verticals within a utility.

Although these early DER integration efforts, which are setting the stage for a burgeoning VPP market, offer many lessons and best practices, no one-size-fits-all approach to DER integration will emerge, given the wide range of factors influencing market dynamics. Vendors must be flexible in their technical offerings and business models to ensure they can capitalize on all available opportunities and evolve with the changing industry. As this industry advances, software platforms are likely to emerge as the key to overcoming the challenges facing DERs and unlocking the maximum value of these technologies. Software that allows for the centralized management and control of these resources, allowing them to act similarly to traditional grid systems while balancing the needs of customers and the grid, will be critical to the market's successful growth.

Section 6
ACRONYM AND ABBREVIATION LIST

ARENA .... Australian Renewable Energy Agency

AUS $ .... Australian Dollar

C&I .... Commercial & Industrial

DER .... Distributed Energy Resource

DESS .... Distributed Energy Storage System

DG .... Distributed Generation

DR .... Demand Response

GHG .... Greenhouse Gas

ICT .... Innovative Clean Technology

IESO .... Megawatt

kW .... Kilowatt

kWh .... Kilowatt-Hour

MW .... Megawatt

MWh .... Megawatt-Hour

NRI .... Northern Reliability, Inc.

PV .... Photovoltaic

ROI .... Return on Investment

T&D .... Transmission & Distribution

TOU .... Time-of-Use Electricity Pricing

VPP .... Virtual Power Plant

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Section 9

SCOPE OF STUDY

This white paper examines the current market dynamics for the DER and DESS markets. This paper draws upon Navigant Research studies of distributed energy storage and DER deployments, in addition to interviews with select utilities and vendors that have explored DER integration platforms through pilots and other programs. The goal of this white paper is to clarify the factors that determine the locational value and challenges facing DER deployment and present an objective analysis of the key considerations for customers and vendors in the market.

SOURCES AND METHODOLOGY

Navigant Research's industry analysts utilize a variety of research sources in preparing Research Reports. The key component of Navigant Research's analysis is primary research gained from phone and in-person interviews with industry leaders including executives, engineers, and marketing professionals. Analysts are diligent in ensuring that they speak with representatives from every part of the value chain, including but not limited to technology companies, utilities and other service providers, industry associations, government agencies, and the investment community.

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NOTES

CAGR refers to compound average annual growth rate, using the formula:

CAGR = (End Year Value ÷ Start Year Value)$^{(1/steps)}$ – 1.

CAGRs presented in the tables are for the entire timeframe in the title. Where data for fewer years are given, the CAGR is for the range presented. Where relevant, CAGRs for shorter timeframes may be given as well.

Figures are based on the best estimates available at the time of calculation. Annual revenues, shipments, and sales are based on end-of-year figures unless otherwise noted. All values are expressed in year 2017 US dollars unless otherwise noted. Percentages may not add up to 100 due to rounding.

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