White Paper:

Transforming Today's Energy Grid—

How specialized design, integration and supply chain expertise are the key success factors for the grid of the future

Introduction

Electric grids are evolving rapidly, disrupted by deregulation, distributed energy resources, renewable portfolio standards, smart grid technologies, and more. Energy storage is uniquely positioned at the heart of all of this change. Unlike any other asset on the grid, energy storage can play multiple roles, acting as both load and capacity depending on whether it is absorbing excess generation or feeding back into the grid. Add to that its ability to react near-instantly, and energy storage can help utilities and customers smooth the integration of new assets, enabling the grid to emerge more stable and responsive.

Energy storage's flexibility and improving economics have driven demand for this new asset class. To guide customers through their first energy storage purchases, energy storage companies are trying to demystify energy storage systems. While it's important to simplify the purchasing process for utilities and commercial and industrial-scale users, it's also critical to ensure that the energy storage solution offered takes full account of the range of use cases desired and grid conditions faced by the customer. For the customer, whether a utility, developer, or commercial or industrial end user, this means that finding the right energy storage partner is more akin to hiring a systems integrator than simply choosing a vendor.

This white paper will explore three critical skills for rapid and successful deployment of turnkey energy storage systems and implementation:

1. Expertise in designing a system of systems
2. Experience in integrating a flexible software platform
3. Excellence in managing the supply chain

With all three skills in place, an energy storage vendor can not only tailor the best solution for a customer's need today and in the future, but also deploy energy storage rapidly.

1. Designing a System of Systems

Before looking at how energy storage is designed and implemented, it’s important to understand why integrating energy storage into the grid is more challenging than integrating other grid assets, such as a solar farm or peaker plant. Energy storage is, arguably, the most complex asset in a grid. The ultimate pinch-hitter, it can provide a wide range of grid services, whether installed before or behind the meter. For commercial or industrial customers, energy storage can provide load shifting, peak shaving, demand response, emergency backup, and more. For utilities, its use cases range from providing voltage regulation to acting as spinning reserves, as illustrated by SEPA’s table below.

TECHNOLOGIES	ENERGY	GENERATING CAPACITY	DISTRIBUTION CAPACITY	VOLTAGE REGULATION	FREQUENCY REGULATION	LOAD FOLLOWING	BALANCING	SPINNING RESERVES	NON-SPINNING RESERVES	BLACKSTART
DISTRIBUTED SOLAR	Energy Generator	◑	◑	●	●	●	●	No	No	No
DISTRIBUTED SOLAR + ADVANCED INVERTER FUNCTIONALITY	Energy Generator	◑	◑	⊙	⊙	◑	●	No	No	No
BATTERY STORAGE	Energy Storage	⊙	⊙	⊙	⊙	⊙	⊙	Yes	Yes	Yes
INTERRUPTIBLE LOAD	Load Shaping	◐	●	●	●	●	⊙	Yes	Yes	No
DIRECT LOAD CONTROL	Load Shaping	◐	◐	●	◐	⊙	⊙	Yes	Yes	No
BEHAVIORAL LOAD SHAPING	Load Shaping	◑	◑	●	●	◑	◑	No	No	No
ENERGY EFFICIENCY	Reduce Load	◐	◑	●	●	●	●	No	No	No

● Unsuitable for reliably performing the specified service.

◑ May be able to perform a service, but is not well suited or can provide partial support.

◐ Able to perform a service, but may be limited by factors such as availability or customer behavior.

⊙ Well suited to perform a service; may exceed legacy technologies for providing the service.

This Smart Electric Power Alliance table from its October 2016 “Distributed Energy Resources Guide” shows that storage is well suited to provide a wide variety of critical grid support services.

For energy storage to successfully offer some or all of this wide range of services, it must operate as a fully integrated part of the grid. This requires sophisticated integration of a multi-tiered set of technologies that need to be orchestrated to function effectively throughout the system's lifetime. The energy storage system consists of hardware (battery cells, cooling and fire suppression systems, containers, and inverters or power conditioners), software, and the wider energy ecosystem it operates in. Each system within the storage system has to not only work with the other systems, but also work as a single system in concert with the grid.

For energy storage customers, that means that it is critical to find a partner with the ability to model the range of services that your energy storage system will need to provide. Why? Because modeling drives the design of the system and choice of components. Without detailed modeling driving the design of the complex system of systems, the following challenges arise:

- Poor economic and technical rationale for project investment
- Lack of trade-off analysis through the life of the system
- Lack of long-term strategy and comprehensive set of considerations and goals

Whether the resulting recommendation is for a plug-and-play system or a fully customized system, the initial design and modeling process is critical. This complex modeling determines what the system should look like, how the components will work together, and how it will deliver benefits to and make money for the end customer.

Designing for Safety

Energy storage is only as strong as its weakest link. If any component part has a bad day—the batteries, the inverters, a fan in a pack of batteries, the HVAC system, the fire suppression system—there's risk not only to the hardware but also to the system's long-term return on investment. A bad day can happen during the earliest stage of deployment or at any time during the life of system spanning five to ten years or more.

Ensuring long-term safety requires a tradeoff analysis looking at a multitude of battery technologies: lithium-based chemistries, flow batteries, sodium sulfur batteries, as well as new battery innovations. Depending on the use case, it may be appropriate to spend more on a battery that increases system cost but improves performance. Through modeling, an energy storage system supplier can analyze those tradeoffs so companies, independent power producers and utilities make the best possible choice. The common denominator across these battery chemistry alternatives for energy storage is safety.

Safety should play a critical role throughout both the build cycle and the ongoing operation of an energy storage system. When the system supplier selects battery and power conditioning system (PCS) vendors, it's important to consider not only the battery's and inverter's technical characteristics, such as cycle life and efficiency, but also their bankability. If you have to call upon the warranty during the operational life of the system, you must be sure the supplier has a healthy balance sheet to stand the test of time. This is significant as energy storage projects—whether small pilots or large bankable projects—are analyzed much like power purchase agreements for solar and wind farms. Due diligence can cover the safety track record not only in manufacturing but also in actual utilization of batteries for use cases that are similar to energy storage use cases. After selecting the batteries and inverters, the system supplier can perform testing to make sure all components meet factory specifications relative to their intended use case. Even when modeling results in the recommendation of a plug-and-play energy storage solution, it's important to know that the vendor has done this testing during the system's design.

Designing for Security

In large grid-scale projects and behind-the-meter deployments, build and quality are critical for system performance as well as actual functioning of transmission and distribution networks. At the communication layer, energy storage system software not only orchestrates data flow between potentially thousands of distributed energy resources, but also must protect against cybersecurity threats. According to cybersecurity analyst FireEye iSIGHT Intelligence, there have been 1,552 industrial control system vulnerability disclosures since 2000. The vast majority of them have occurred in the last six years. While physical security enhancements like fences and surveillance cameras are absolutely necessary to safeguard the grid, hackers are principally interested in data, not hardware. Hackers will exploit the weakest link in the chain of communications at any point between the network operation center and the end customer. Thus, it's incumbent on the energy storage system to help protect the grid against intentional disruption.

Case Study: Designing a System for PJM's Ancillary Services Market

The importance of modeling the system of systems can be illustrated with a real world example. In 2015, Greensmith Energy deployed an 18 MW energy storage system that needed to respond to frequency excursions at the site of a large-scale wind energy facility in western Pennsylvania, providing stability to the PJM transmission system.

To qualify for the PJM ancillary services market, the project had to pass three tests, continually responding to regulation signals every two seconds for an extended time. PJM scored projects based on precision and accuracy, approving those with a performance score of 75 percent. By modeling the project in the design phase, and by understanding the ecosystem—the grid conditions—in which the energy storage system would operate, Greensmith qualified on the first try with an average score of 97 percent.

Greensmith delivered the project in five and a half months despite significant challenges. Equipment had to meet stringent permitting requirements and pass through narrow access roads, under low bridges, and across mountainous terrain. After construction, the regional transmission organization and the electric service provider placed an initial operating limit of 2 MW on the project. The flexibility of the Greensmith's GEMS software platform enabled the project to immediately enter the market at a 2 MW capacity and expand later.

2. Integrating a Flexible Software Platform

Thinking of energy storage as a system of systems it becomes clear that the foundation of the system is software, and the right software can singlehandedly make the difference between a positive and negative return on investment for the system owner. Energy storage software is composed of a complex architecture with three functions: a control layer that integrates the various sub-systems or components such as the batteries, inverters, and cooling systems, a logic layer that yields multiple workflows so that the energy storage system can provide various services, and an integration layer that makes it possible to automate processes and continuously repeat best practices.

Because energy storage requirements are situational, an effective storage solution requires a software layer that can continually send data to component parts—the batteries, inverters and temperature controls, among others—and respond to signals from those components as well as the grid. The energy storage software platform serves as a symphony conductor for the system of systems, performing these functions and more: integrating with generation, charging the batteries when power plants are operating, and standing by or discharging the batteries when they are not; interpreting grid conditions to provide services like frequency regulation and voltage control; optimizing performance; balancing power production needs with long-term asset management strategies; and, engaging in fleet management to streamline processes in the control room.

Grid-Connected Software

Storage software decisions do not occur in a vacuum. Whether interconnected on the utility side of the meter or the customer side of the meter, the control software must understand how the grid operates to be able to optimize performance within a network of grid assets. In short, storage is a virtual power plant, one that's capable of satisfying all the requirements of today's fragmented grid while enabling a transition to the highly instrumented smart grid of the future.

Energy storage is sometimes viewed as a complementary asset that can sit alongside a traditional power plant, but utility-scale storage performs with far more versatility than generation on its own. One widely recognized function of grid-scale storage is to save energy for later. Another function is to deliver a more streamlined power flow to the transmission and distribution systems, improving grid reliability. To do this and more, grid-scale storage requires software that can integrate with grid-side technologies, including outage management systems and substation automation, as well as customer-side technologies, such distributed generation and dynamic pricing. With the ability to control generation and load, storage becomes one of the most critical assets in the utility portfolio.

Software for Future Flexibility

The software has to not only meet today's conditions and needs but also be designed for unknown conditions in the future. Anyone can locate pathways on the electric grid threatened by instability and connect the latest battery technology there, temporarily shoring up a weak point in an aging network. However, as grid conditions evolve, use cases for storage also change, bringing perhaps increased need to provide firm power from intermittent renewables or to react quickly to frequency excursions, among other services. System design for multiple applications and a robust control algorithm are critical for performance.

The distributed grid of the future needs to empower utility customers to simply and effectively control energy usage, generating power if they choose, integrating electric vehicles along the distribution system and forming microgrids where they can improve quality of service. Storage system technologies will enable grid transformation, but only to the extent that they streamline complex processes and simplify energy management both before and after the meter. Without software designed to accommodate changing conditions, inefficiencies will arise from islanded assets, grid congestion, and underperformance. Proven software technologies and processes enable the grid and its participants to continue to enhance grid stability and mitigate risk.

Software's Role in O&M

The software plays a role in the system's O&M as well: Having the right software controlling your system enables flexibility and reliability. For example, if one battery string has an under-voltage alarm and needs to be serviced, without the right software, the entire system would need to come offline, and that would mean a loss of revenue or increased charges. Having the right software means that one string can be taken offline while the rest of the system operates as usual with slightly less battery capacity. On a site with multiple inverters, if one inverter has an issue and is taken offline, software can dynamically adjust the available resources to maintain maximum reliability while triggering the appropriate maintenance alerts to get the full system back up and running as soon as possible.

Case Study: Using Software for Future Flexibility in Puerto Rico

With energy generation projects, tradeoff analysis is an essential part of the design phase. A utility-scale solar project developer may want to model output using a fixed mounting system versus single-axis trackers and double trackers, and then perform a cost-benefit analysis to determine if the performance improvement justifies higher capital expenditures and operating costs. The difference with energy storage is that the tradeoff analysis is not only more complex than would be required for an energy generation project but also required to keep weighing alternatives throughout the life of the system.

Let's use Puerto Rico as an example. When Puerto Rico Electric Power Authority (PREPA) directed solar and wind energy project developers to incorporate energy storage with minimum technical requirements that improve grid stability while facilitating the adoption of distributed energy resources, one requirement stated that any storage solution must be able to provide 45 percent of maximum generating capacity for one minute to smooth the ramp rate of power, discharging stored energy to compensate for drops in output due to intermittency. Another requirement called for storage solutions to be able to output 30 percent of a project's rated capacity for about 10 minutes to help regulate grid frequency, ensuring that key sections of the transmission grid continuously operate close to the regional standard speed, usually either 50 Hz or 60 Hz. Those requirements were fed into the tradeoff analysis performed during the design process.

Energy storage systems have historically been deployed for a single use case, such as demand charge reduction or frequency regulation, but the shift to a multi-application approach allows system owners to maximize return on investment and open new

revenue streams. Greensmith designed and deployed PREPA's behind-the-meter grid-scale system from the ground up, from design to procurement, testing, installation, and commissioning. Two of PREPA's requirements, addressing ramp rate control and frequency regulation, can only be addressed by incorporating intelligent and flexible software controls. Because PREPA is one of the first electric power companies in North America to mandate energy storage, the entire industry is watching how project developers adapt to new market conditions, and how the system will adapt as those market conditions change over time.

The design challenge is not a simple matter of optimizing system size and capital expenditures. Developers need control software that has passed rigorous testing in the lab and in field conditions to be certain that batteries respond to environmental conditions with speed and precision. Meeting PREPA's technical requirements is only the first step, addressing the needs of the electric grid. To satisfy investors, an effective battery storage system must be able to incorporate new and updated technologies, as well as adjust to future uses or variables that may not have been considered when the system was originally designed. Greensmith's multi-application software platform, GEMS, is designed to offer additional select grid operations that can create additional revenue streams for PREPA over time.

3. Managing the Supply Chain

The third and final critical skill that an energy storage provider should have is the ability to draw on an established and well-managed network of Tier 1 suppliers. An energy storage system's optimal performance requires numerous parts work seamlessly together. The whole system is only as strong as its weakest link: if the temperature-control system fails to keep all the batteries and other electrical equipment from overheating at any point during system lifetime, for example, it could diminish performance and take a bite out of the return on investment. A storage system provider should have deep relationships with Tier 1 suppliers for each core component: batteries, inverters, containers, HVAC, and fire suppression. These relationships not only assure access to the most reliable products and services, they also help to mitigate risk. There is no substitute for effective supply-chain management if a project aims to achieve greater than 99 percent system uptime.

The supply chain also needs to incorporate a broad selection of sub-systems or components. Energy storage projects can be constrained by premature component selection, and having too few suppliers could skew the design decisions. A commitment to the wrong battery technology early in a project may become extremely expensive to course correct once the problem is discovered. Without a strong and deep network of suppliers combined with a software platform that can adapt to and work with many different technological components it's possible to get locked into specific solutions that might not be the best match for the job at hand. There's no quick fix here. An energy storage company has to invest significantly to become expert in each component's leading technologies and vendors. For example, every battery technology is unique, as is each vendor. If an energy storage company invests significant resources in developing a strong chain of Tier 1 battery suppliers and optimizing all types of batteries within a storage software platform, it will be nimble enough to always pick the optimal battery for any application.

A Model for Supply Chain Excellence

Supply chain management underwent a transformation starting in the late 1990s as many industries moved from localized manufacturing and regional distribution to regional manufacturing and global distribution. Business processes started out in segments and silos because that matched the way people made purchases and the way goods were produced. In short order, companies found themselves managing multiple databases and struggling to overcome the resultant process inefficiencies. Supply chain solutions emerged as companies started to optimize functions in isolation, and then optimized the entire process flow. As companies made the switch from material requirements planning (MRP) to enterprise resource planning (ERP), solutions became more complex and they integrated with one another for stepped improvements.

One example of supply chain innovation was Dell, which pioneered a configure-to-order production model where customers could customize products before Dell assembled them, and Dell could dynamically adjust component pricing based on supply and demand. This rapid customization involved a deep and complex supply chain that depended on strong relationships with trusted vendors and sophisticated software to manage the flow of inventory. An extraordinarily complex transaction was radically simplified for the consumer and the producer.

Some in the energy storage industry are beginning to apply this template for supply chain excellence. To build transformative technology, an energy storage company not only needs an expert-level understanding of every cost, performance, and quality decision but also must be able to deliver solutions in any conceivable configuration with the optimal balance of cost, performance, and time to market.

An experienced storage system vendor achieves a competitive cost structure through access to a Tier 1 supply chain. Past performance mitigates risk in the emerging storage market where there is no shortage of excitement about the transition to the smart grid but a real limit on expertise gained through trial and success. Knowing that the opportunity costs stemming from underutilized storage are huge, a seasoned supplier will have made the deployment process incredibly efficient to commission new systems as quickly as possible.

Excellence in supply chain management requires a larger investment than the customer might realize because it is not just about expertise in each component and supplier. Energy storage companies also have to understand the interactions between the systems within the systems. In high power situations, the results of incorrectly assembling disparate components from multiple vendors into a single solution could result in potentially dangerous and expensive failures, so it is essential to rely on a partner who has both the experience and the proprietary technologies needed to do the job correctly and quickly.

The most obvious impact of a well-run supply chain is the ability to deploy systems quickly. Processes must be fully implemented on the front end so customers can match storage solutions to their technical and economic specifications and expect prompt component shipment, construction and commissioning.

Time in the Market

Successful supply-chain management and battery selection satisfy a lot of the demands of system design. Consider a project team that has picked all the best original equipment manufacturers for its storage needs and recruited an engineering and construction group to expertly assemble all system components and interconnect them with the transmission and distribution network. The product of all this work is a virtual power plant with a whole new set of challenges: real-time performance monitoring, equipment testing, maintenance and repair. The system supplier may offer to provide these services directly or through a contract partner, but the project team needs different criteria to make an evaluation. How long have these storage systems been operating in the field? And how do they respond when everything is not proceeding to plan?

It's one thing for an early adopter in the residential storage market to risk a few thousand dollars on a product with little to no track record; there's no real alternative, given the immature state of the market. In grid-scale storage, however, investors need to explore an energy storage provider's track record. One path is to look at any systems deployed for PJM, a regional transmission organization serving the Mid-Atlantic and parts of the Midwest. Its wholesale energy market for regulation services to support grid reliability is considered the largest, with over $250 million in 2014 and consistent revenue growth since 2012. PJM represents about two-thirds of the entire regulation market, according to a 2016 ancillary services market survey by Argonne National Laboratory. Distributed energy resources such as energy storage systems that provide regulation services must be able to respond to signals from the system operator and change output in a matter of seconds. They also get scored on the accuracy and precision of the power being delivered and the timeliness in which they deliver it. These scores provide insight into the ability of energy storage to deliver on the services they are asked to provide.

Case Study: Leveraging a Supply Chain for Aliso Canyon

When the energy storage market was largely focused on pilot projects to prove value, deployment time was not such an issue. Today, the energy storage market is maturing, and rapid deployment of highly customized solutions has become a reality. A recent example was Greensmith's record-setting deployment of a 20 MW / 80 MWh system in Southern California.

In October 2015, crews discovered a leak at California's largest natural gas storage facility, located at the northern edge of Los Angeles. When Southern California gas powered generation facilities faced a sudden shortage in supply, the energy storage industry got a chance to demonstrate that large-scale storage could step into the gap. Greensmith Energy, one of three providers deploying an 80 MW storage system, set a record by successfully completing and commissioning the first 20 MW / 80 MWh energy storage system at the AltaGas Pomona Energy Facility in Pomona, California. Working in close partnership with AltaGas, Greensmith set an industry record, designing, integrating, installing and commissioning the state-of-the-art energy storage system in less than four months.

The project highlighted how Greensmith's supply chain expertise accelerates time-to-market for grid-scale energy storage systems. Aliso Canyon demonstrated our ability to leverage major OEM relationships to deliver North America's largest and most complex energy storage system safely, quickly and reliably. The project had a very tight construction and delivery time frame and Greensmith worked seamlessly with Tier 1 supply chain and established ecosystem to deliver this benchmark project on time. Greensmith's system-wide expertise and deep integration experience was paramount to the successful delivery of this installation.

Conclusion

In October 2016, the Smart Electric Power Alliance published a report called "Distributed Energy Resources Guide" documenting that storage is the most versatile smart grid technology for performing critical grid-support services as utilities replace traditional power plants that fire up to supply peak load only. Held up against renewable generation, energy efficiency, and demand-side management, it's true that storage is an inherently superior resource. But not all energy storage systems are created the same. To achieve optimal performance, storage must be highly customized, efficiently deployed, and operationally flexible so it can adapt as market conditions evolve. This requires a project development team that brings expertise in designing a system of systems, has experience in integrating a flexible software platform, and has a proven track record of excellence in managing the supply chain.

Choosing the right team, one which fully understands the energy ecosystem and has ample experience with large-scale storage system deployment, will result in a solution that not only meets today's and future needs but also is able to be deployed quickly. We've seen that that requires a deep understanding of the system of systems inherent in energy storage design, and a flexible software platform that can manage a wide range of use cases and grid environments. Equally important however is the development team's ability to leverage relationships with Tier 1 suppliers to source the most appropriate batteries and other components for the project at hand. Experience with all battery technologies is essential to making the right section. Expertise at solving all the operational challenges that arise in wholesale energy marketing must also be considered. When storage is the last defense against rolling blackouts, reliable service is too important to be entrusted to unproven technology. When all of these skills are present, the result is an energy storage system that maximizes the system owner's return on investment.

Only recently in a select few markets have regulators and grid operators begun to ask electric service providers to integrate storage into their asset portfolios, and in some cases, they have set short-term deadlines for deployment. Developers need to carefully balance economic and technical considerations to make sure they not only satisfy requirements for market participation but also achieve long-term value for shareholders. They also need the capability to engage in trade-off analyses that account for multiple use cases for energy storage and the flexibility to adapt as grid conditions and hence investment priorities evolve. Today's grid-scale storage systems serve regional power grids that interconnect large-scale centralized generation and huge numbers of residential, commercial, and industrial energy users. The future may bring decentralization of grid infrastructure as the deployment of microgrid technology increases. Energy storage, if properly designed and managed, will be ready for anything.

About Greensmith Energy

As the leading provider of energy storage software and integration services, Greensmith's mission is to make energy storage a fundamental part of a cleaner, more intelligent and distributed energy infrastructure. Now in its fifth generation, Greensmith's GEMS software platform optimizes the performance of energy storage by lowering costs and maximizing system return on investment.

Greensmith Energy designs and deploys the world's most advanced energy storage systems. From grid-scale to behind-the-meter and microgrid solutions, the Greensmith GEMS software platform enables effective and efficient delivery of stable power with unsurpassed performance and profitability.

West Coast Office

2000 Powell Street, Suite 1625
Emeryville, California 94608

East Coast Office

485 Springpark Place, Suite 1500
Herndon, Virginia 20170

Phone: +1.888.882.7430
Email: info@greensmithenergy.com
http://www.greensmithenergy.com