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Battery Energy Storage

Assessment and Valuation of the New Green Multi-Tool

Abstract

Following on the heels of rapid wind and solar generation adoption, battery energy storage is fast becoming the next disrupter to the power industry. Plummeting costs, expanding end-uses, and regulatory driven gigawatt-level installation targets are driving increasing interest and early adopters. With the current and expanding opportunities for battery storage, utility planners and investors require appropriate analyses, valuation approaches, and tools to assess project value for this rapidly evolving technology.

Affordable energy storage is commonly considered the missing link between intermittent renewable power produced by technologies such as solar and wind, and 24/7 reliable supply of renewable electricity. In addition, no other power industry technology can serve so many vital roles: renewable production smoothing; energy shifting and arbitrage; fast ramping ancillary services; alternatives for peaking generation, transformers, and line upgrades; voltage and frequency support; microgrid supply; electric vehicle charging support, and on and on. Energy storage, and particularly battery-based storage, is developing into the industry's green multi-tool. With so many potential applications, there is a growing need for increasingly comprehensive and refined analysis of energy storage value across a range of planning and investor needs. To serve these needs, Siemens developed an integrated framework and analytical toolset to determine battery storage value for utility planning and merchant generator needs.

This whitepaper provides a description of key issues the grid and participants in electricity supply face, the many ways in which battery-based storage projects can help solve these issues, and the methods and tools used to forecast revenue streams and project value under uncertainty.

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[1] *For the purposes of this paper, merchant generators or merchant storage are meant to refer to non-utility projects designed to supply power to competitive wholesale power marketplaces and who do not rely on long-term bilateral purchase agreements as their primary revenue source.*

Introduction

Participants across the electricity supply chain face a range of issues for which battery-based storage may offer a solution. Utilities and regulators want to reduce supply and grid operating costs, improve resiliency, and increase renewable integration; while financial institutions and developers see storage revenue opportunities in markets by providing ancillary services and energy arbitrage and thereby supporting higher levels of renewables.

Several viable battery use cases have emerged to address these issues, and more are certain to develop as technology costs decline, battery experience develops, and longer duration batteries enter the market. While the technology is increasingly understood, the determinants of project value are not. Siemens Energy Business Advisory's experience serving energy suppliers, consumers, and investors across the country evaluating battery storage projects suggests project value depends largely on quantifying how operators can optimize the flexible operational characteristics of batteries to serve increasingly renewable and volatile markets. Understanding how a given battery project might operate and generate revenue or value in today's markets is one thing, but projecting how that asset and markets will change over time, and what revenues and value may be generated in the future, is quite another. Siemens Energy Business Advisory (Siemens EBA) has developed methods and tools to help utilities, developers, and investors quantify the revenue potential and battery storage project value when operators optimize battery commercial and technical operations.

Grid and Planning Issues

Increasing grid complexity and volatility are placing new demands on parties which supply, transmit, distribute, consume, and invest in electricity. For example, the impacts of rapidly changing renewable generation as clouds shield and expose solar panels, or wind velocity increases or ceases to blow, can cause significant voltage spikes and frequency excursions that extend from the generator to distribution circuits and customer homes. Further, traditional electricity production planning analytical approaches are not designed to capture these rapid supply and demand changes. Forward thinking utilities and regulators are recognizing the need for increasingly integrated planning across all segments of the electricity value chain. By forming integrated generation, transmission and distribution (GT&D) planning teams and analytical methods, these utilities are increasingly able to plan for the impact of both increased renewables penetration and natural disasters to better serve their customers and respond to regulators.

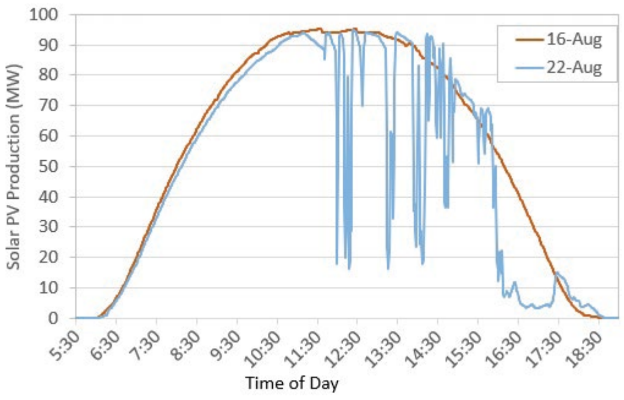
Increasingly, merchant operators are using optionality analysis to understand and successfully optimize storage value. Optionality analyses involves the stochastic assessment of the simultaneous valuation of the multiple revenue streams available to a storage project selling into a power market and then selecting the service to provide, at any given time, based on the highest revenue potential. While complex, the optionality analysis is the best method to provide a comprehensive financial valuation that captures the unique flexibility of storage. The merchant storage business model is new but is poised to become an important contributor to the continuing growth of renewables, renewables combined with storage, and standalone storage projects.

Renewable Integration

The increasing quantities of the variable output of wind and solar generation create challenges to electric operations at any level – utility feeder, utility grid, or even regional system level. Two common use cases for storage projects serve to provide renewable integration support, in the form of:

- renewable production smoothing for an individual project
- system-level support to respond to the combined effects of variations in distributed solar output and/or utility-scale wind and solar production

Solar production and, to a lesser degree, wind production, can vary significantly on a minute to minute or even sub-minute basis driven by rapid fluctuations in wind speeds and solar radiation. The impact of scattered clouds, as shown in Figure 1, generates the highest variations in solar radiation and the resulting solar energy production. It is not unusual to see a solar project's generation fall by over 60% in a few minutes, only to return to previous levels in the subsequent minutes.



Source: Siemens Power Technologies International

Figure 1 Sample One Minute Average Solar Radiance

This production variability creates high peak discharge and charge requirements for battery applications supporting and smoothing the production from a large solar penetration. A utility system with multiple solar projects dispersed across a large geographic area will tend to have some averaging and damping of the cumulative solar variability as the scattered clouds travel across the system. This averaging of the cumulative output across a system can reduce the ratio of battery capacity to solar capacity required to produce the same production smoothing.

Analysis of these project and system-level requirements typically take the form of a stochastic (probabilistic) analysis of production variability of the cumulative wind and solar sources to define confidence intervals associated with variations in renewable output over given time periods (e.g., 1-minute, 5-minute, or 15-minute intervals depending on the available production data and system needs). These variations are then compared to the peak ramping capability (up and down ramping) of the existing energy sources that can adequately respond (sufficiently fast) to the changes in the renewable production. The difference between the existing fast ramping resources and the desired renewable smoothing (e.g., a 99% probability that the stated level of MWs of fast ramping capacity will be able to compensate for any expected 15-minute variation in solar and wind production) provides the needed peak output capability of battery storage. This analysis also supports estimating the energy capacity that is needed for a defined confidence level that batteries will have sufficient energy capacity to address multiple ramping events in a single day.

T&D Planning for Non-Wire Alternatives

In a growing number of jurisdictions, regulators require utilities to assess energy storage and other Non-Wire Alternatives (NWAs) when evaluating traditional generation and grid investments. As load forecasts change, the modular nature of battery storage systems permits utility planners to add smaller increments of storage over years rather than a single large project all at once. This staged investment approach serves to better time the investment with the need. In a recent analysis, Siemens defined a storage project to increase distribution capacity to meet a once per year load spike that was expected to continue growing, as shown in Figure 2. The recommended project plan supported the utility's incremental addition of battery storage in five stages over ten years. The project was designed to support adjustments in both the size and timing of the future battery storage additions to perfectly match the actual growth.

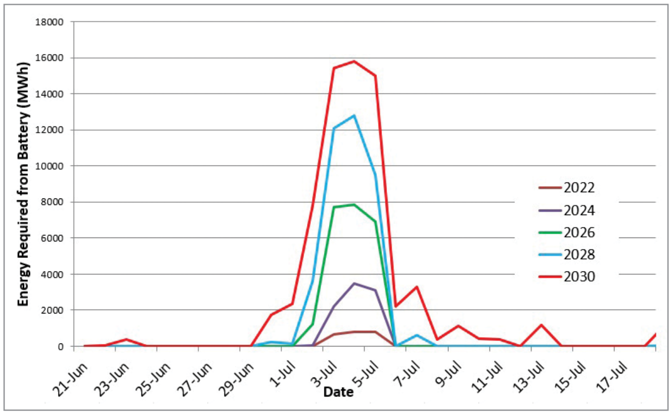


Figure 2 Sample Substation Peak Energy Requirement Growth

Contrast this project plan for incremental storage additions with a traditional utility approach that would have made a single large investment in a substation transformer sized to meet the year 10 forecasted load that, in actuality, may never fully materialize or may arrive sooner or later than forecasted. Rather than following the traditional approach and adding expensive substation capacity to address loads that may only be seen a few hours a year, NWAs provide greater system benefits at lower costs, and are fast becoming the preferred option of commissions and stakeholders.

Regulators across the country frequently require utilities consider NWAs (i.e., DERs) in Integrated Resource Plans and in transmission and distribution project analyses. In other words, utilities must assess DERs on an equal footing with utility-scale generation, new transformers, new power lines, etc. The assessment of NWAs includes their ability to serve or reduce load, but also as replacements or deferral of investments in new utility-scale generation and traditional T&D additions. However, substituting these NWAs for traditional utility infrastructure brings new planning and operational challenges. A comprehensive comparison of NWAs to traditional investments requires that utility planners assess the impacts of these options across each of the grid elements in a much more detailed and aligned fashion than has traditionally been performed. While this requirement expands the complexity of utility planning, a comprehensive assessment of all benefits and impacts has always been the preferred approach for utility planners and regulators. Unfortunately, the historical utility planning methods, tools, and organizations are not well-suited to this expanding need to align the GT&D and DER planning processes. To address the limits of traditional planning approaches, Siemens EBA now employs an Integrated Planning methodology that combines GT&D planning employing aligned assumptions and planning objectives.

Resiliency Planning

Rapid cost declines for solar generation and energy storage bring utility planners new distribution-level options for economically improving local resiliency, but to employ these options, planners require data with more granular temporal and geospatial resolution. Smaller and more distributed placement of energy sources generally offers resiliency benefits over the historical large centralized generation model. Due to its scalability, ease of siting, and zero carbon output, solar plus storage has become a preferred building block for microgrids and other resiliency projects.

In our recent Integrated Planning work with the Puerto Rico Electric Power Authority (PREPA), Siemens developed a strategy to increase system reliability by dividing the island system into eight Minigrids (large microgrids), as shown in Figure 3. These Minigrids will normally operate connected but could each be islanded individually or in groups during emergencies. All the Minigrids are supported by storage, renewable generation, and fossil resources to minimize outage impacts and speed restart in the event of emergency.

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[2] *Traditional "wires" alternatives include large centrally located generation and the grid infrastructure used to transport the power to customers, e.g., transmission and distribution lines, transformers, etc. NWAs include storage, energy efficiency, demand response, and other distributed energy resources (DERs) that can be employed individually or in combination to replace or defer investment in traditional wire alternatives or provide other benefits such as reduced carbon emissions.*

Eight MiniGrids – Ten Areas

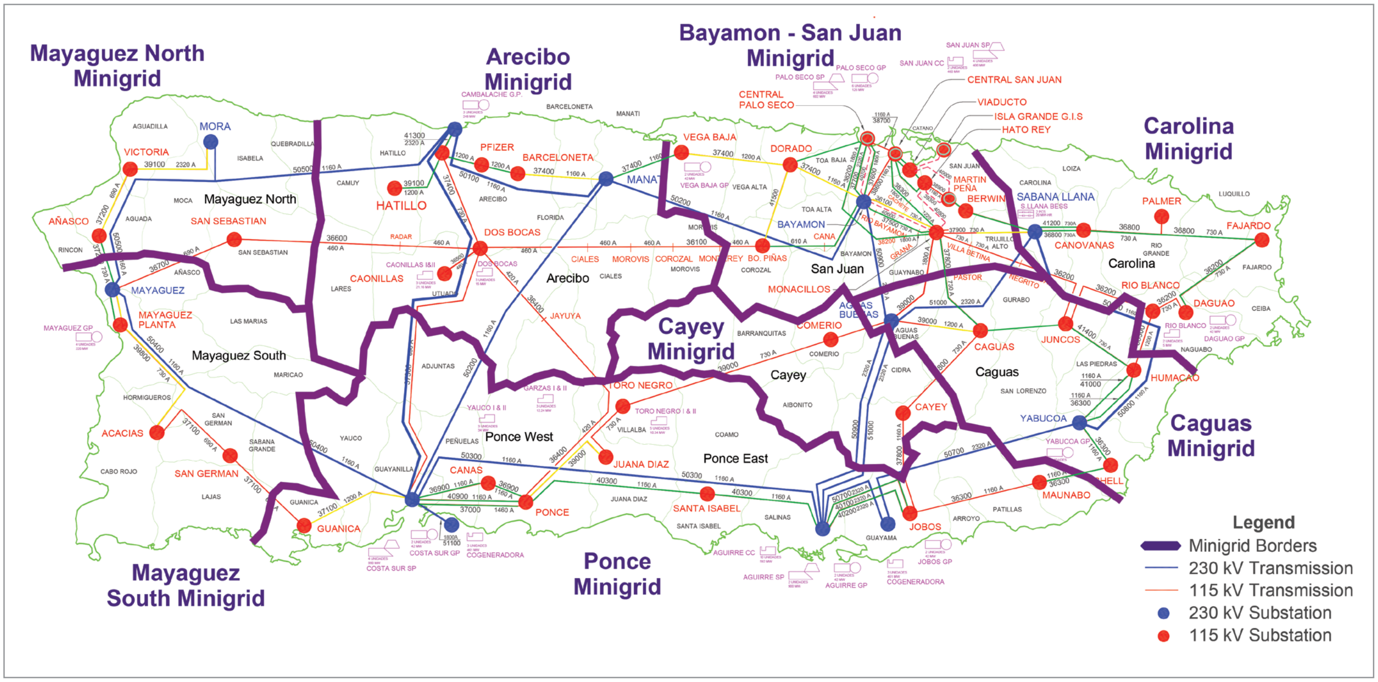


Figure 3 PREPA Minigrid Design

Stacked Value of Storage

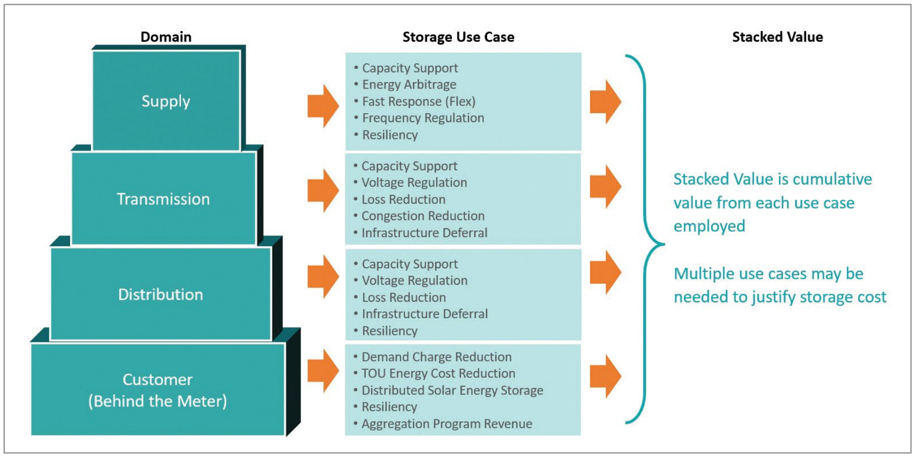
Siemens EBA has long been a proponent of the benefits of combining planning for GT&D in a single Integrated Planning process. The need for, and utility interest in, Integrated Planning continues to increase with the growth of renewables and DERs. Analyzing the multiple uses for storage across the different GT&D planning domains makes Integrated Planning a necessity for effective analysis and benefits valuation of storage. Figure 4 depicts the concept of assessing and combining multiple use cases (or stacked value) for battery energy storage. Not surprisingly, the amount of battery energy storage recommended for PREPA was strongly correlated with the total amount of solar to be installed and the local energy supply required for the Minigrids. Further, storage was deemed vital to each Minigrid to ensure system voltage and frequency regulation, and to smooth the output and time shift energy from renewable sources. Siemens recommended that additional solar or wind projects should only be approved for the PREPA system based on the rate that PREPA is able to add energy storage to the system.

While battery-based storage costs continue to decline, storage remains relatively expensive compared to traditional grid alternatives unless the user stacks multiple use cases for storage and their associated revenue streams to justify storage investment.

The first step in assessing stacked value is to identify the potential uses from storage connected at the customer, distribution, or transmission level.

In considering these use cases, it is important to note that storage typically provides service upstream of its installation location in the system. For example, storage connected at the customer provides value for the customer, distribution system, transmission system and supply (i.e., generation). Alternatively, storage connected at the transmission level typically only supports the transmission system and supply.

The next step is to prioritize potential storage services. Prioritization should be based on identifying the most valuable use of storage and assessing other potential use cases that could incrementally enhance the value proposition.



- Capacity Support
- Energy Arbitrage
- Fast Response (Flex)
- Frequency Regulation
- Resiliency

- Capacity Support
- Voltage Regulation
- Loss Reduction
- Congestion Reduction
- Infrastructure Deferral

- Capacity Support
- Voltage Regulation
- Loss Reduction
- Infrastructure Deferral
- Resiliency

- Demand Charge Reduction
- TOU Energy Cost Reduction
- Distributed Solar Energy Storage
- Resiliency
- Aggregation Program Revenue

Stacked Value is cumulative value from each use case employed

Multiple use cases may be needed to justify storage cost

Figure 4 Stacked Value

Utility Perspective of Stacked Value

A simplified example provides a useful illustration. In a current Siemens EBA project, the GT&D domains of a utility are being assessed in a combined process where storage could be applied in each planning domain. In this analysis, Siemens found that currently operating older fossil generation units run only a few hours per year to support local peak load since the transformer capacity is insufficient to import less expensive and cleaner power from regional suppliers. In this example, the options under consideration include:

- Install additional transformer capacity to support increased imports to provide:
  - Capacity to serve load during peak load hours
- Install a storage battery to provide:
  - Capacity to serve load during peak load hours
  - Energy arbitrage during the remainder of the year by purchasing low-priced, off-peak energy from the grid to be used to offset on-peak, higher-cost purchases from the grid.

This single battery project can potentially also provide other benefits in this case, for example, smoothing local solar project output or providing voltage regulation.

However, batteries have limitations regarding what services can be offered and when they can be offered, based on peak output (MW) and capacity sizing (MWh). These limitations must be considered when allocating the finite capabilities of a battery. First, the highest value use cases should be addressed, and second, increasing the size of the battery should be considered only if the increased cost can be justified with the added uses.

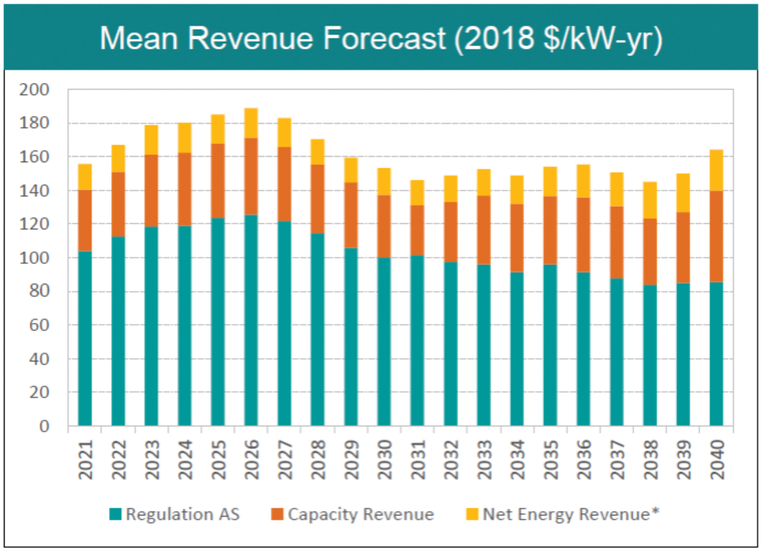
Although not comprehensive, Figure 5 provides a sampling of the diversity of clients and use cases for which Siemens EBA has assessed battery storage projects. To make these use cases viable projects, stakeholders are testing a variety of technology ownership models, business models, and operating methods and toolsets.

Merchant Generator Stacked Value Perspective

For merchant storage, market requirements, structures, and pricing drive investors to look for all potential revenue streams, whereas utilities generally focus on a single primary use for battery benefit cost analysis. In some wholesale markets, regulation ancillary services (AS) may deliver 60% -70% of storage project revenue, while in other markets, storage project revenues are driven by the energy arbitrage potential.

Forecasts for these market prices are filled with uncertainty. As a result, Siemens EBA believes value potential should be evaluated based on the projected range of market conditions and asset performance. To accomplish this, we apply a stochastic modeling approach to forecast a range of potential market outcomes to determine the impact of uncertainty and risk on the project's financial and operational performance.

The graphic below depicts the results of a recent analysis Siemens EBA conducted for a merchant battery project under consideration in the PJM system. The analysis estimated a stochastic spread of market revenue potential for a battery operating between up and down regulation AS, capacity sales, and energy sales using an energy arbitrage philosophy to dictate hours of charge (energy purchases) and discharge (energy sales). In this case, project revenues are forecasted to be driven primarily by regulation AS and capacity services.



*Net Energy Revenue is net of charging costs
**Average values based on the 20-yr nominal values

		Use Cases								
Client	**Client Business**	**Frequency Regulation**	**Voltage Regulation**	**T&D Infrastructure Deferral**	**Fast Response (Flex)**	**Capacity Support**	**Energy Arbitrage**	**Renewable Integration**	**Resiliency**	**Microgrid Support**
California Community Choice Aggregation (CCAs)	CCA					X	X	X		
Puerto Rico Electric Power Authority (PREPA)	POU				X	X	X	X		X
Columbia Water and Light	POU		X	X	X	X	X	X		
New York Prize Microgrids	POU		X	X		X		X	X	X
Confidential Eastern Utility	IOU		X			X				
Confidential Mid-Continent Utility	IOU					X		X	X	X
Hawaiian Electric Company (HECO)	IOU	X	X			X		X	X	
Tucson Electric Power	IOU	X		X	X	X		X		
Confidential Energy Investment Firm	MG				X	X	X	X		
Confidential Energy Infrastructure Firm	MG				X	X	X	X		

Figure 5 Sample of Battery Storage Use Cases Being Assessed

CCA – Community Choice Aggregation
IOU – Investor Owned Utility
POU – Publicly Owned Utility
MG – Merchant Generator

Concluding Thoughts

The grid and those participating in electricity supply and delivery face many challenges for which battery-based storage is appearing to be an answer. For utilities, Integrated Planning analysis, with the ability to integrate GT&D analysis, is needed to fully assess the potential stacked value of battery storage. For merchant investors and developers, stochastic analysis of storage is required to assess the optionality value of merchant storage sales for multiple wholesale market products. Continued reduction of storage costs and introduction of storage technologies and projects able to retain larger amounts of electricity for longer time periods will only serve to increase the potential storage use cases. Utilities, merchants, and investors all need to gain comfort with the need and benefit of enhancing their analysis and valuation methods of storage to fully capitalize on this evolving industry green multi-tool.

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