Leveraging a Modular Approach to Large-scale Energy Storage

Enhanced flexibility to accelerate project deployments

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For larger utility scale projects, sourcing modularized battery energy storage system (BESS) hardware and control solutions from various vendors offers potential advantages compared to the legacy integrated approach. This Stem eBook shows how developers, asset owners, and independent power producers can leverage a modular approach to large front-of-the-meter (FTM) storage and solar + storage projects to gain an edge in the market.

Introduction

Battery energy storage continues to play an increasingly crucial role on the electricity grid, with cost and technology improvements and new value streams driving larger installations and expanding storage markets. But challenges around hardware procurement have added uncertainty and complexity to the project development process.

A modular approach to large-scale energy storage projects has emerged that offers developers, asset owners, and independent power producers enhanced flexibility and speed to market. By having the flexibility to source modularized ESS HW and controls from various vendors, project teams can avoid delays and other risks associated with depending on a single integrated supplier.

This Stem eBook offers a closer look at the modular approach: what's involved, pitfalls to avoid, and potential benefits for your large-scale energy storage and solar + storage projects. It also shows why software is key to deploying modular energy storage – and how selecting the right partner can enable long-term success across clean energy projects and portfolios.

The Evolution of the Energy Storage Market

Macro trends

The energy storage market continues to grow at an impressive clip. Based on Wood Mackenzie data, Stem projects a 14% compound annual growth rate for large-scale, front-of-meter energy storage in the U.S. through 2027 (Figure 1)[1]. Similarly, the Solar Energy Industries Association (SEIA) estimates a sixfold increase in battery storage systems in the U.S. by 2030.[2]

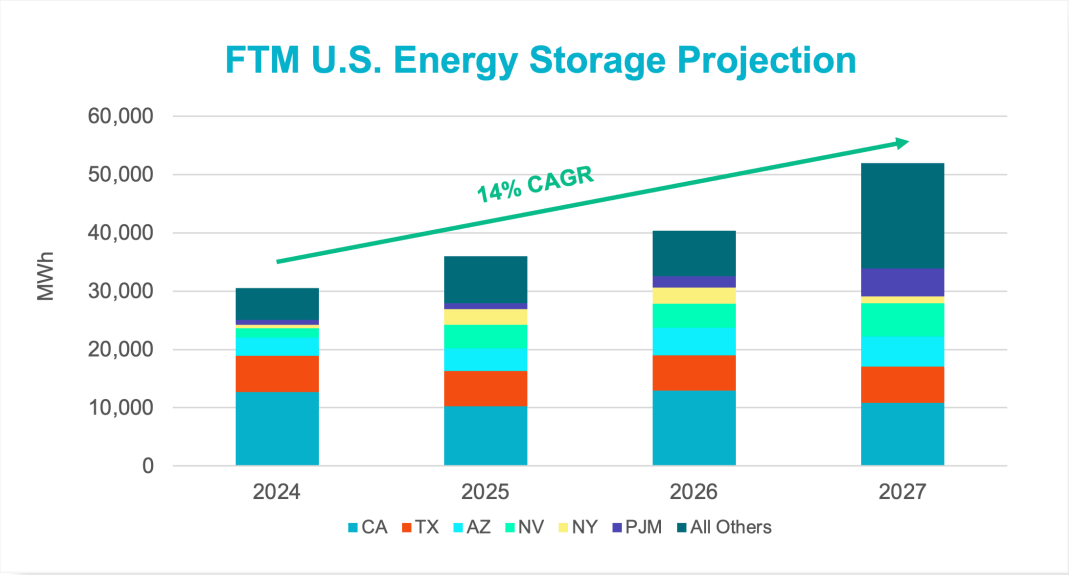


Figure 1: Projected growth for U.S. front-of-meter (FTM) energy storage.
(Source: Wood Mackenzie, Stem.)

After a brief uptick during the Covid-19 pandemic, battery costs have continued to fall substantially. Globally, costs for lithium-ion batteries have fallen by 90% over the last 15 years, according to the International Energy Agency (IEA), and could fall an additional 40% by 2030.[3] This has both expanded the number of economically favorable energy storage projects and attracted new investors and financiers to the industry.

Battery technology continues to evolve, with notable improvements in energy density; RMI reports that battery energy densities have doubled since 2015.[4] Additionally, battery hardware for FTM projects has converged around a common form factor: a 20-foot container with five megawatt-hours (MWh) or more of storage capacity (Figure 2).[5]

[1] Wood Mackenzie, US Grid Scale Energy Storage Outlook 2024. https://www.woodmac.com/reports/power-markets-us-grid-scale-energy-storage-outlook-2024-150289219/.
[2] *Energizing American Battery Storage Manufacturing*, Solar Energy Industries Association (SEIA), November 2023, https://seia.org/research-resources/energizing-american-battery-storage-manufacturing/.
[3] *Batteries and Secure Energy Transitions*, International Energy Agency (IEA), April 2024, https://www.iea.org/reports/batteries-and-secure-energy-transitions.
[4] *X-Change: Batteries*, Rocky Mountain Institute (RMI), 2023, https://rmi.org/insight/x-change-batteries/.
[5] Cameron Murray, "Is BESS commoditising? Industry converges to 20-foot, 5MWh products," *Energy Storage News*, July 9, 2024, https://www.energy-storage.news/bess-commoditising-industry-converges-20-foot-5mwh-products/.

Figure 2: Battery hardware for FTM projects has converged around a common form factor. (Source: Stem)

Finally, energy storage has continued to benefit from strong policy tailwinds at both the state and federal levels. While California and Texas remain the largest markets, Maryland, New Mexico, and Michigan have all set targets for FTM energy storage, while New York, New Jersey, Illinois, and Maine have all expanded or operationalized existing targets.[6] The U.S. Energy Information Administration (EIA) has projected record-high battery storage installations in 2024, due in part to the expansion of investment tax credits under the Inflation Reduction Act.[7]

Project trends

FTM battery storage projects are getting bigger. Analysis by S&P Global showed that planned projects in late 2023 averaged about 100 MW, compared with 40 MW for installed projects.[8] This is likely due in part to battery cost and technology improvements, but also to the speed advantage of smaller projects in navigating interconnection queues proving to be less than expected. With similar interconnection timelines and levels of effort, larger projects generally offer larger revenue streams and "bang for the buck."

In parallel, policy requirements for FTM storage projects are getting more stringent. Larger systems of 75 MW or more that connect to the bulk power system are subject to Critical Infrastructure Protection (CIP) performance standards administered by the North American Electric Reliability Corporation (NERC). Some of these NERC CIP requirements will shift downward and apply to projects as small as 20 MW, bringing with them large penalties for non-compliance.[9]

Many battery storage and other clean energy projects experience delays, with American Clean Power (ACP) reporting that more than 63 GW of solar, storage, and wind capacity has been delayed since 2021.[10] While delays mainly relate to permitting and interconnection, vendor and supply chain issues can postpone hardware deliveries and extend project timelines.

Finally, new revenue streams are emerging for FTM storage projects. Wholesale markets continually evolve to introduce new value streams, as does the mix of available tax incentives and state and utility incentives. While these generally enhance project economics, they also introduce significant complexity – especially for entities operating across multiple markets.

[6] Mark Lazaroff and Maggie Curran, "State by State: A Roadmap Through the Current US Energy Storage Policy Landscape," *Morgan Lewis: Insight*, https://www.morganlewis.com/pubs/2024/03/state-by-state-a-roadmap-through-the-current-us-energy-storage-policy-landscape.
[7] "Solar and battery storage to make up 81% of new U.S. electric-generating capacity in 2024," *Today in Energy*, U.S. Energy Information Administration, February 15, 2024, https://www.eia.gov/todayinenergy/detail.php?id=61424.
[8] Neil Ford, "US battery bonanza in solar states signals major role for storage," *Reuters*, November 16, 2023, https://www.reuters.com/business/energy/us-battery-bonanza-solar-states-signals-major-role-storage-2023-11-16/.
[9] North American Electric Reliability Corporation (NERC), *Analysis of the Changing Mix of Generating Resources on the BPS*, February 2023, https://www.nerc.com/FilingsOrders/us/NERC%20Filings%20to%20FERC%20DL/Amendment%20to%20Work%20Plan%20Filing%20RD22-4_final.pdf.
[10] Brian Martucci, "US energy storage installations rise 62% in Q2, to 2.9 GW: ACP," *UtilityDive*, September 6, 2024, https://www.utilitydive.com/news/us-energy-storage-installations-rise-62-percent-in-Q2/726311/.

Upshot: A modular approach to FTM energy storage has emerged

With energy storage playing an increasingly crucial role on the electricity grid, and with developers, asset owners, and independent power producers racing to complete ever-larger projects using standardized hardware components, a modular approach to FTM storage has emerged that can yield benefits in terms of cost, configurability, and speed to market.

In Stem's view, both the integrated and modular approaches are entirely valid; they just serve different needs. Since the modular approach is newer and can involve significant complexity, this eBook offers a closer look at what it involves and how it could benefit your large-scale energy storage and solar + storage projects.

Understanding Modular Energy Storage

The energy storage value stack

Successful FTM storage projects combine all three layers of the storage value stack (Figure 3):

Hardware and equipment. Batteries and inverters form the bedrock of the storage value stack for standalone storage projects, while solar + storage projects also include solar panels, PV inverters, and DC-DC converters. A BESS controller is crucial for both project types.

Energy management system (EMS). The EMS is responsible for securely executing control strategies that maximize economic value, optimize battery performance, and extend system life on storage and hybrid assets. The EMS interfaces with market operators, utilities, and/or optimization solutions for coordinated dispatch, while providing real-time monitoring and visibility into site performance.

Asset Performance Management (APM). The APM software is an advanced cloud platform to monitor and optimize the performance of solar, BESS and hybrid assets. This allows operators to identify potential issues, predict maintenance needs, and maximize energy production throughout the asset lifecycle, improving reliability and reducing downtime.

Market participation and optimization. With the EMS orchestrating the hardware elements, successful wholesale market participation is a function of the services provided. These include voltage or frequency stabilization, demand charge reduction, renewable energy integration and smoothing, and others.

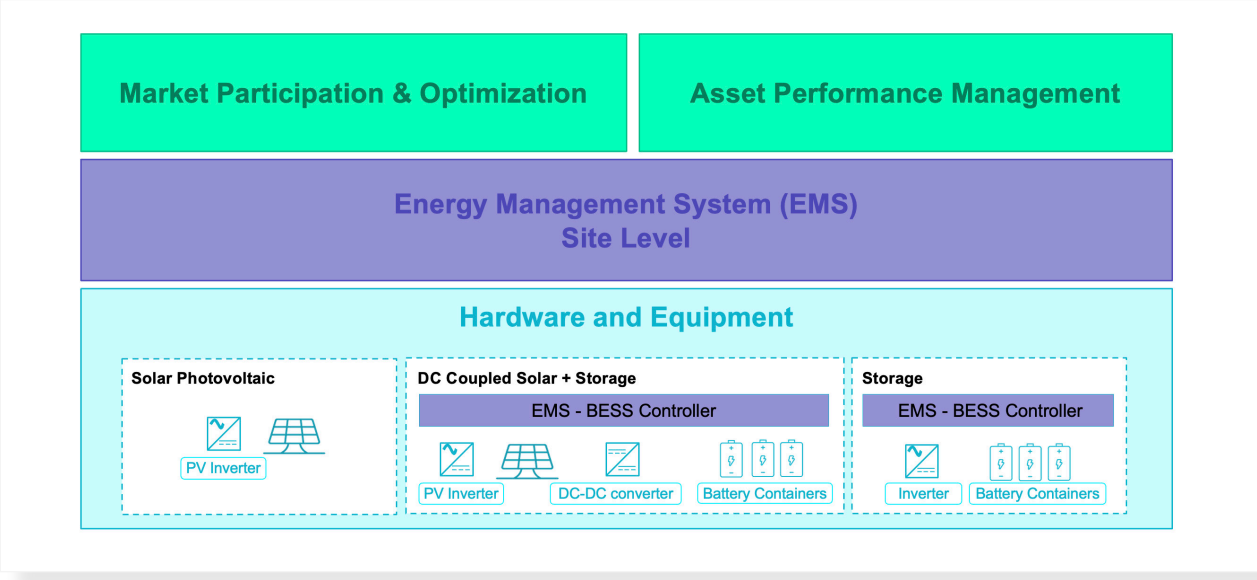


Figure 3: The value stack for FTM energy storage projects. (Source: Stem)

Because the modular approach to FTM storage relates primarily to hardware and equipment, this eBook focuses on the first layer of the value stack.

Integrated vs. modular storage

There are typically two approaches to procuring and operating FTM storage hardware and equipment. The first is the integrated approach, where batteries, inverters, and the BESS controller are packaged together and purchased from the same vendor (e.g., Tesla, Sungrow, and others). This has been the dominant approach for several years.

But recently, a modular approach has emerged, particularly for larger projects of 100 MW and above. This involves procuring batteries (or "DC blocks") from cell manufacturers and inverters (or the "power conversion system," or PCS) from inverter manufacturers, and then partnering with a third party to provide the BESS controller. The third party also integrates, tests, and qualifies all of these components to ensure they work together effectively. Figure 4 summarizes the two approaches.

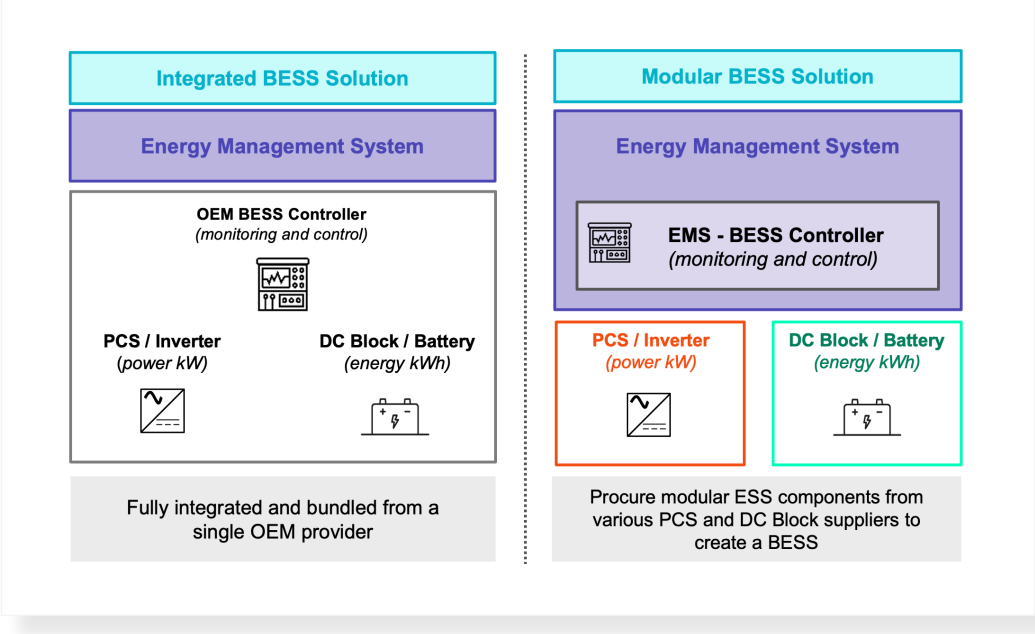


Figure 4: Integrated (left) and modular (right) approaches to FTM storage projects. (Source: Stem.)

Potential advantages of modular storage

In short, modular storage allows developers, asset owners, and independent power producers to mix and match ingredients from different vendors to gain an edge for their projects. There are four main advantages to this approach:

1. **Speed to market.** Mixing and matching hardware and equipment from various manufacturers diversifies your project's supply chain and reduces the risk of delay, which in turn can reduce overall deployment time.
2. **Cost savings.** Accessing competitive pricing can lower overall project costs.
3. **Configurability.** Sourcing specific hardware allows you to design and size your system efficiently, without any wasted capacity.
4. **Enhanced uptime.** Utilizing a third-party BESS controller can provide much more data and insight into project operations and performance compared to the integrated approach, which can accelerate troubleshooting efforts and enhance project uptime.

A tale of two projects: Success with modular storage

Two Stem projects illustrate the breadth and appeal of modular storage. The two customers, a developer and an electric cooperative, are very different and operate in different markets. They also have very different use cases: the developer wanted a system to participate in ERCOT's wholesale market, while the co-op was seeking a tolling arrangement. The projects are also vastly different sizes, with one roughly 10 times the size of the other.

Regardless, modular storage worked for both customers as they shared similar challenges. Each wanted to address performance gaps with integrated hardware solutions. And each was particularly concerned with optimizing asset operations for maximum uptime.

In the developer's case, they began with an integrated OEM solution but pivoted to the modular approach due to better pricing and expedited delivery dates. Meanwhile, the co-op identified its optimal battery after dismissing others due to performance and pricing concerns. Each customer had strong preferences regarding inverters, which the modular approach easily accommodated.

Ultimately, modular ESS worked well for both customers because it provided them with optionality in terms of price, delivery time, performance, and other factors. As an expert partner, Stem helped both customers select and procure the best combination of hardware for their needs and harness the power of the modular approach.

Project Developer

Use Case: ERCOT

Project Size: 140 MWh

Commercial Operation Date: Jan 2025

Outcomes

- Expedited CATL DC blocks and Sineng inverters qualification including UL9540 certification
- Wholesale market participation enabled by Stem's Market Optimization solution

Electric Cooperative

Use Case: Toll Signal

Project Size: 1,200 MWh

Commercial Operation Date: June 2025

Outcomes

- Co-op's choice: partnering with preferred SMA inverter vendor
- Quick qualification: CATL DC blocks with SMA inverters with Stem's EMS including UL9540 certification

Blueprinting an Effective Modular ESS Strategy

The popularity of lithium-ion batteries in grid applications has drawn many competitors to the market. Developing successful projects requires selecting and procuring the right components from many available suppliers and ensuring they perform as expected. This section offers insights on key considerations in navigating the hardware value chain and explains why the BESS controller is key to tying it all together.

Navigating the hardware value chain

Upfront cost is only one consideration in selecting BESS hardware. Based on more than a decade of experience as a trusted partner to successful energy storage and solar + storage projects, Stem recommends four key selection criteria.

1. **Total cost of ownership.** Beyond upfront costs and capital expenditure (CapEx), operating expenditure (OpEx) must also be considered, including all commissioning and operations and maintenance (O&M) costs, to get a full picture of the total cost of ownership (TCO) of assets over the life of the project.
2. **Supply chain availability.** Suppliers must have both an appropriate service footprint in the U.S. and a demonstrated ability to respond quickly to customer concerns.
3. **Performance guarantees.** Availability guarantees ensure uptime, are measured in terms of power (kW), and are usually provided by inverter/PCS suppliers. Capacity guarantees ensure the capacity of the battery over the life of the project and are provided by battery suppliers. Both are essential in de-risking FTM storage and solar + storage projects.
4. **Safety.** Suppliers should be up-to-date and compliant with certifications like UL 9540 and standards like NFPA 855[11,12].

Facilitating interoperability: The BESS controller's role

Selecting the right BESS controller is arguably the most important decision in the modular storage approach, as it is essential to ensuring that hardware and equipment from various vendors operates smoothly and performs as expected. Stem recommends evaluating third-party BESS controllers according to four key characteristics:

1. **Hardware/technology agnostic.** Controller software should be easily adaptable to interoperate with various BESS hardware suppliers and technologies.
2. **Standard interface.** Having a standard interface simplifies integration and OEM supplier onboarding and provides intuitive edge-to-cloud functionality.
3. **"Digital Twin" evaluation structure.** "Digital twins" create virtual replicas of BESS components to ensure compatibility and establish a baseline for expected performance.
4. **Versatile data visualization.** A feature-rich user interface can represent complex data sets in an easy-to-understand way for actionable monitoring and control of FTM storage and solar + storage projects.

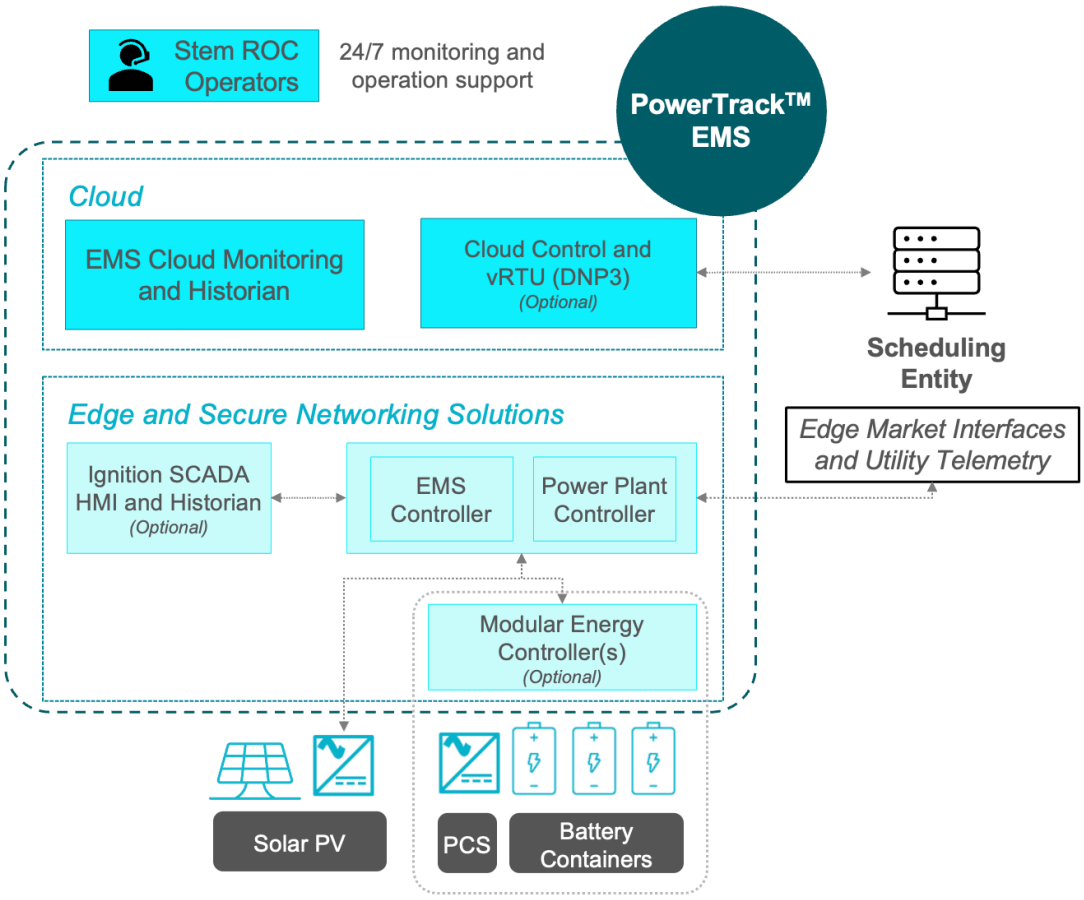
[11] "UL 9540 Energy Storage System (ESS) Requirements," UL Solutions, May 20, 2020, https://www.ul.com/news/ul-9540-energy-storage-system-ess-requirements-evolving-meet-industry-and-regulatory-needs.

[12] "NFPA 855 Standard for the Installation of Stationary Energy Storage Systems: 2023 Edition" National Fire Protection Association (NFPA), https://www.nfpa.org/codes-and-standards/nfpa-855-standard-development/855. Accessed September 15, 2024.

Seamless Integration: Stem's PowerTrack™ EMS

Interoperability is key for modular energy storage projects: the BESS controller ensures interoperability of hardware and equipment, while the EMS ensures interoperability of the full energy storage value stack.

Stem's PowerTrack™ EMS works seamlessly with Stem's cloud-based applications for bid optimization and asset performance management. This solution facilitates high availability of the BESS by enabling proactive evaluation of the health and operations of the BESS and effective control of the equipment to minimize degradation of the BESS. Stem's 24/7 Remote Operations Center (ROC) also ensures increased uptime and minimizes risk through careful warranty management.



Stem's Approach to Modular Storage

Stem’s Modular Energy Controller (MEC)

The MEC, an optional offering with Stem’s EMS, is designed to enable Stem customers to streamline their modular ESS strategy. Integrated within the EMS, the MEC acts as a smart unit controller for battery energy storage systems. The MEC provides an intelligent and user-friendly user interface (UI) along with web access for monitoring system behavior and strategically planning controlled maintenance processes over the anticipated 15 to 20-year BESS lifespan. The system also features diagnostics to assess battery health and projected battery lifespan, which typically determines the optimal timing for modernization investments.

The MEC software architecture incorporates abstraction layers for the inverter/power conversion system (PCS), battery/DC block, and integration of the Energy Management System (EMS). This framework establishes a standards-based interface that facilitates communication between the MEC and upstream monitors and controls entities, while also supporting downstream monitoring and control.

Highlights

- Hardware- & technology-agnostic: interoperable with Top Tier Battery and PCS Suppliers
- Scalable from 125kW to 400MW
- Configures, Monitors, and Controls
- Easily installed by an EPC

Is a BESS augmentation strategy right for you?

Expert advisory support can be especially helpful in deciding whether and how to pursue a BESS augmentation strategy for your large-scale storage project. As energy needs and use cases evolve, strategies to augment BESS capacity and efficiency become increasingly important.

There are two key strategies here: **AC augmentation** and overbuilding. AC augmentation involves adding new AC assets with new DC blocks/battery units that are connected to the grid through separate PCS/inverters. Each new unit operates independently, allowing for incremental growth and redundancy.

Overbuilding involves oversizing the system by installing more battery capacity upfront than is initially required to account for future needs and battery degradation. Typically, the oversizing of battery capacity varies between 10–40%, depending on project needs and operational lifetime. Financial analysis and annual energy throughput analysis must be performed to justify the oversizing and ensure project flexibility.

Each strategy has its own advantages and trade-offs, depending on factors such as cost, scalability, performance guarantees, efficiency, and long-term goals. AC augmentation is typically better suited for projects where demand growth is uncertain, technology evolves rapidly, or budget constraints necessitate phased investments. It offers flexibility and adaptability, making it a practical choice in dynamic energy markets. Overbuilding is generally more advantageous in scenarios where long-term demand is predictable and there is confidence in the system's design and operational longevity. It ensures stable, efficient operation over the system's lifespan, though it requires a higher initial capital outlay.

If you have questions about which strategy might be right for your project, please contact us anytime at sales@stem.com.

Partnering for Project Success

The modular approach offers several potential advantages but involves more variables and complexity than the legacy integrated approach. Services providers, software providers, or those offering both can contribute much-needed expertise in bringing together all elements of a successful project (Figure 5). In some cases, providers offer comprehensive, end-to-end contracts spanning the design, deployment, and operation phases to ensure projects perform as expected over their useful lives. We'll offer key recommendations on what to consider when selecting service and software providers.

Selecting a software provider

Selecting a software provider is an important decision that directly impacts the operational success and scalability of your energy storage, solar, or hybrid projects. The right partner should excel across key criteria to ensure your portfolio's long-term success.

Integrated Platforms and Compatibility. The ideal software provider offers a unified platform capable of monitoring and optimizing diverse asset portfolios- from BESS to hybrid/co-located systems to solar- with seamless integration across technologies. Standardizing operations with an interoperable solution based on industry standard data models and interface conventions ensures consistency and efficiency across your portfolio, regardless of the technologies in use.

Proven Track Record and Data. Experience matters. A trusted software provider should demonstrate a strong history of leveraging data to drive insights through advanced reporting and AI. This expertise enhances operational performance, reliability, and financial returns, enabling your projects to adapt to changing market dynamics with confidence.

Scalability and Future-Proof Design. In a rapidly evolving sector, your software must be flexible enough to grow with your portfolio. The right solution supports customization to support evolving control requirements, integration of new tools, and management of diverse configurations. Scalable and adaptable software ensures your operations remain ahead of the curve.

Operational Efficiency and Cost-Effectiveness. Choose a software solution that minimizes financial and operational burdens. It should be easy to onboard into your organization, integrate seamlessly with existing workflows, and provide an intuitive user experience. A cost-effective solution maximizes return on investment while empowering teams to make informed decisions efficiently.

Ideally, a provider offers software, services, or both, as Stem does, enabling streamlined processes, seamless integration, and optimal operation. This combined approach ensures comprehensive support while meeting the unique challenges of modular and hybrid systems.

Selecting a services provider

In Stem's experience, potential partners distinguish themselves across four key criteria that can be decisive for overall project success.

Trusted Advisory and Subject Matter Expertise. Above all, prospective partners should bring a long track record of ushering successful projects to market. Given the various technical, regulatory, and operating challenges projects may face and the specialized expertise needed to overcome them, the value of experience can't be overstated. Advisory support can also be especially valuable in evaluating project-specific augmentation strategies (see text box) and capitalizing on revenue opportunities from siting denser, more powerful batteries closer to urban loads.

Comprehensive End-to-end Solutions. Partners who offer a full suite of professional services can support projects throughout the entire lifecycle: from early-stage development, interconnection, and deployment through asset operations and performance. This allows developers, asset owners, and independent power producers to meet the unique needs of specific projects while scaling entire clean energy portfolios.

Flexible Procurement Options. With the profusion of hardware options available on the market, partners offer value by vetting OEMs, verifying their service footprints in the U.S., and understanding the specifications, capabilities, and requirements of a wide range of battery and PCS components. And since integration is key to deploying modular storage successfully, partners should bring extensive experience configuring different types of energy storage and solar + storage systems.

Long-Term Services & Support. With projects typically operating for upwards of 25 years, services and support contracts from partners can offer valuable peace of mind. Elements can include access to a Remote Operations Center (ROC) and warranties for the entire system and/or individual components, in addition to guarantees for battery round trip efficiency (RTE) and even overall system availability. Partners also must demonstrate software offerings adhere to the strictest cybersecurity standards to ensure system safety.

Next Steps

Taking a modular approach could bring significant advantages to your large-scale energy storage or solar + storage project. If you have questions or want to discuss your needs with a leading software and services provider, please contact us anytime at sales@stem.com. Our experts bring more than a decade of pioneering experience in markets across North America and are heavily invested in partner success.

About Stem, Inc.

Stem is a global leader in AI-enabled software and services that enable its customers to plan, deploy, and operate clean energy assets.

The company offers a complete set of solutions that transform how solar and energy storage projects are developed, built, and operated, including an integrated suite of software and edge products, and full lifecycle services from a team of leading experts.

More than 16,000 global customers rely on Stem to maximize the value of their clean energy projects and portfolios. Learn more at stem.com.

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