Five lessons from the storage frontline


RES' Jake project; one of the pioneers

Credit: RES

Grid storage | Deploying battery storage at grid level is relatively uncharted territory, but a number of pioneers projects are now in the ground. Patrick Leslie and colleagues at RES, which built some of the first wave of storage projects, teases out the key technology, finance and regulatory lessons the industry can learn from these early experiences

Renewable Energy Systems (RES) started developing battery energy storage projects over six years ago. In early 2014 RES commissioned its first project in Ohio, a 4MW lithium-ion battery for frequency regulation in the PJM interconnection area of the North-Eastern United States. In total, RES has now completed six projects for a total of 73.4MW/30.8MWh and has six further projects in construction phase. Inevitably, there have been valuable lessons learned along the way. Heeding these lessons will be important for developers, utilities and asset owners as the storage industry grow further.

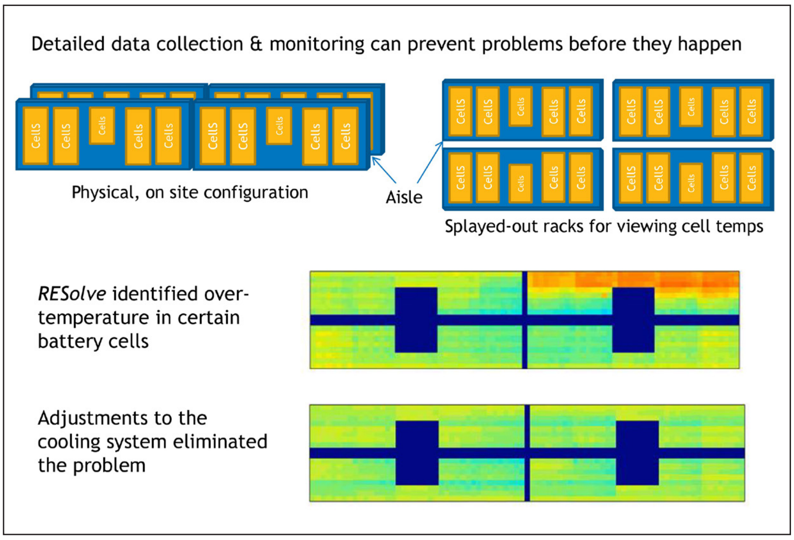
1 - Controls and monitoring are essential to ensure safety and maximise value for owners

Lithium-ion is currently the battery of choice for grid-scale energy storage, and individual projects are scaling up to the tens and soon hundreds of megawatts. These battery cells have certainly proven themselves in laptops, cell phones, and electric vehicles, but for large-scale grid energy storage, the battery system architecture is quite different. Large grid batteries typically have long battery strings, sometimes with as many as 300 cells each. The performance of the system often hinges on the weakest link, which introduces new challenges and some risks. With grid energy storage projects that contain thousands of cells, the controls and data acquisition systems are critical.

Failure to properly monitor and manage these long strings can result in poor performance, premature degradation, and potentially what Tesla's Elon Musk would call "RUD" (rapid unscheduled disassembly). A battery fire at a grid energy storage project is the last thing this industry needs while it is just gaining momentum. Further, a project's revenue may also hinge on how good the controls are. For example, as the PJM market becomes saturated with energy storage the system operator has changed the market rules to rank and call storage resources by their performance score. A few percentage points can make the difference between being called into the market, or sitting on the sidelines.

There are many control systems within a typical energy storage system (ESS). Each string of cells has a battery management system which reads individual cell conditions such as voltage and temperature. Each power conversion system (PCS) has its own control system. The ability of these components to work together lies in the site controller.

RES has developed a proprietary site controller, RESolve, which interfaces with the OEM battery management system and PCS controllers and allows greater visibility of and control over the overall system (Fig. 1). The site controller's functions are twofold: first it must aggregate many PCSs and strings of cells into a single site and second it must make dispatch decisions given any number of internal and external pieces of data. Aggregating many cell strings and PCSs requires the site controller



Credit: RES

Figure 1. How site controllers monitor and maintain the health of energy storage systems.

to ensure that both components are available to operate safely and without damage to either component.

Next the site controller must split the dispatch signal between all of the PCSs and cell strings while optimising state of charge (SOC) balancing, PCS efficiency curves and degradation. The site controller will also take input from the energy storage system, the network and remote signals to make real and reactive power decisions and commands which will allow the ESS to optimally perform its service in the now, but also positioning the SoC to be ideal for what is likely to happen in the future.

While the site control requirements in PJM frequency regulation projects are relatively straightforward, as the revenue is generated by a single application, future project applications will require far more sophisticated control strategies to maximise the value created by the ESS.

RES' recently announced project with Western Power Distribution, the largest distribution network operator in the UK, is a good illustration of the importance of advanced control systems in developing multiple layers of value from a single battery asset. The project will see a 300kVA/640kWh lithium-ion battery installed at an existing UK solar park, and will demonstrate nine different use cases for integrating energy storage with solar PV. These are set out in Table 1.

RES will use RESolve to provide 24/7 management of the battery's operation for this project, to allow scheduling of services and ensure the different value streams are delivered as expected. RESolve has been developed with these requirements in mind, and includes a wide range of operating modes as diverse as voltage control, solar ramp rate control and demand charge management, alongside a sophisticated scheduling system that allows for multiple operating modes throughout the day, or even concurrently. In addition, advanced SOC management techniques are employed to ensure the ESS is able to deliver the service when it is most valuable.

RES is actively developing several projects in the UK where we will optimise multiple storage assets across several values streams. These include frequency response, distribution constraint management and peak charge avoidance across a combination of grid connected energy storage projects and energy storage located behind the meter on generation or industrial sites.

2 - Integrated solutions are essential for cost-effective design, successful operations and commercial simplicity

A complete ESS is far more than just batteries and an inverter – numerous components are integrated to make the whole (Figure 2). All are important, and most are essential to good performance and longevity. Despite efforts underway to make the components "plug-and-play", the industry is not there yet. The integrator role remains essential for end users who want a project with few headaches and where one party is responsible for its ultimate success, from design and engineering through to long-term operations and maintenance.

Some of RES' projects to date have been done with a single vendor supplying the entire integrated battery and inverter system, and RES engineering, procuring and constructing the balance of systems (transformers, wiring, civil works, and controls). RES also has experience with full integration of an ESS using different vendors for the batteries and inverters. The latter approach introduces complexity but can be well worth the effort for certain projects, depending on the intended use case, and it gives more flexibility to achieve a design that will result in a safe and reliable system.

Integration of the ESS with the local electricity grid is critical. The grid connection process can be time consuming and challenging, so intimate knowledge of the process, network standards and operating protocols are key for on-time and on-budget project delivery. The ESS must seamlessly interact with the complex grid environment of protection schemes, metering and controls. These requirements will change on a project-by-project and client-by-client basis. For example, utility customers will often request significant changes to standard designs in order to meet their particular definition of "utility grade". This is something that many battery and inverter vendors are not familiar with, and to successfully deliver a project, holistic engineering and expertise with the intricacies of the local electricity grid is essential.

Holistic engineering also plays a part when considering how the balance-of-system marries with the OEM equipment. RES has found several examples where a design change that adds hundreds of pounds to the storage equipment cost

1.	**Sell electricity for higher price per kWh**
2.	Shape generation profile to demand
3.	Peak lop network demand
4.	Raise minimum demand to limit voltage rise
5.	Voltage control
6.	**Peak lop generation to enable larger solar parks**
7.	Smoothing/power quality
8.	Change peak lopping level
9.	Constructive interactions (between modes above)

PV owner benefits

DNO benefits

Table1. Nine use cases targeted by WPD solar-storage project.

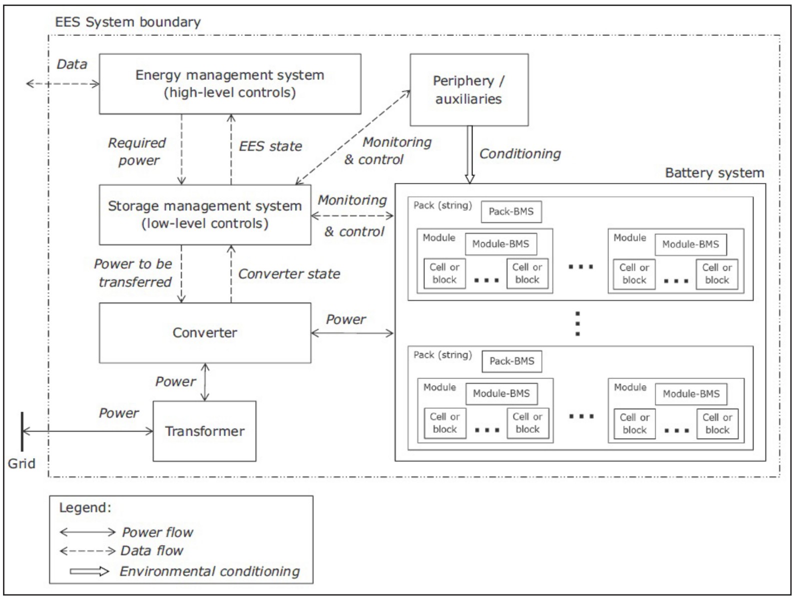


Figure 2. Diagram showing the main elements of an EES system, including device, converter, auxiliaries and management systems [1].

ends up saving thousands on the balance-of-system cost.

In order to deliver a successful storage project it is a great simplification to have a single party in control of the design, development, permitting, detailed engineering, testing, warranties and operations to ensure there are neither contractual gaps nor overlaps. This is achieved by provision of 'fully wrapped warranties' where the client only looks to a single company for all warranties on a project. Clients prefer this, especially when they do not have significant experience with contracting for and owning energy storage technologies; however, it is still quite unusual in the market as energy storage providers typically pass through manufacturer warranties and then the clients end up looking to multiple parties for warranty claims related to different parts of an installation.

3 - Financing a large-scale battery storage project is possible

Extensive deployment of storage will not happen until projects can be financed with reasonable ease. The same is true for any growing industry. The solar market has soared once given access to project finance for large-scale projects. The good news is that mainstream financial institutions are becoming familiar and comfortable with financing battery storage projects.

A great illustration of this was the announcement in October 2015 that RES and Prudential Capital Group had closed on the financing of the 'Jake' and 'Elwood' battery storage projects in Chicago. RES developed and constructed the two projects, and combined they offer a flexible power range of 79.2MW. Each project has a nameplate capacity of 19.8MW and the ability to store 7.8MWh of energy. The financing is the first non-recourse senior project financings completed for a utility-scale battery storage system in North America. The financing included a preferred equity investment representing approximately 50% of the total equity and non-recourse senior secured project financing debt representing approximately 50% of the total project costs.

A major challenge with this undertaking was that it required a great deal of education on both the technology (battery storage) and the market (frequency regulation in PJM). A great deal of education was necessary for all involved, including the insurers who were aware of the early problems that some grid storage vendors had. After the counterparties became comfortable with the technology and the market, the deal became much like other project financings.

Ultimately what made this financing successful was the fact that RES has experience with similar deal structuring with wind, solar, and transmission. The projects used a single large and well known OEM technology provider for the battery and inverter system, and were backed by a robust warranty. The project cash flows had certainty as they were backed with hedge on frequency regulation prices, with the debt raised to match the tenor of the hedge. The projects were large enough to warrant the time and cost to structure the transaction, and the same counterparty provided both the debt and equity.

4 - Regulations and (the lack of) market rules continue to create uncertainly, which places additional burden on the early projects

Despite strong progress over the last several years, lack of clarity on certain regulations and with market rules continues to hinder progress in the grid storage industry. For example, as RES developed its first project in Ohio, it was clear that the US Federal Energy Regulatory Commission (FERC) would consider the project as a generator, but it was initially unclear whether the State of Ohio would determine it to be generation, transmission or distribution. This led to significant uncertainty around both property tax and sales tax leading to material differences in projected return on investment. The next hurdle was with the IRS, the US tax authority. The rules were unclear as to what

The Jake and Elwood battery storage projects attracted the first non-recourse senior project financings for storage in North America.

Credit: RES Corporation

depreciation rate could be applied, which also made a measurable difference to the projected economics.

Unfortunately the same regulatory uncertainty and unsuitability of existing network and market arrangements for storage is strongly evident in other markets, such as the UK. Given that the UK has historically had very few operational electricity storage sites, UK energy policy, market arrangements, network access and charging rules are not adequately designed for storage. This results in a number of unnecessary and no doubt unintentional barriers to the uptake of electricity storage.

For example, the application in the UK of 'final consumption' levies to energy that is imported by an ESS only to then be exported for use by its actual final consumer creates a situation where energy storage needs to 'buy high and sell low'; hardly a route to a sustainable business. In addition, while the regulatory position of storage is unclear (is it generation, is it demand, or is it another new category?), it is difficult to develop the necessary solutions to industry codes to enable the uptake of storage. In any market, until such situations are clarified is clarified it will be hard to realise the value that storage can provide.

5 - Long-duration lithium-ion is becoming viable

It is commonly assumed that lithium-ion batteries don't work for long-duration applications. RES believes otherwise and is proving that point. The company is constructing a six-hour energy storage project for a US utility in a dense urban pocket of a major East Coast city and lithium-ion technology has proven to be the best choice across a range of considerations including cost, safety and noise performance, and land use.

The driver for the project was a particularly challenging transmission and distribution constraint faced by the local utility. Demand growth in a specific area began to overload two sub-transmission feeders serving two substations. The traditional solution would have been a new substation, switching station and sub-transmission feeders at a total estimated cost of roughly US$1 billion. The utility chose instead to procure an innovative portfolio of energy efficiency, demand response, distributed generation and energy storage to defer the need for the upgrade. The energy storage system serves an important role in the overall solution given its flexibility in being able to fill any gaps from the less predictable and dispatchable resources such as the energy efficiency measures.

Notable price declines in lithium-ion battery cells make help make projects like this possible and continued projected price declines will open up even more opportunities for batteries. The future offers much potential for new energy storage technologies that will drive down the cost of long-duration storage, e.g., flow batteries, but considering that most alternatives are currently not seen as 'bankable', lithium-ion remains the best bet in the near term. Many of the press releases for new storage technologies generally refer to pilot projects or demonstration systems. Innovation and demonstration projects are essential, and certainly one of these technologies will replace lithium-ion at some point, but grid-scale systems being deployed today must operate with high reliability and safety for at least 10 to 20 years. Utilities have high standards and all new technologies will need a substantial period of vetting before they can be deployed on a broad scale.

Safety is paramount and, especially given the dense urban location in this case, fire safety received intense attention. Some, but not all, lithium battery chemistries are subject to a rare but possible condition called thermal runaway, which can create a fire that destroys the entire battery system. Cell and system design can and must be used to reduce or eliminate the potential for thermal runaway. Monitoring systems can identify and warn of potential safety issues, and properly designed protection, monitoring and fire suppression systems can assure that any fault does not cause danger to life or property.

Noise can also be a significant consideration. While the batteries do operate silently, certain ESS designs can feature large fans and air conditioners that can create a surprising amount of noise. This can cause permitting challenges and must be considered early on during the design process.

Finally, land is at a premium in big cities and as such this project needed to fit in a very tight footprint. As of today, lithium-ion batteries represent the highest energy density of all commercially available batteries, which means smaller enclosures and foundations, less balance of plant (conduits, junctions, etc.), and overall smaller project sites, and fewer fire suppression systems. Additionally, given the high efficiency of lithium-ion batteries (88%+), cooling loads are minimised, reducing the size of heat rejection equipment such as vent fans and air conditioners that is required.

Conclusion

It is an exciting time for the energy storage industry. The technology has firmly demonstrated the role it can play in electricity systems and the value it can bring to consumers. But this is just the beginning and there is much to be done before the industry is considered fully established. The industry must prove that it can consistently provide utilities with high-reliability and predictable operations, asset owners with 'bankable' returns, services buyers with high performance and consumers with value for money.

For RES, the lessons learned about the need for high performing controls and monitoring; the value of a highly integrated design and delivery approach; the success factors needed to secure energy storage finance; the importance of really understanding local regulations and how they can create unintended impacts on energy storage business cases; and the viability of lithium ion for much more than just short duration business cases, will be crucial as we seek to play a leading role. ■

Authors

Patrick is responsible for US energy storage business development & strategy, with a focus on the economics of battery storage. Before joining RES, Patrick developed two battery storage projects for Puget Sound Energy, an investor-owned utility in the Pacific Northwest. He also worked on large-scale power plant development and acquisitions.

Andy Oliver is chief technology officer for the Americas and global head of storage for the RES Group. He has been involved in over 3,500MW of operational wind and solar plant. Over six years ago he set up an energy storage division within RES and the company now has 88MW/52MWh of energy storage either operational or under construction.

John Prendergast leads energy storage project development for RES in the UK and Ireland. This includes the recent signing of RES' first UK energy storage project; a battery system integrated with solar PV and delivering nine different operating modes. Prior to this, John worked on RES' first UK solar PV projects.

References

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