

Augmentation strategies to manage long-term battery degradation

Battery oversizing | With storage playing an increasingly central role in the energy transition, the importance of managing battery degradation is coming to the fore. Giriraj Rathore of Wärtsilä Energy Storage & Optimisation explores some of the main strategies for successful battery augmentation as a means of offsetting the impacts of system degradation



Credit: Wärtsilä

Energy storage is the backbone of the renewable energy transition, able to offset periods when the wind isn't blowing and the sun isn't shining. With broad market recognition that energy storage is key to catalysing a future powered by zero-carbon energy sources, the sector is experiencing robust growth. Energy storage deployments in 2023 are on track to double those of the year prior. By the end of the decade, total capacity is set to expand tenfold, surpassing 400GWh.

All battery-based energy storage systems degrade over time, leading to a loss of capacity. As the energy storage industry grows, it's critical that project developers proactively plan for this inevitable 'degradation curve'. Failing to do so will not only limit potential revenues but could even jeopardise the role of energy storage

as a key enabler of grid stability and, by extension, the energy transition.

As the initial wave of grid-scale energy storage deployments begins to mature, managing the effects of battery degradation will emerge as a key strategy for developers looking to future-proof assets and accelerate renewable energy adoption. Many industry experts suggest that augmentation is poised to be the solution of choice, allowing developers to take advantage of declining battery costs and technological advancements.

Understanding battery degradation

Battery degradation in energy storage systems is a natural phenomenon. Just like portable electronics wear out to become less efficient over time — think of how long your old phone can hold a charge —

the amount of energy that can be stored and dispatched from energy storage systems gradually declines. Whereas the average rate of battery degradation in electronics or electric vehicles is generally predictable, it's harder to calculate the decline of energy storage systems with similar accuracy. The rate of degradation and capacity loss is influenced by a variety of factors, including frequency of use, operational pattern, battery chemistry, and ambient operating environments.

Energy storage systems that engage in heavy arbitrage are particularly prone to rapid degradation. Arbitrage strategies involve purchasing and storing energy when prices are low and selling and discharging it when the demand for energy increases. Optimal charging and discharging intervals often run contrary to preferred arbitrage opportunities, meaning developers have limited visibility into the pace at which energy storage systems lose capacity. This is significant considering nearly 60% of installed energy storage systems were used for price arbitrage in 2021 — a number that is expected to continue to grow.

Degradation rates also differ by battery type. There are several kinds of lithium-ion battery chemistries being used in the energy storage market today, and each comes with its respective benefits and drawbacks. Nickel manganese cobalt (NMC) had historically been the dominant chemistry for energy storage, but this is quickly changing. By 2030, lithium iron phosphate (LFP) is expected to be the dominant chemistry — growing from a market share of 10% in 2015 to more than 30% in 2030. The primary benefit of LFP battery technology is that it enables a

Augmentation will become increasingly important as battery systems age

longer lifespan compared to other lithium-ion chemistries.

Temperatures, both hot and cold, can have a significant effect on battery degradation. Higher temperatures may increase energy storage system performance in the short term, but eventually lead to higher degradation rates and a diminished lifespan. Once temperatures surpass 100 degrees Fahrenheit (approximately 38 degrees C), degradation in lithium-ion cells quickly accelerates. Prolonged exposure to extreme cold can also impact battery performance. When temperatures drop, internal battery resistance increases, which requires more effort to charge. This, in turn, lowers the system's overall capacity.

Managing degradation through oversizing or augmentation

Battery degradation in energy storage systems is inevitable. But it can be managed with careful planning and consideration. It can even present opportunities for developers to improve the profitability and efficiency of energy storage facilities.

Traditionally, developers have accommodated battery degradation by oversizing their installations at the initial outset of the project. This approach involves installing more battery capacity upfront than needed and typically consists of site preparation, wiring, and system integration. The excess capacity enables developers to offset the expected degradation losses over the years, allowing them to maintain the contracted capacity over the project's lifetime.

A key advantage of oversizing is that it doesn't require site mobilisation, permits, additional labour, or the commissioning of new hardware down the line. By front-loading the installation process, developers can keep their energy storage systems operational even as they contend with degradation. There's no need for assets to be shut down — either partially or entirely — for weeks or longer to perform retrofits. Oversizing also enables developers to lock in capital expenditures at the project outset, mitigating future cost uncertainty and helping to improve forecasting. As the cost of lithium-ion batteries continues to fall to new lows, however, developers may lose out on significant savings by taking this approach.

Alternatively, developers may choose to offset degradation by augmenting the capacity periodically throughout the project's lifetime. In this case, there must

be extra physical space with adequate electrical configuration in the initial project layout to add new hardware. Proper planning is critical to minimise downtime and risks associated with augmentation.

In 2013, one kilowatt-hour (kWh) of lithium-ion battery technology cost more than US\$730. Flash forward to 2021 and that price had come down to US\$141/kWh — a marked reduction of more than 80%. Had a developer opted to oversize their system back in 2013 as opposed to augmenting it years later, they would have paid almost twice as much while missing out on important technological advances that offer greater efficiency. Of course, battery prices do occasionally tick up — like in 2022 as a result of inflationary pressures and supply bottlenecks — but these can be seen as an exception to a much wider trend.

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Suppliers have since rebounded from 2022's difficulties and battery prices are once again trending downward. Costs are further expected to fall as battery manufacturers ramp up production. By 2030, lithium-ion battery capacity is set to more than double, which will go a long way towards alleviating supply shortages. Furthermore, the US National Renewable Energy Laboratory suggests that the costs of lithium-ion energy storage systems could decline by up to 47% by 2030.

As prices continue to fall, augmentation is becoming an increasingly attractive way for developers to mitigate battery degradation and capacity loss. It may not be right for every situation, though, as each energy storage project is unique and different augmentation strategies depend on the appetite for potential risk and reward. Still, the likelihood of further cost reductions — especially considering the already low price of lithium-ion battery technology — makes augmentation particularly alluring.

Choosing between augmentation strategies

There are two primary methods of augmentation — alternating current augmentation (AC) and direct current (DC)

shuffling — that developers can choose between based on their system type, grid connection, and needed services.

AC augmentation focuses on improving the interplay between the energy storage system and electrical grids, enhancing system stability, and enabling grid support functions. With AC augmentation, new physical infrastructure is added to the project, including inverters and Power Conversion Systems (PCS), which are responsible for making AC electricity usable in downstream devices like energy storage.

Alongside the PCS, new protective enclosures are installed to house essential components, including the batteries themselves and associated safety, control and monitoring equipment. The added capacity of AC augmentation can be installed without requiring significant modifications to existing equipment, minimising disruption. It also offers significant system flexibility, allows for incremental sizing, and presents an extremely low risk of technical complications.

However, there are a few drawbacks associated with AC augmentation that developers should keep in mind, particularly for grid-connected energy storage systems.

Adding new PCS equipment — while relatively straight forward from a technical standpoint — requires permitting and regulatory approval when connected to the grid. This process is cumbersome, time-consuming and extremely complicated, slowing down the ability of developers to augment their systems. These limitations don't impact energy storage systems that are independent from the grid, however. Islanded microgrids can forgo lengthy bureaucratic approvals, making them well-suited for AC augmentation. For grid-connected energy storage systems, DC shuffling is the more suitable augmentation strategy.

DC shuffling prioritises the internal distribution of energy within battery stacks to ensure balanced charging and discharging of individual cells and modules, which is vital for prolonging battery lifespan and maximising overall system efficiency.

Whereas AC augmentation primarily focuses on external interactions between energy storage systems and the grid, DC shuffling optimises energy distribution within battery stacks, delivering greater internal efficiency and resiliency.

By reconfiguring battery enclosures



Credit: Wärtsilä

The choice of augmentation method depends on the type of system, its grid connection and the services it provides

from one string of batteries and transferring them equitably throughout the system, DC shuffling leads to a more balanced distribution of energy across the battery stack.

A new string of enclosures is then introduced behind the PCS from which the existing batteries were shuffled. This addition guarantees that the overall system retains its power capacity and that the number of PCS units and the nominal power of the plant remain unchanged. This allows DC shuffling augmentation to bypass permitting and regulatory approval, as there are technically no new connections being made to the grid.

DC shuffling also benefits from lower equipment costs relative to AC augmentation, as there's greater repurposing of infrastructure. DC shuffling is well suited for grid-connected ESS, though it may not always be possible due to technical limitations, from auxiliary load breaker and busbar limitations to short circuit ratings. Consequently, developers must diligently evaluate the specific technical and operational aspects of their systems before deciding whether to invest in AC or DC augmentation.

Bringing it all together

There may not be a standardised rate of battery degradation in energy storage systems, but software can provide invaluable insights, helping inform augmentation decisions. Sophisticated energy management programs, such as ES&O's GEMS Digital Energy Platform, can gather operational data over a period to inform recommendations on capacity

enhancements that can result in significant monetary gains.

Energy management software is not only useful for making data-driven decisions, but it's also key to seamlessly and cost-effectively implementing augmentation strategies. Software optimises the dispatch of augmented energy storage systems and harmoniously integrates the new and existing equipment. Energy management software must be flexible and powerful enough to incorporate disparate battery technologies and capacity levels. In cases where new equipment differs significantly, a software system's ability to coordinate and control these diverse technologies is indispensable.

Developers must also consider the importance of complementary augmentation technology. Augmenting with batteries of different capacities can introduce significant complexities that need to be handled with the utmost care. LFP batteries, for instance, require different thermal management strategies compared to NMC batteries. Improperly integrating these technologies can lead to potential repercussions, including voltage imbalances that could trigger thermal runaway. Moreover, developers that incorporate battery modules from different manufacturers run the risk of software incompatibilities, which could impact monitoring and controlling processes and risk overall system performance and safety.

To mitigate these issues during augmentation — whether AC or DC shuffling — developers should look to leverage complementary technologies wherever

possible. The careful selection of augmentation equipment and the utilisation of advanced software solutions can help ensure the successful and safe augmentation of energy storage systems.

Battery degradation management will remain important into the future

The energy storage landscape may be dominated by lithium-ion battery technology today, but that could very well change in the future. There is a range of emerging technologies including sodium-ion (Na-ion), hydrogen, and long-duration energy storage (LDES) that have significant potential.

Na-ion batteries, for instance, offer a reduced environmental impact and safety benefits relative to lithium. Hydrogen, lauded for its high energy density and versatility, also holds great promise as a clean and flexible storage solution. Meanwhile, LDES technologies offer extended discharge periods, addressing the need for sustained power during prolonged lulls in renewable energy production.

These technologies, while promising, have not yet been deployed at scale. They will have to prove themselves individually at the grid level before developers have enough faith in being able to use them for augmentation. But as these up-and-coming storage technologies mature, they have the potential to reshape the augmentation landscape, providing developers with an array of options that can enhance the resiliency, efficiency, and sustainability of their energy storage systems.

With hundreds of gigawatts worth of battery-based energy storage systems operating at a global scale, mitigating capacity losses will become a central part of managing projects for developers and integrators in the years to come. Careful battery degradation management practices including augmentation will enable developers to drive greater performance, lower lifetime costs and keep the renewable energy transition moving forward. ■

Author

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