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The increasingly essential role of energy storage for grid security

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Until relatively recently, energy storage has been discussed primarily in terms of its potential contribution to a low-carbon grid – that is, as a resource to firm intermittent clean generation and support distributed resources.

While still a key consideration, the essential role of storage and the variety of benefits it offers to the grid are quickly becoming more broadly appreciated. As the US electric grid becomes more stressed due to massive increase in demand, years of underinvestment in transmission, changing and increasingly turbulent weather patterns, and policy uncertainty, storage (especially utility scale battery storage) may just be the magic bullet needed to help manage these impacts in the near and medium term.

Last year, the US electric grid saw additions of new generation capacity of more than 70 percent over the previous year, a trend that is expected to repeat this year. This is a significant increase, but it pales in comparison to the expected three-fold increase in demand over the next few years driven by artificial intelligence (AI) and data centre growth, and the electrification of transportation and industrial operations.

To accommodate the growth, trillions of dollars of investment will be required not only in a variety of supply sources, but also in technologies to modernise and support the grid and to optimise delivery. Storage is already playing a fundamental role in the expansion, and is expected to continue to gain prominence.

At present, batteries and pumped hydro are the main storage technologies in use in the US. Pumped storage projects represent over 20GW of capacity on the US grid, some of which are able to provide multiple days of generation capacity. Another 50GW is planned, although construction of these kinds of projects can be quite difficult to build due to a variety of factors, ranging from state and local regulations to geographical challenges to high costs and financing challenges.

In fact, over the past decade, of the additional capacity that has been added to the US grid in the form of storage, more than 90 percent has been batteries (including more than 20GW of utility scale battery storage in the past five years, according to the US Energy Information Administration). Only a small percentage is attributable to pumped storage, and most of that, upgrades to existing projects.

Battery storage has become increasingly affordable in recent years, making short duration battery technologies (typically one to four hours) a viable and economically effective option. Improvements have been made in battery life and safety, and costs have declined rapidly, even in the face of uncertain trade policies, supply chain issues and critical minerals shortages.

Researchers at both the National Renewable Energy Lab (NREL) and the Lawrence Berkeley Lab have highlighted how organised electricity markets in the US have tended to incentivise deployment of four-hour duration storage (which roughly aligns with summer demand peaks), with capacity rules that essentially provide the same compensation to four-hour batteries and longer-duration batteries, reducing economic incentives to deploy longer-duration storage.

The rise of winter peaks in recent years, however, along with growing appreciation for the additional functions that battery storage can provide to the grid, is prompting the industry to rethink the battery value proposition.

Valuing a battery resource is a more complex exercise than for other resources. The cost of a battery resource is deeply intertwined with the engineering operations of the grid, and the arbitrage function of battery storage complicates the determination of the market value of the resource. Moreover, battery storage provides a variety of values to the electric system. The cost will vary depending on which service is needed at any given time to optimise which market, and will affect how battery storage is bid into the market and at what level of charge. This sets battery storage apart from other distributed resources.

In the US in the near term, solar plus storage, especially battery storage, is expected to represent the majority of new capacity additions. However, critical questions include not only whether these additions can keep pace with demand, but also whether they are viable without the extensive policy support they received under the previous administration.

For the past several years, battery storage has had significant support from tax credits under the Inflation Reduction Act and state mandates to reduce carbon emissions. Now, the future of these incentives, especially at the federal level, is uncertain. Tariffs also pose a growing challenge. Even if a stable tariff regime were to prompt repatriation of manufacturing to the US (a trend that was already underway during the prior administration), this does not happen overnight. Rising domestic costs, disruptions to global supply chains for essential components, and the current volatile tariff regime are all taking their toll on the battery storage industry.

Importantly, even under ideal development conditions, batteries alone will not satisfy the magnitude of demand that faces the grid. Already, generation retirements are being delayed and some decommissioned units are being brought back online. Interconnection queues are lengthy – often taking from two to seven years, or longer. Some large loads, faced with immediate need for massive, reliable power supply, are turning to oil and gas majors to build their own (mostly gas-fired) generation.

In the case of hyperscalers committed to clean energy solutions, this represents an opportunity for other low or zero-emission resources needed to offset those fossil resources. Some are also exploring a variety of co-location and novel power purchase arrangements, although these, too, have their challenges.

Apart from batteries, other technologies demonstrating promising characteristics, with additional investment, may enter more prominently into the resource mix. Among these are solid state batteries, supercapacitors, compressed air, flywheels, liquid CO2 storage and clean hydrogen. The NREL has been working for a number of years on a low-cost, long-duration thermal energy storage technology that would use sand, which is cheap, abundant and has a high thermal stability across a very broad range of temperatures. This project is especially interesting because it can be integrated into existing infrastructure, such as by converting coal plants, that are already interconnected to the electrical system.

There is an acute need to harmonise the perspectives of storage developers, operators, the project finance community and regulators. This must happen quickly, so that the right incentives and signals are created to attract capital.

A few of these technologies are deployed in the US (e.g., compressed air and flywheels), although none has a significant presence on the US grid yet. Factors such as reduced dependence on critical raw materials, resistance to supply chain disruptions, and longer duration operability will all contribute to which ones are the more attractive investments and can most rapidly and cost-effectively be developed and deployed.

Several storage technologies that are being brought to scale outside the US also show promise. Denmark has deployed a molten hydroxide salt energy storage project, and announced plans to build a 1GW project that its developer hopes to commercialise in the near future. Molten salt storage offers a number of benefits including safety (a reduced chance of explosion and non-flammable, non-toxic components), extended life cycle without degradation, thermal stability, high energy density, and the ability to operate efficiently even in extreme heat or cold. Australia has recently completed a first of its kind industrial steam heat energy storage demonstration project. This technology, too, has the advantage of low cost and integration with existing infrastructure. And a Swiss company is deploying gravity-based systems using cranes, high rise buildings and mineshafts.

The tremendous increase in demand is creating challenges and opportunities not only in availability of supply, but also on the delivery side of the equation. As the grid becomes simultaneously more modernised and constrained, longer-duration technologies will be essential to optimising operations. Here, too, storage will play a major role in managing reliability and resilience at the grid and distribution levels. Storage can help to relieve transmission congestion, which means some transmission investment can be deferred. It also can help to improve utilisation of transmission lines constructed for remote resources, which provides added flexibility to the system.

Some thought will need to be given to valuing these attributes of storage. At present, the North American Electric Reliability Corporation, the entity responsible for grid reliability in the US, is reluctant to include storage as a contributor to reliability because storage is not yet predictable enough. For battery storage, this means that as technologies are developed, improvements to provide visibility into state of charge and the operating performance will be needed so that grid and market operators can make better decisions. AI is expected to help, but significant investment in both hardware and software will be needed to get there. For other technologies, cost, reliability and speed of deployment will be key considerations.

Finally, there is an acute need to harmonise the perspectives of storage developers, operators, the project finance community and regulators. This must happen quickly, so that the right incentives and signals are created to attract capital. Without a common understanding of the value of storage across the electric grid, deployment may be disjointed – a situation that the urgency of the moment cannot afford. ■

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