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Agility in managing electricity grids: The case for batteries

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Abstract

The deployment of renewable energy over the last decade has created unprecedented challenges for the planning and operation of power systems. Consequently battery-storage technologies have attracted great interest, as they allow utilities and network operators to adopt a flexible and adaptable approach to managing the electricity grid, balancing supply and demand. In this article we particularly examine the potential future role that batteries might play in grid management, and explore the drivers and barriers to greater battery storage use in major markets. We also highlight how this represents new opportunities for industrial companies and investors.

The rise in renewable energy has created unprecedented challenges for the planning and operation of an electricity grid that was built on the assumption of power being provided predominantly by large, centralized generation sources and consumed as soon as it is produced. As a means of addressing these challenges, battery-storage technologies are therefore attracting great interest, and this article looks at their future role and the drivers and barriers to their greater adoption in major markets.

Introduction

The electricity grid is in a state of flux. Low-cost renewables and the increased use of distributed energy generation represent profound challenges to the operation of a grid built on the assumption of power being provided predominantly by large, centralized generation sources, and consumed as soon as it is produced. In particular, the old model of stable baseload power being supplemented by gas and hydro for peaks in demand is giving way to a world where renewables predominate, supported by other, flexible generation assets for when the sun isn't shining or the wind not blowing. The severe pressures on power utilities in Europe and elsewhere (and their share prices) reflects the magnitude of this transition.[1]

[1] See: "The future of energy utilities," Prism 2/2013; "Radical change for European power utilities," Prism 2/2014

To confront the challenge of maintaining a reliable and affordable electricity supply while also providing acceptable returns to shareholders, utilities and network operators must adapt their business models, technology portfolios, and approaches. In particular, they must become more *agile*, being both flexible and adaptive in how they develop, deploy and manage grid assets.

Energy storage is seen as one key tool for improving the flexibility and adaptability of the grid, for example, by smoothing the output from renewable sources and storing energy in times of high generation for later release, when demand is strong. When it comes to storage, battery technologies have attracted particular interest due to their scalability, efficiency and rapid response. Additionally, there are strong synergies between battery use for energy storage and in other applications such as electric vehicles and consumer devices. However, there are barriers to the implementation of battery storage, such as regulatory uncertainty, commercial arrangements, technology maturity and associated costs.

In this article we examine the potential future role that batteries might play in the management of the grid in different geographies, based on a recently published[2], multi-client ADL study. We explore the drivers and barriers to battery storage, trends in major markets, lessons for market players and potential business case for batteries for industrials and investors.

Batteries for grid storage: drivers for use

Grid battery storage remains a small business today, with less than 1 GW deployed (the equivalent of enough capacity to power 725,000 homes). Nevertheless, several recent developments clearly demonstrate that the sector is taking off:

- Within four years the world’s biggest storage-capacity project in Los Angeles will be delivering over 100 MW for about four hours at peak periods
- In European countries such as Italy and the UK, national transmission service operators (TSOs) are undertaking trial deployments of storage technology, and learning lessons from a technical and commercial perspective

[2]See: “Battery storage: Still too early?” January 2017

- M&A activity is increasing; for example,Total's recent acquisition of Saft
- Companies such as Tesla and LG Chem are building huge "gigafactories" to supply burgeoning demand, at least partly from the grid sector

There are a number of specific drivers for the increased interest in battery storage:

- **Rising renewables penetration** – As the percentage of renewable generation grows, there is an increasing need for flexible capacity that is able to step in/out at short notice (seconds to minutes) due to fluctuating, unpredictable power generation in the network.
- **Increasing decentralization** – As the grid shifts towards distributed generation, there is pressure on the distribution network to accommodate this new and unpredictable generation capacity, especially since much distributed generation is "unplanned" and out of the control of the grid TSOs and distribution service operators (DSOs).
- **Tight flexible-capacity markets** – In many electricity grids, capacity margins have reduced, reflecting low flexibility in the system to accommodate intermittent renewables, and relatively lower capacities of firm supply buffers to be used in case of need on the grid.
- **Poor security of supply** – In some parts of the world aging and/or inadequate grid infrastructure means security of supply is not as high as it should be. This increases the attractiveness of batteries that can "back up" the grid during outages.
- **Rising peak-trough spreads** – Increasing quantities of "must-run" renewables can lead to periods during which supply exceeds demand, leading to very low or, in extreme cases, negative wholesale power prices. Conversely, lack of renewable generation (such as on non-windy nights when solar and wind assets are not active) coupled with high demand can lead to very high prices as expensive back-up generation is pressed into service. Batteries can smooth these peaks and open arbitrage opportunities, in which revenues are generated from charging/buying electricity during low-price periods and selling/discharging during high-price periods.

- **High retail electricity prices** – In some geographies, such as Germany and Japan, high retail electricity prices encourage the storage of self-generated energy (such as from solar) for later use.
- **Cross-industry synergies** – Batteries are, of course, used in many other applications, particularly in consumer electronics and, increasingly, battery-electric vehicles (BEVs). There are strong synergies across these applications in terms of technology performance (in which lithium-ion – Li-ion – technology, in particular, is applied across all three), production (in which volume growth and manufacturing optimization help to drive cost reductions), and usage (most obviously between grid storage and BEVs, in which BEVs can feed back to the grid in times of high demand and charge at times of low demand).

From this list we believe the key factors driving the attractiveness of battery storage are renewable penetration (grid and distributed) and the flexible-capacity margin, which is the proportion by which the total expected firm available generation exceeds the maximum expected level of electricity demand.

A selection of countries have been mapped against these two drivers, allowing the identification of countries with high potential for battery deployment, in Figure 1. Broadly, these fall into two categories:

- Countries with high renewables penetration and moderate capacity margins (Archetypes I and II in Figure 1). Germany is the classic example, although Spain, Portugal and Denmark share similar characteristics. Germany has seen a booming residential-storage market, partly due to policy measures to promote hybrid distributed systems (photovoltaic solar [PV] + batteries). However, the industrial and commercial sectors have so far lagged behind due to an unfavorable regulatory regime and high interconnectedness with neighboring markets.

- Countries/regions with moderate renewables penetration but low firm-capacity margins (Archetypes III and IV in Figure 1). The prime example here is the United Kingdom, although California, Belgium and Greece demonstrate similar characteristics. Recognizing the potentially key role that batteries may play in supporting grid operation, the United Kingdom has begun to make changes to the policy and regulatory landscape to further support the deployment of batteries. National Grid (the UK TSO) foresees the deployment of 1 GW of non-pumped storage by 2020, providing that regulatory barriers are removed.

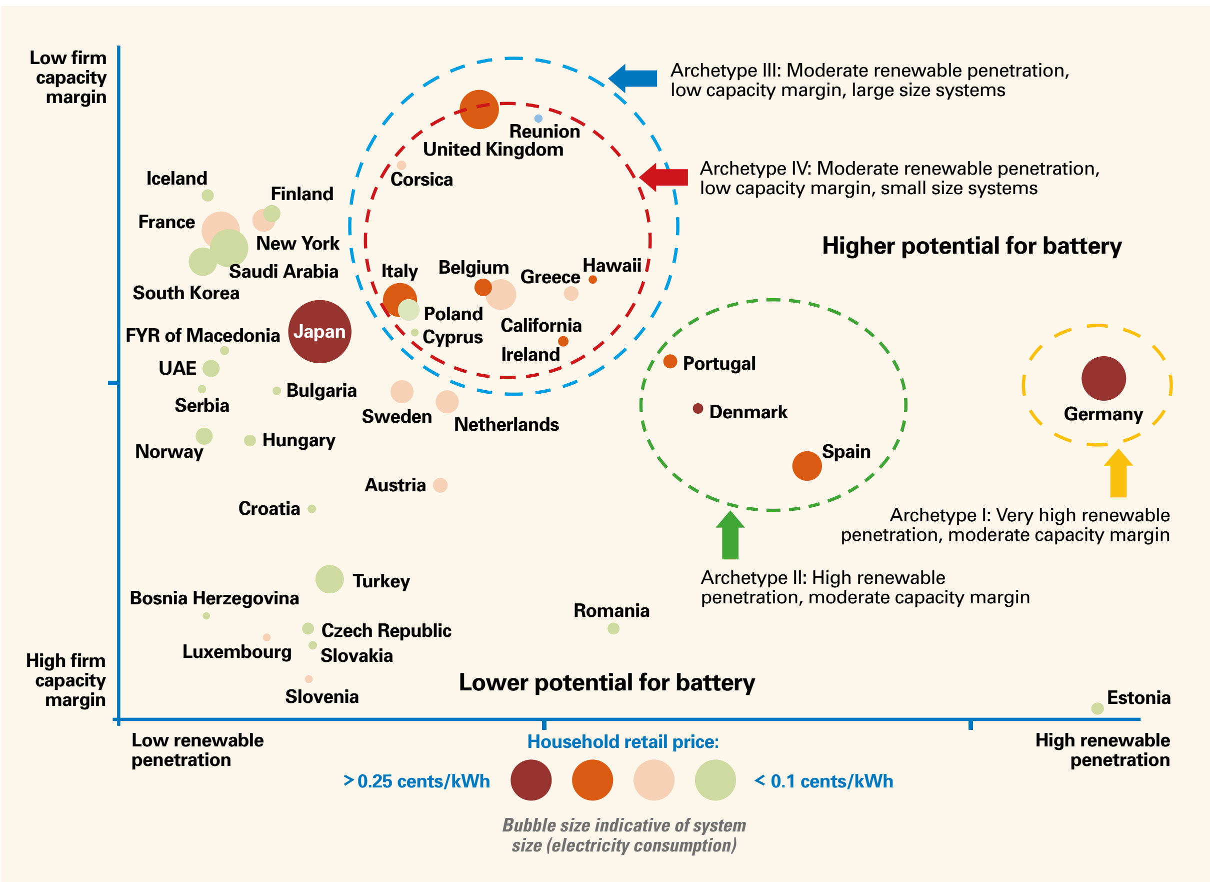

Figure 1: **Regional archetypes**

Challenges to the use of batteries

While the benefits of deploying battery technologies for grid management are clear, so far there has been very limited development of the grid-battery market in Europe. Why is this? We see three main reasons: cost, regulations, and alternatives.

1. Cost

The costs of batteries are too high for most grid applications to be viable at present, other than where local regulations incentivize deployment. Typical ranges for battery costs by energy stored and power delivered are shown in Figure 2.

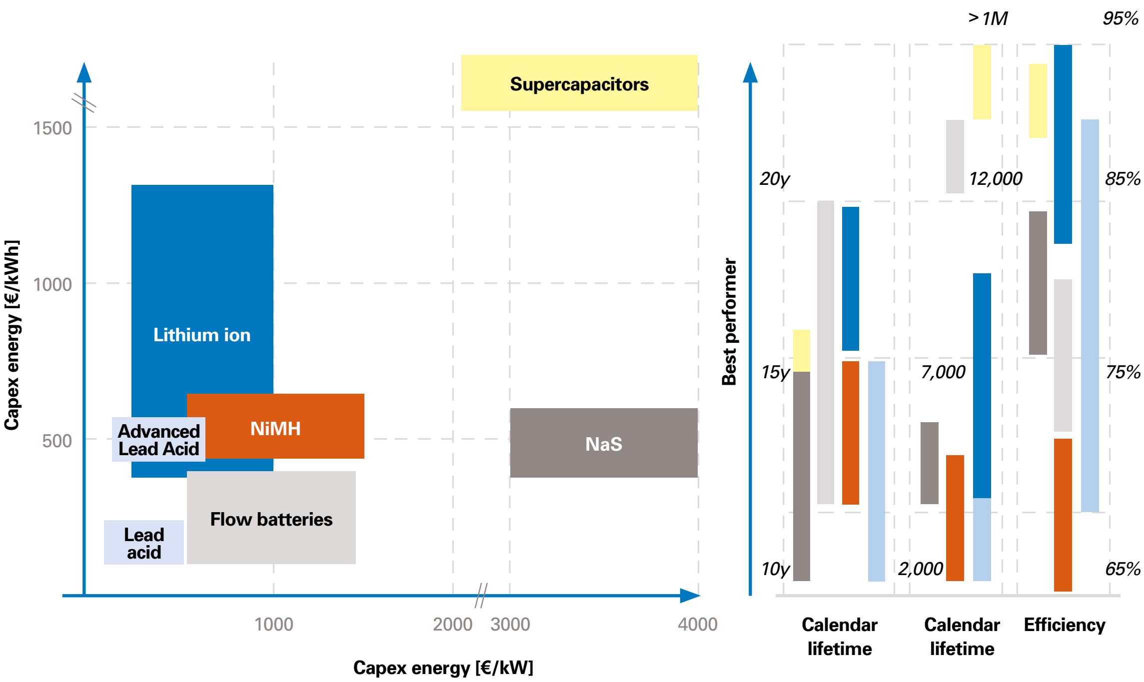

Figure 2: **Battery costs and performance**

However, the cost of batteries is reducing sharply. The industry has invested heavily in battery technologies that can also be used within electric vehicles and consumer electronics, such as lithium-ion technology. The cost of lithium-ion battery packs is reducing by 10–15% per year, and if this pace of development continues, they will fall to \$100–150/kWh by the early 2020s. At this point many grid applications will become economically viable.

2. Legislation and regulation

At present, in most countries regulatory barriers prevent the deployment of battery storage on grid, except in Italy, where the regulatory framework has been amended. System operators are therefore restrained from developing battery-storage solutions beyond pilot projects because of the regulatory definition of battery storage and the role the regulator expects the system operator to play. The development and ownership of batteries by TSOs certainly raise questions about market distortion and the funding of regulated monopolies, but there seems to be a clear case for their deployment in this way, in markets where conditions are not appropriate for commercial deployments.

It is therefore imperative that clear regulatory frameworks and market mechanisms are established to allow the development of storage assets, with clear targets for deployment. For example, California's Public Utilities Commission requires utilities to build energy-storage capacity and has clarified the market rules for battery aggregation. Following these moves, Southern California Edison (SCE) bought 261 MW of energy storage by the end of 2014.

Finally, there is a strong argument for providing direct incentives for use of battery storage to catalyze their development and bring costs down, which has worked in the renewables sector. The strong influence of regulation can be seen by contrasting Germany and Spain, two European countries with relatively high renewables penetrations. In Germany the residential storage market is booming because of the incentives provided (such as 30% investment grants and low-interest loans), reducing stress on the grid. In contrast, battery deployment in Spain remains very limited.

3. Alternatives to batteries?

Batteries are far from being the only option for balancing supply in a distributed energy grid with high renewable use. Other important options include interconnectivity, fast-ramping fossil-fueled plant, demand-side response, and other storage technologies.

Interconnectivity

Good regional and international interconnectivity helps in two ways. Firstly, the intermittency of renewables decreases over large areas – it is always sunny or windy somewhere. Secondly, integration over a large area allows for a greater mix of power sources to be utilized. For example, the proposed 1.4 GW UK-Norway interconnector will allow the UK to import predominantly hydro power from Norway, while interconnectors to France can utilize the large amounts of nuclear power there. High interconnectivity is a major reason the German industrial and commercial battery sector has not yet taken off.

Fast-ramping fossil-fueled plant

Fast-start and rapid-ramp fossil-fueled plant has played a key role in meeting peak power-supply requirements for many years and will remain important in the future.

Demand-side response

Demand-side response (DSR) is a further emerging approach for balancing the grid. Demand response refers to the reduction of electricity demand in response to either price signals or automated controls. This is already established in the generation market and, to some extent, in the industrial sector. The business model of incentivizing end consumers to reduce their consumption or switch to "behind-the-meter generators" in response to grid requirements has been widely tested and enabled through regulatory changes. However, the extent to which operators could rely entirely on third-party response and replace assets with DSR has not been fully proven.

Other storage technologies
Other energy-storage technology options under development include compressed-air energy storage, thermal energy storage, and kinetic energy storage (such as flywheels). Pumped hydro storage is mature and will continue to be used where geographic conditions allow. Some companies are experimenting with local pumped storage in combination with renewable sources such as wind.

Battery storage: The case for network operators and utilities

There remains considerable uncertainty in the details, timing and extent of the role batteries will play in grid management. How then should network operators and utilities position themselves to take advantage of the opportunities presented and react to changes in the marketplace? In our view it is essential for industry participants to adopt an agile approach. We see the key lessons as:

- **Adopt a flexible approach to the business model and partnering** – New, more agile approaches and partnerships will be required to fully exploit the opportunities presented by grid battery storage. For example, utilities may contract with third-party aggregators of distributed storage assets to provide back-up for their renewable generation sources.

  An extension of this is the virtual power plant (VPP) model, whereby a large number of generation and demand sources are aggregated into controllable power plants. The German, French, Belgian and UK markets have been incubating virtual power plants for the past five years. VPPs have started to become viable, and this evolution will accelerate as battery costs decrease and strong players such as Tesla enter the market.

- **Look to serve multiple applications from the same asset** – Given the challenge of developing a viable business case for a single application at present, a combination of applications is essential to stack revenue streams and build a positive business case.

  For example, utilities and generators could use battery storage for a number of complementary applications:

  - To decrease exposure to imbalance charges from renewables intermittency
  - To optimize asset production and sales in the wholesale market based on market signals (arbitrage)
  - To capture revenues from ancillary services and capacity mechanisms. For example, AES recently commissioned a 10 MW battery to provide fast-response ancillary services to EirGrid in Ireland
  - To support industrial or consumer groups in avoiding system charges, where these are calculated based on consumption at peak periods, and negotiate to receive a portion of these savings.

- **Develop a portfolio of storage assets and technologies** – Although Li-ion looks to be the most likely technology to succeed, at this point it is not clear which battery technology will win for most grid applications. Market players should look to develop a portfolio of assets and technologies, and not be tied to one particular technology approach. This is the model that Terna (the Italian TSO) followed by testing multiple technologies for similar applications.

  Moreover, it is not just about the battery technology. Other technologies, such as sensors, communication and software (for example, for modeling and prediction), and generation will also be important. E.ON, for instance, released its home storage system combining PV, storage, app and tariff in Germany in April 2016.

- **Use storage as a differentiator** – Utilities can leverage batteries as a differentiator in the retail market and a provider of flexibility services to TSOs. Engie is developing its 20 MW / 20 MWh energy-storage park in Belgium to provide R1 ancillary services, initially from different suppliers. It will then develop a pool of batteries that can be rented for applications such as industrial sites, for which it can provide demand response. Benelux utility Eneco has been supplying the Tesla Powerwall to its customers since the start of 2016. It then expanded its services to CrowdNett with the support of Tesla, SolarEdge and Ampard, whose software allows the remote control of residential batteries, facilitating provision of ancillary services. In exchange for the use of 30% of the battery capacity, residential customers receive a guaranteed €450 in compensation over the next five years.

Battery storage: The case for industrials and investors

Industrials and large companies may have a truly compelling case to invest in battery storage, for various reasons:

- Need to cope with power-outage issues (especially in South Asia and Africa)
- Company commitment to sourcing 100% power from renewables (e.g., Google, Apple and Facebook)
- Paying high tariffs for their electricity (such as in Italy)

Industrials have the option of outsourcing their battery-storage operations to power utilities or aggregators, or collaborating with DSOs and TSOs, potentially earning extra revenues by providing ancillary services to the grid (such as voltage stability or black start).

While we see few applications of this business model to date, it can provide a particularly good alternative for system operators that have their hands tied regarding their roles in storage activities.

Battery storage is a relatively young industry, and such projects do not have track records of five or more years of real returns, which makes the bankability for storage a challenge. However, recently, Advanced Microgrid Solutions and Stem raised significant money for new storage project financing ($200mn and $100mn, respectively). This behavior is very similar to the caution demonstrated by investors in early solar projects. However, as more data, in terms of revenues and returns, becomes available from the storage projects under operation, investor confidence will grow.

The emergence of leasing models can also become attractive to different types of investors, as was the case for the meter industry, representing low risks for stable revenues.

Insight for the executive – Fast move for some, wait for others

Battery storage is a much-debated part of the energy market solution, with both energy majors and technology providers investing heavily into research, development and try-outs to create successful business cases. The challenge is not technology: differences in market and regulatory conditions can make identical solutions worthwhile or pointless, as economic viability is determined by the revenue and profit models within the regulated energy industry in individual markets.

We recommend that executives looking to invest successfully keep in mind these guidelines:

- Tailor the solution (technology, ownership, and revenue model) to the local market conditions, depending on:
  - Market characteristics (the amount of renewables penetration, degree of grid interconnectedness, regional electricity generation mix, electricity network topology and system size)
  - Regulatory framework (revenue models, operational requirements)
  - Incentives and commercial signals
- Explore how to benefit from a combination of applications, as it is essential today to stack revenue streams to build a positive business case
- Influence energy-market design (such as the definition of ancillary services, access to grid services and the possibility of stack services) to make the most of battery storage and enhance the business case

Deployment of battery storage by industrial and commercial customers is likely to remain limited in the short term (two to three years), given its current challenging economics. However, the most promising applications will be grid-scale storage, and investors increasingly have this opportunity on their radar. Indeed, for grid-scale applications, it is time for early adopters to make a move. Power utilities are stepping into the market, and a series of large-scale commercial battery-storage contracts have been announced over the last year. Even if it seems early for big asset investments at this time, it is key for industry players to prepare their strategies now and plan for "rapid deployment" tactics to later embrace the larger opportunities that are currently emerging.

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