Storage of electrical energy is going to become vital as increasing amounts of decentralized and renewable generating capacity are connected to power grids. Jon Slowe surveys the technologies available and those under development – concluding that utilities, in particular, will be taking a greater interest in storage in the future.

Emerging electricity storage technologies

'You can't store electricity' is a phrase often used in teaching people about the electricity sector. Electricity markets are typically structured around this false principle. Why false? For three reasons – the third of which may have large impacts on electricity and decentralized energy markets.

- There is nearly 100 GW of pumped hydro storage capacity in Europe, North America and Eastern Asia. These systems interact with electricity markets, pumping water when electricity is cheap, and generating power when it is expensive. But as availability of sites for new pumped hydro is very limited, it has only limited potential for growth.
- Batteries storing electricity are widespread – not only in portable electric appliances, but also in businesses requiring secure and critical power. Lead acid batteries are at the heart of uninterruptible and standby power supply systems in businesses and industry. But frequent charging and discharging of these batteries leads to a rapid deterioration in performance, so current UPS (uninterruptible power supply) systems have very little potential to play a part in electricity markets.
- Most exciting is a new breed of electricity storage technologies – such as flow batteries, high temperature batteries, lithium ion batteries, flywheels, and advanced compressed air energy storage. Rapid advances have and continue to be made with all of these technologies. The modular nature of many of these technologies means they can de deployed at customer sites, at electricity substations, on microgrids, at wind farms, and even in electric and hybrid electric vehicles. These new technologies will play a significant role in future electricity markets.

This new breed of electricity storage technologies is already being deployed on utility networks. Japan is on the leading edge – nearly 200 MW of advanced high-temperature batteries have been deployed at industrial sites and substations, regularly shifting load from day to night.

Electricity industry engagement to drive forward markets for these emerging technologies is likely to be critical. Without this, technology developers will find niche markets to play in, but will struggle to fulfil the potential that their technology offers. Indeed it is the utilities – including network companies, vertically integrated utilities and transmission system operators – that stand to gain the most value from these technologies. Only a handful of utilities are actively engaging with them today – but we see a strong rationale for utility engagement, and expect this to increase over the next few years.

Electricity storage doesn't fit neatly into any of the conventional electricity sector 'boxes.' Some view it as a form of distributed generation, others view it as part of electricity distribution networks; while some see it as a way of smoothing large central generation. However it is viewed, it is highly relevant for decentralized energy and on-site power production. As more and more intermittent generation – much of which will be on-site or distributed – finds its way onto networks, storage can be used to avoid network upgrades and to achieve a better balance of generation and demand. In other cases, it can be a competitor to on-site power production, using stored electricity to supply electricity in place of an on-site generator.

THE EMERGING TECHNOLOGIES

Table 1 provides an indication of the development status of the technologies. The only widely used bulk electricity storage technology is pumped hydro stations, of which there is around 100 GW of storage capacity worldwide. Nevertheless, all these technologies have the potential to command a presence in the power markets of tomorrow. Most of these can be deployed at MW or multi-MW scale, making them attractive to energy users as well as utilities and power traders.

WHY ARE UTILITIES GETTING INVOLVED?

The truth is that the majority of utilities are not engaging directly with emerging storage technologies. Most are aware, and some are keeping a close eye on technology developments, but only a handful across the globe have installed systems on their networks.

Grid upgrade deferral

This application has come to the forefront in the US – where weak grids and long rural feeders provide drivers for some utilities to consider electricity storage. Increasing demand for electricity (especially summer peaks, driven by increased use of air conditioning) and an ageing infrastructure are necessitating large-scale renewal of distribution assets.

In many – even most – regulatory regimes, utilities would be able to construct a new transmission or distribution line and recover the costs through use of system charges or another form of regulated return. However, in some jurisdictions, putting off capital expenditure on grid upgrade for several years can be very attractive. Storage is used to meet a proportion of daily peaks, meaning average load on the network or transformer can be allowed to rise significantly.

There is only a handful of installations of electricity storage for grid upgrade deferral. American Electric Power, for example, installed the first MW sized sodium sulphur (NAS) battery in North America primarily to defer grid upgrade on a rural feeder. PacifiCorp installed a vanadium redox battery for the exact same application in Utah.

Utility reliability improvement

Utilities often have reliability targets imposed on them by regulators, or in some cases from customer demand for a premium product. Costs of planned and unplanned outages vary from country to country, but become very significant beyond a certain number of outages a year. In areas with a weak grid the ability to 'island' all the demand on a feeder using storage is potentially very attractive to utilities facing regulatory punishment for excessive blackouts.

Storage can be attractive to utilities that have long isolated feeders in remote areas – grid reliability is low and the alternative (installing a contingency feeder) is an expensive and time-consuming process. Furthermore, customer expectations for reliable power, as well as costs of blackouts, are constantly increasing. These factors are driving American Electric Power's next two battery installations, planned for 2008.

Pacific Gas and Electric is another high-profile utility installing storage specifically to increase reliability a 6 MW zinc bromine flow battery will be installed at a substation in 2009.

Load shifting and bulk arbitrage

Storage serves to shave the demand peaks – where the main value lies – and also to fill in the troughs. Reducing daily peaks provides obvious benefits to the electrical system as a whole: a smoother demand profile at any point on the network allows generation to operate at optimum capacity and reduces the need for peaking plant. Load shifting using storage is particularly attractive in a number of specific situations:

- Poorly inter-connected or small transmission systems (for example Japan – where the eight utility areas are very poorly interconnected).
- Small systems with little generation (islands) – storage allows small diesel gensets to be run more efficiently, often as hybrid systems with wind or solar power. This is a key area of interest in storage in parts of Europe.
- Systems with high nuclear penetration (again, for example Japan).

Tokyo Electric Power Company has supported over 100 MW of storage at its industrial customer sites. Japan is one country in the world where underlying imbalances between supply and demand have made for day–night price differentials that make load-shifting attractive in a number of sectors.

New York Power Authority (NYPA) is working with its customer, the Metropolitan Transport Authority of New York, to install a 1 MW battery at Long Island bus station. The purpose of the on-site battery is to shift bus station electrical demand from the grid from day to night.

Renewables grid integration

Many wind/solar farms are located in remote areas served by low capacity radial distribution networks. These networks often have insufficient capacity to ship the power to demand centres when the turbines are generating at full capacity. High penetration of wind can also bring grid stability issues on specific lines, for example with frequency and voltage control problems. These situation-specific grid issues have meant grid-companies are increasingly reluctant to guarantee connection for new wind farms.

There are many examples of grid systems struggling to cope with increased wind penetration:

- Parts of Spain are rapidly approaching limits in connecting new wind farms to their network. System operators are now approaching a stage where they are being forced to curtail wind farms if they are to be connected.
- Ireland, also approaching the limits of wind development, is probably the most promising market in Europe for storage to integrate wind into the grid. A weak grid, with little inter connection and a huge wind resource combine to offer a great opportunity for storage. A 6 MW flow battery is to be installed on a 32 MW wind farm and, if successful, this could kick-start a great market for storage.
- The primary wind development area in California (with a

potential of 4500 MW) is connected to the main load centres by a very constrained transmission line. Although a new line may be built in the future, storage is being considered to enable wind developers to connect in the shorter term.

Renewables output firming

Firming of intermittent renewables, especially wind, is an issue of increasing concern for utilities. The concern is manifesting itself in three ways:

- At high levels of wind penetration, electricity generation may exceed demand (or may interfere with the running of baseload plants, such as nuclear).
- Variable wind speed will at some times lead to rapidly changing levels of generation – a particular concern is where wind increases push every turbine on a wind farm over its cut-out wind speed, meaning generation can drop by tens or hundreds of megawatts in seconds.
- Forecasted changes in wind generation (over tens of minutes and hours) will put a premium on flexible and peaking generation.

These issues are manifesting themselves in a number of markets, including Texas, Ireland and Japan. The Japan Wind Development Company is installing 34 MW of batteries at its 51 MW wind farm in Rokkasho.

Ancillary services

Historically, vertically integrated utilities provided their own ancillary services, but today market reforms have opened up provision of these services, as regulators try to drive down costs. Storage technologies can be well suited to provide several of these services – in fact provision of ancillary services may well provide the greatest financial opportunity for emerging storage technologies in the coming years.

The different ancillary services are attractive to different storage technologies. Frequency regulation is suited to technologies with high power and low energy. Beacon Power, a flywheel manufacturer, is stepping up to take full advantage of this. It plans to construct 20 MW flywheel plants in the US to provide a frequency response service to the system operators.

Provision of primary reserve is another example of an ancillary service. Energinet.dk, the Danish TSO, is developing a 1 MW, 2 MWh VRB system at Riso for just this application. If results are promising, a similar system will be installed at a substation at the beginning of the interconnector to Sweden. The TSO sees this option as a potentially cheaper alternative to purchasing this service from a conventional power plant.

The Golden Valley Electricity Association installed a 27 MW nickel cadmium battery to provide primary reserve (spinning reserve) on its main feeder into Fairbanks, Alaska.

IMPLICATIONS FOR UTILITIES

We have classified these technologies as 'emerging' as they are approaching commercialization or have recently been commercialized. However, in most cases these technologies are still expensive, and do not offer a compelling economic proposition. Utilities shutting their eyes to these technologies may feel they are not missing anything of significance.

Careful consideration of a utility strategy may result in a decision to do nothing now. But we believe that drivers for storage will become stronger and stronger over time, and that the long-term future for storage looks very rosy. The electricity network in the US will become more and more constrained and the bureaucratic hurdles associated with laying new transmission lines will remain prohibitive. The European network may be strong, but ever-increasing penetration of renewables is quickly causing serious problems. And importantly, the cost of storage technologies is falling.

This is not to say that electricity storage will be a certain winner – there are other alternatives to solving the above challenges. However, the promising results from current installations would suggest that there will be a place for these technologies in the electricity networks of the near future. How big a place and how near a future is not clear, but utilities that are prepared now to understand how storage can be used, and develop and implement a strategy will be well placed to respond as opportunities open up in the future. And in some applications, such as provision of ancillary services, first movers will gain a significant commercial advantage over their competitors.

TABLE 1: Technology development status

Commercial	Pre-commercial	Demonstration phase	Developmental
Pumped hydro	Flywheel	Electrochemical capacitor	Lithium ion (grid applications)
Flywheels (local power quality)	Flywheel (grid device)	Hydrogen loop	Super-magnetic energy storage applications)
Compressed air energy storage (CAES)	Zinc-bromine battery		
Lead acid battery	Vanadium redox battery		
Ni-Cd battery			
Sodium sulphur battery			

Source: Delta Energy & Environment

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