ENERGY STORAGE: BATTERIES AND BEYOND

Viable, large-scale energy storage solutions could transform electricity generation and transmission and improve grid reliability, while making the economics behind renewable energy generation more attractive. Although the technologies exist, considerable challenges still have to be overcome. As Nancy Floyd, founder of Nth Power, once said, "Whoever figures out the energy storage issue will make billions of dollars."

ELECTRICITY is a wonderful thing, but it lacks one important quality – unlike other energy sources, it cannot easily be stored. The electricity market today operates on a 'just-in-time' basis. To avoid the need for storage, utilities simply build excess generating and transmission capacity, creating an entire infrastructure capable of meeting the highest demand for power, even though this is only needed for a relatively small percentage of the time.

A number of factors have combined to make this a less desirable option – high fossil fuel and infrastructure prices, fears over climate change and energy security as well as planning obstacles to building more power stations.

Although electricity itself cannot be stored, it is easy to store energy in other forms and convert it to electricity when needed – a process described by Martin McAdam of wind company Airtricity as "like TiVo [the TV programme storage technology] for electricity". Energy storage has an important role to play in the global energy system, one that has not yet been fully realised.

There are a number of drivers for energy storage. It would cut the need for new generating and transmission capacity by allowing power stations to be run more efficiently and cost-effectively. Baseload generation units would run outside peak times and the energy would be stored and then sold when needed, making them more cost efficient. It would also defer the need for expensive transmission expansion by selectively injecting power into the grid to improve the flow of electricity during heavy periods of demand.

Energy storage significantly improves the reliability of the grid. A new factor, but one that is growing in importance, is the ability to guarantee power quality. This is vital in a computer-run economy, where minute variations in power output can trigger disruption to machinery and plants costing millions of dollars.

On a larger-scale, the fragility of the grid in Europe was amply demonstrated recently when an overload in Germany's power network triggered blackouts in France, Spain, Italy and Austria. Similar outages were experienced across the northeast US in 2003.

Energy storage will play a key role in making renewable energy viable. One criticism of renewable energy sources is that power output is not constant and often not generated when it is most needed. If the power can be stored and sold at peak times, making the energy 'dispatchable', the economics of renewables become much more attractive. Storage can be used in four ways for renewables – off-grid, distributed generation support, dispatchable wind and baseload wind.

There are three main timeframes for the application of energy storage. In the long term (hours), it allows a decoupling of electricity generation and consumption: power can be produced when it is cheapest to do so and sold when it gets the best price. In the medium term (seconds or minutes), it assures continuity of service when switching from one generation source to another, while in the short term (milliseconds to seconds) it prevents poor power quality from disrupting sensitive equipment.

ANALYSIS

MAIN TYPES OF POWER STORAGE

COMPRESSED AIR ENERGY STORAGE

About two-thirds of the energy produced in a conventional gas turbine is used to pressurise the air for combustion, according to the US Department of Energy. CAES systems use off-peak electricity to pre-compress the air, which is then stored in an underground reservoir and released at peak times to operate the turbine. By decoupling air compression from turbine operation, a CAES plant uses all of its mechanical energy to generate electricity thus increasing the amount of power that can be produced per unit of fuel by two to three times.

In a refinement of this technology, General Compression, a US company, uses wind turbines to compress the air, allowing it to offer, it claims, the lowest-priced wind energy in the world in a wide range of applications, including energy on demand, CO2 sequestration and liquid air products. Other companies involved include Ridge Energy Storage and Dresser-Rand Company. There are two CAES plants in the US and one in Germany.

PUMPED HYDRO POWER STORAGE

Pumped hydro power storage is the largest and oldest large-scale power storage technology. Water is pumped from a hydro-electric plant's lower reservoir to the upper reservoir in off-peak hours, to be released at peak demand times. This is the most developed and best value proposition in energy storage, but it also has the worst prospects in terms of growth. Most available sites have been developed or have high environmental and financial costs. They also have long lead times and have to be situated in remote areas, given their size.

MAIN TYPES OF POWER STORAGE CONT'D

BATTERIES

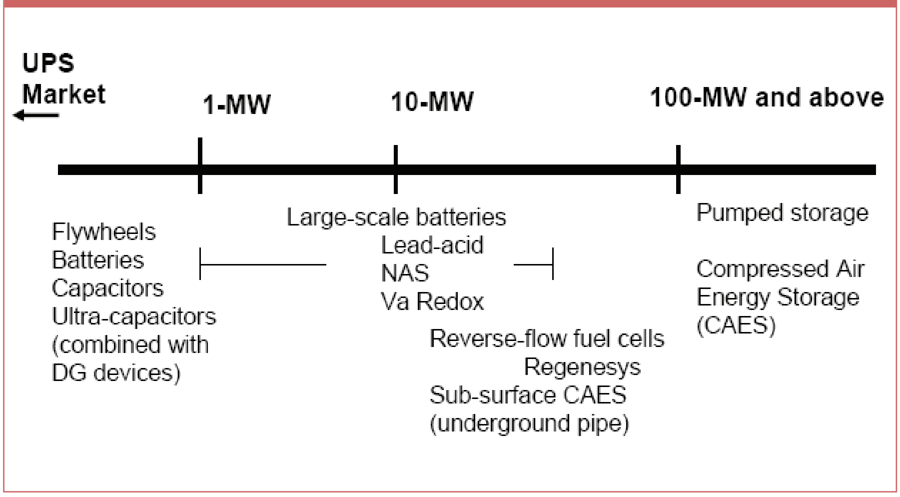
LITHIUM ION (LI-ION) BATTERIES. Li-ion offers significant benefits over conventional lead-acid and nickel metal hydride (NiMH) batteries, including reduced weight, cost and improved performance. This has led to Li-ion rapidly becoming the technology of choice for portable battery applications, such as mobiles and laptops, as well as for hybrid electric vehicles. The lithium rechargeable battery market is projected to reach USD 7.0bn in 2015. A number of large manufacturers make Li-ion batteries, such as Sanyo, Matsushita and Sony, currently under siege after some of its laptop batteries caught fire. Other Li-ion companies include Saft of France and Japan's Hitachi. US silver-zinc battery technology developer, Zinc Matrix Power, uses water-based battery technology, which it claims is safer, has better performance and is more environmentally-friendly than traditional Li-ion batteries.

LEAD-ACID BATTERIES. Lead-acid batteries are the oldest and most reliable batteries but they suffer from operational limitations. They have a limited lifespan, due to corrosion and sulphation, take a long time to recharge and are large and heavy. However, companies such as Firefly Energy claim to have removed many of the limitations of lead-acid batteries by using carbon-graphite foam-based technology and given the technology a new lease of life.

SODIUM-SULPHUR BATTERIES (NAS). NAS batteries are also electro-chemical cells and their main applications are in the retail market for energy management and power quality. Key companies in this segment include NGK Insulators and SEI.

FLOW BATTERIES. Flow batteries, also called regenerative fuel cells, are based on an emerging technology that stores and releases energy through a reversible electrochemical reaction between two electrolytes. Current designs centre on zinc bromide, vanadium bromide (Va Redox) and sodium bromide. Companies involved in this technology include VRB Power Systems, Powercell and ZBB Energy.

FIGURE 1: ENERGY STORAGE TECHNOLOGIES



Source: *Courtesy of the Energy Storage Council*

SUPERCONDUCTING MAGNETIC ENERGY STORAGE (SMES)

SMES systems store energy in a magnetic field and have very high efficiency ratings (95% and above), with power available almost instantaneously. However, they are expensive to run and thus best for providing constant, deep discharges. American Superconductor is one of the market leaders in this technology.

WIND SUPERGRID

An alternative suggestion for 'storing' energy comes from Airtricity, the Ireland-based wind generator, which has proposed a European 'super-grid', linking off-shore wind farms from the West Coast of Ireland to Portugal to the North Sea. It would involve 2,000 turbines covering 3,000 square km and create a constant source of wind power. However, it presupposes a single electricity market in Europe, as well as investment of billions of euros, so it is some way from being realised.

FLYWHEELS

Flywheels store kinetic energy in a rotating mass. The amount of stored energy is dependent on the speed, mass, and configuration of the flywheel. They have applications in uninterruptible power supply, power quality improvement, hybrid vehicles and industrial power management. Companies active in this field include Active Power, AFS Trinity Power, Beacon Power and Pentadyne Power. Much of the energy in flywheels is lost before it can be put to use. Cambridge University researchers are investigating how superconducting bearings and motors running at cryogenic temperatures could reduce these energy losses.

ULTRACAPACITORS

Ultracapacitors (or supercapacitors) store electrical energy in the electric field between two electrodes and are used in hybrid vehicles, in devices such as mobile camera phones and in large-scale commercial and industrial applications. Companies such as Maxwell Technologies, Saft, Cap-XX, Nanotecture and EPOD are active in this area.

HYDROGEN STORAGE TECHNOLOGY

Hydrogen energy storage technology is furthest from commercialisation, but work on it is feverish, because it is one of the key barriers to a hydrogen economy. Once the problem is solved, we will be on the way to using hydrogen to power everything from mobile phones to cars.

At room temperature and pressure, hydrogen's density is so low that it contains less than 1/300 the energy in an equivalent volume of gasoline. In order to fit into a reasonably sized storage tank, hydrogen has to be somehow squeezed into a denser form. The three ways of doing this are:

LIQUEFACTION. Chilled to near absolute zero, hydrogen gas turns into a liquid containing one-quarter the energy contained in the equivalent volume of gasoline. For decades, NASA has used liquid hydrogen to power vehicles such as the space shuttle. The cooling process requires a lot of energy – roughly one-third of the amount held in the hydrogen. Storage tanks are bulky, heavy and expensive.

COMPRESSION. Some hydrogen-powered vehicles use tanks of room-temperature hydrogen compressed to 10,000 psi. General Motor's Sequel, unveiled in January 2005, carries 8kg of compressed hydrogen this way, or enough to power the vehicle for 300 miles. Refueling is relatively fast and simple. But even when compressed, hydrogen requires tanks four to five times the volume of a petrol tank with an equivalent mileage range. Then again, fuel cell cars can accommodate bigger tanks because they contain fewer mechanical parts.

SOLID-STATE. Certain compounds can trap hydrogen molecules at room temperature and pressure, then release them upon demand. So far, the most promising research has been conducted with a class of materials called metal hydrides. These materials are stable, but heavy: a 300kg tank might hold a few hours' fuel. However, exotic compounds now being studied could provide a breakthrough to make hydrogen storage truly practical. "High-pressure tanks are a stopgap until we can develop materials that will allow us to do solid-state storage efficiently," says Dan O'Connell, a director of GM's hydrogen vehicle program.

Companies working in this field include FST Energy, Millennium Cell, Quantum Fuel Systems Technologies, Nanomix and Dynetek.

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