BATTERY STORAGE

Looking beyond lithium-ion

Novel battery formulations are set to challenge more established rivals in the energy storage market. Here, *Andrew Mourant* evaluates the possibilities.

Cruachan power station.jpg The Cruachan pumped storage hydro power station in Argyll and Bute is located in the hollowed-out mountain, Ben Cruachan, and was built in the 1960s. *Photo: Drax*

It seems perverse to talk of certainties in a world flipped upside down by coronavirus. However, few would doubt that the world's capacity for storing power in batteries must grow exponentially. It is, after all, essential for integrating intermittent energy sources such as wind and solar.

Though current forecasts are mired in uncertainty, activity last year points to an ongoing upward trend. A survey by RenewableUK, published in December 2019, showed that the cumulative capacity of battery storage planning applications soared from nearly 6,900 MW to 10,500 MW during the previous 12 months. The number of UK companies involved rose from 300 to more than 450, with an average battery project size of 28 MW.

While current industry consensus favours lithium-ion batteries for storage projects, some concerns remain over the technology's long-term viability. There are ongoing issues with child labour exploitation in the Democratic Republic of the Congo, where much of cobalt used in lithium ion batteries originates. It's also costly to recycle cobalt and nickel battery components.

Then there are practical limitations: 'Lithium-ion doesn't scale up well to the larger sizes needed to provide backup power for cities,' says Michael Perry, Associate Director for electrochemical energy systems at United Technologies Research Centre, Connecticut.

Future in flow?

Alternatives – such as flow battery systems – are evolving with the potential for greater storage capacity than lithium-ion formulations. Flow, or reduction-oxidation (redox) flow batteries, store charge in holding tanks of liquid electrolyte. This is pumped through electrodes to extract electrons, and the spent electrolyte returned to the tank. Then, when a solar panel or turbine provides new electrons, the pumps push them back via the electrodes, causing the electrolyte to be recharged.

Scaling up the batteries to store more power only requires, in theory, bigger tanks of electrolytes. Advocates of redox flow claim the technology has 'near unlimited' longevity.

Most flow batteries rely on vanadium, which occurs naturally in more than 60 mineral and fossil fuel deposits. It's a popular electrolyte component because it charges and discharges reliably for thousands of cycles.

However, critics of systems using vanadium say set-up costs are high. Some claim that they suffer from low energy and low power densities and are complex compared with lithium ion alternatives.

Different electrochemical energy storage systems have various properties. This affects the price – or levelised cost of storage – which is crucial in determining what system to pick. Any choice should factor in recycling, energy efficiency and maintenance. Flow costs have fallen significantly over the last decade. The technology has been backed on a grand scale in China, where Rongke Power has developed the world's largest vanadium flow battery, said to be capable of storing 800 MWh of energy.

UK energy storage firm redT – which in March 2020 announced a merger with American firm Avalon Battery Corporation – has been in the redox market worldwide since 2016. Last summer, redT flow batteries were granted pre-qualification status from National Grid to provide dynamic firm frequency response (DFRR) services. These are used to manage the normal second-by-second changes on the electricity transmission grid system.

The company's new projects include manufacturing 5 MWh vanadium redox flow batteries as part of the Energy Superhub Oxford scheme. However, the batteries will be hybridised alongside a lithium-ion system provided by European technology group Wärtsilä. The partners claim this will become the world's largest hybrid storage system and the UK's biggest single deployment of flow batteries. The £41mn project, part government-funded, aims to showcase rapid electric vehicle (EV) charging, hybrid storage, low carbon heating and smart energy management.

Assessing the alternatives

As vanadium prices rise, other options are being explored, such as the use of organic compounds to grab and release electrons. But these compounds can degrade rapidly and need replacing after a few months. Some only work with electrolytes that can eat away at the pumps and prove dangerous if tanks leak.

A team from Glasgow University led by Leroy Cronin, the Regius Chair of Chemistry, has investigated polyoxometalates, inorganic metal oxides with diverse structures and properties. Cronin claims to have hit on a flow battery that stores far more charge than vanadium cells of the same volume. 'We could pile a lot more electrodes into the liquid and dramatically increase the capacity of the battery,' he said, announcing the proof of concept stage in August 2018. 'The amount of energy it can store increases by almost 10 times.'

Cronin's team was also trying to work out how to make the battery lighter and more portable – something an existing flow battery wouldn't allow for. One snag is that the Glasgow system was using tungsten, less abundant than other metals such as iron, which Cronin hopes could eventually work as a substitute. Time will tell.

Swedish firm Azelio has developed another alternative type of solar power storage system – said to reduce reliance on diesel by up to 95% – with an eye expanding into markets where the electricity grid is either unstable or entirely lacking.

A recycled aluminium alloy is heated to 600°C, changes from solid to liquid to maximise energy density and is subsequently able to store energy for long periods. According to Azelio, the aluminium suffers no degradation in capacity over time. Using a heat transfer fluid, thermal energy can be transferred from storage to a Stirling engine. This runs a generator to produce electricity on demand, with zero emissions and more cheaply than diesel.

Azelio claims its technology is scalable from 100 kW to 100 MW. The storage base is made of recycled scrap aluminium, an industry first. The company has been running trials in Sweden, Morocco and Abu Dhabi.

Any would-be inventors of lithium-ion alternatives want new formulations to be cheap, sustainable and durable. Something based on abundant elements, with low flammability and the ability to conduct ions would be ideal. Two years ago, scientists from Switzerland-based Empa's materials for energy conversion laboratory came up with a water-based battery using an easily soluble saline electrolyte, sodium bis fluorosulfonylimide (FSI) so concentrated as not to contain 'surplus' water.

According to Empa, sodium FSI cells can be constructed more safely and easily than lithium ion batteries. If future developments are successful, inexpensive water storage batteries could be within reach.

Any would-be inventors of lithium-ion alternatives want new formulations to be cheap, sustainable and durable – something based on abundant elements, with low flammability and the ability to conduct ions would be ideal

Hydro and hydrogen

From pumped hydro (the oldest) to flywheel (still finding its way) there are various alternatives to chemically engineered battery storage systems. Pumped hydro works on a simple gravity principle, using reservoirs at different altitudes. When water is released from the upper to the lower, energy created by the downflow is directed through a turbine and generator to produce electricity. The water is then pumped back to the upper reservoir.

This system can offer crucial back-up in helping maintain grid stability and providing reserve generation. Unlike thermal, pumped storage can respond to sudden changes in electrical demand within seconds. In January 2020 National Grid struck a six-year deal with the Drax-owned Cruachan pumped storage hydro power station in Argyll and Bute. Under the contract, one of Cruachan's four turbines will no longer generate power. Instead it will be used only to provide power system support services such as inertia and reactive power, to help movement around the grid.

Inertia acts like a shock absorber, helping control changes in frequency to ensure the grid maintains a frequency of 50 Hz, heading off any need for power cuts. The rise of intermittent, unpredictable generators such as solar and wind has increased the need for this approach.

Other means of storage are gaining traction. In late 2019, the UK had a pipeline of over 600 MW of compressed air or liquid air projects under development. Earlier this year London-based Highview, which uses liquid air as a storage medium, received a reported £35mn investment from Japanese manufacturer Sumitomo Heavy Industries (SHI).

The process entails cooling air to -196°C (-320°F), the point at which it turns to liquid and can be stored in insulated, low pressure vessels. Exposure to ambient temperatures causes rapid re-gasification and a 700-fold expansion in volume that can drive a turbine and create electricity without combustion.

Highview says its battery has a 30 to 40-year lifespan (compared with 10 for lithium-ion and 20 for redox flow) and is scalable up to multiple gigawatts. Unlike technologies such as pumped hydro-power or compressed air it can be located anywhere. It claims the LCOS of $140/MWh for a 10-hour, 200 MW/2 GWh system is a new benchmark.

Hydrogen may yet figure prominently in the energy storage mix. It can be produced from surplus renewables and stored long term – either by compression, cooling or a combination of the two – as pressurised gas in bulk tanks. Rapid response hydrogen proton exchange membranes (also known as PEM electrolysers) can absorb additional renewable energy on the network to help stabilise frequency and voltage variations.

Market leaders include the Pure Energy Centre, based in Shetland, which uses hydrogen electrolysers that can be connected to solar, wind or hydro, or straight to the grid. These span a range of hydrogen flow up to 200 m3/h and above.

H2GO, a spinout company from Cambridge University, has developed portable units the size of a standard shipping container, which are designed to take in renewable energy store it as hydrogen for eight hours or more. A water electrolyser is used to split water, producing hydrogen for storage as needed. This can then be released to a fuel cell, the output being electricity, with water the only by-product. H2GO claims its technology works out at one third the cost of a typical lithium battery over a storage lifetime, with more than twice the capacity.

Flywheel technology, storing kinetic energy in the form of a rotating mass, is being explored by firms such as Guildford-based OXTO. Designed to work alongside wind and solar, OXTO's steel flywheel allows intermittent renewable generation to continue even when not required. It's able to store the excess, releasing energy when demand increases.

The firm claims the system doesn't degrade over its 25-year lifetime and offers a round-trip efficiency exceeding 90%. Using steel rather than costly carbon fibre alternatives allows it to compete with other storage technology and, it adds, offer a low LCOS.

Though lithium-ion batteries are the first energy storage technology to attain mass commercial deployment – including in vehicles and electronic devices – they're far from the only available solution. The array of other options, both established and emerging, should put fears about intermittent renewables to rest. ●