Long time coming: Part 2

Battery technology | First developed by NASA, flow batteries are a potential answer to storing solar – and wind – for eight to 10 hours, far beyond what is commonly achieved today with lithium-ion. In the second of a two-part special report, Andy Colthorpe dives deeper into questions of bankability, market segmentation and manufacturing strategies

Credit: redT Energy.

In the last issue of *PV Tech Power,* it was mentioned that there are "specific circumstances" in which long durations of energy storage, going from four to typically around eight hours, are already economically feasible. Lazard's Levelised Cost of Storage analysis from November 2017 highlighted that flow batteries could be more cost-effective than lithium already for peaker plant replacement, distribution substations and micro-grids. Peaker replacement with a vanadium flow battery system could deliver LCOS of between US$209 and US$413 per MWh, while a lithium battery energy storage system could do the same starting at US$282, albeit with a lower upper price limit of US$347 per MWh.

The three main market segments

Jim Stover of manufacturer VRB/Pu Neng says there are three readily addressable market segments: large-scale utility storage, behind-the-meter commercial and industrial (C&I) on larger sites typically of 250kW to 8MWh, and micro-grids. Stover says the latter in particular are "great because you're going against diesel fuel. At US$1 a litre, most engines, gensets will be about 23 US cents a kWh so you could be close to 30 cents per kWh to operate a diesel genset on an island, or a remote micro-grid."

Craig Evans of ESS Inc, which makes the patented 'all-iron' flow battery, agrees that "coupled with renewable energy, as those prices [for distributed solutions] come down, diesel gensets look less attractive".

"We're kind of seeing a reversal of the format, of diesel genset being the baseload. Now diesel is becoming the backup and solar-plus-storage becomes the baseload for those types of grid," Evans says.

However, with almost every project typically a custom engineering and design job, Jim Stover admits uptake of micro-grids in general has been slower than other distributed energy project types, despite the economics making it "easy to compete" with diesel via solar-plus-vanadium battery storage.

It doesn't yet have the same track record or mainstream visibility as lithium-ion but flow energy storage is finding niches for commercial deployments beyond the initial trial phase

Stover says the larger end of the market is of more interest to VRB, "10MW or larger", per project, and highlights telecoms towers or community batteries as a viable niche. Just a few weeks ago, Australian flow battery provider Redflow announced a deal to deploy up to 60 energy storage systems to assist the rollout of digital television in Fiji, to give a current example.

For C&I energy storage, most of the industry headlines are being made by shorter duration 'peak shaving' projects in the US, or TRIAD avoidance in the UK. Taking out only an hour of peak demand at a time on a monthly basis can be quite effectively done with lithium, as Lazard's analysis found. However, vanadium could be viable as a future-proofing proposition, albeit for larger commercial customers than has been seen in the US peak shaving C&I market.

As mentioned in the previous issue, RedT CEO Scott McGregor argues that 'policy targeting' of peak shaving in specific territories might make economic sense today, but offering a C&I customer "their own distributed energy solution", using flow batteries combined with solar PV, can offer them a de-risked, long-term infrastructure investment. As on-site self-consumption of solar is to be encouraged, so too is storing that solar for longer durations.

"You want to capture more, cheap PV and you want to take out more hours of what you purchase on the grid. Then you are actually de-risking your investment. No one can take that away from a commercial customer," McGregor says.

"It's a reverse of how people have looked at energy storage [commercially]; 80% in our business models are relatively risk-free returns for the commercial customer. No policy, no subsidy changes can take that away. [The remaining] 20%, yes we'll help them extract what they can out of grid services and other stuff."

At grid-scale, we have heard about several huge projects planned in China as part of the nation's first unified energy storage strategy, in many cases to provide long duration smoothing or load shifting of solar and wind. Meanwhile a verification project of 15MW/60MWh at a substation in northern Japan will be coming to the end of its planned third year of data collection and used by utilities and grid operators to assess the technology's efficacy for solar and wind power integration.

So the overall trend is that the front-of-meter grid-scale market remains dominated by lithium, again due to the lack of economic impetus for longer durations of energy storage and as we will see later, due to factors influencing bankability.

On the other hand, RedT's Scott McGregor thinks that one of his company's latest projects – a lithium-vanadium hybrid system in Australia – could show the way forward. By combining the power capabilities of lithium with the energy properties of vanadium, McGregor says the 300kW/1MWh system (120kW C-1 rated lithium battery + 900kWh of flow), can use the vanadium for long duration and the majority of frequency response services, saving the lithium for "big spikes of power", thus "protecting the lithium battery" from degradation. As we have seen with a handful of larger C&I projects recently, the installation combines front-of-meter services with behind-the-meter onsite benefits.

The bankability arms race

Clearly, lithium-ion has something of a head start on other electrochemical energy storage technologies, in that the batteries used are a commodity driven on by li-ion's ubiquitous use in cellphones, laptops, tablets and of course, electric cars.

This contributes to the relative ease of financing energy storage projects using lithium batteries, as the technology has now been in use long enough for stakeholders to be comfortable with the idea of using them in other applications – albeit with lingering concerns around fire safety and end-of-life treatment of used batteries.

ESS Inc's Craig Evans adds that big companies in the lithium-ion space are able to put large projects on their balance sheets, while enjoying the cost reduction curve associated with the scaling of consumer electronics and EV markets. However, Evans is confident that particularly over time, the durability of flow batteries and the ability to offer 20-year warranties with no degradation of battery cells will start to win customers over.

In practical terms, flow energy storage providers can also be proactive in seeking bankability. Evans says that ESS Inc is working on creating assurance schemes so that his company's systems can be insured.

Jorg Heineman of Primus Power also says that despite the perception of competition, lithium-ion has "paved the way" for wider acceptance of grid-scale storage. Primus Power is "making huge strides on bankability", Heineman claims. Now on the third iteration of its product, EnergyPod, the company has amassed close to nine years of field data from existing installations. Primus' tech has already received a favourable bankability study by infrastructure group Black & Veatch, Heineman says. In addition the company is now in discussions with two insurance companies about having a warranty backstop as well as a revenue assurance protection product.

While these "key steps to bankability", as Heineman calls them, are being made he says also that currently booked business spans a range of sizes, applications and locations over the next two to three years, adding vital proof points for prospective customers, investors and other stakeholders.

Of course, this proof that the technology works in the real world is the cornerstone of that bankability. As Jim Stover from VRB says, there's no substitute for "for the hours, the years and the dollars spent to develop and commercialise a product."

Case in point: each of our interviewed providers would claim a big advantage of flow energy storage is that the electrolyte and the battery itself suffers no degradation over potential decades of operation. Most flow battery makers already offer 20-year warranties and argue that the lack of requirement for augmentation, as would be found with lithium batteries, mean a rugged durability over a lifetime's use. Lazard's analysis of storage costs acknowledges that this lack of need for augmentation could be significant economically, but austerely notes that due to the relatively short history of the technology in the field, we have not yet seen those claims to be proven correct on a big scale.

But it is therefore just a matter of time. Stover claims VRB/Pu Neng may have already reached 800,000 hours of operation on flow battery systems of differing scale and at locations ranging from laboratories on a research basis, to customers on a commercial basis. Other battery chemistries such as Aquion's much-talked about saltwater electrolyte devices that have emerged from the lab into the market have not scaled in the way the makers hoped for, Stover points out.

He says that the company was "thrilled" with the success of test deployments at China State Grid since 2012, which included a rigorous 240-hour test against four different applications including peak shaving, renewables load-shifting, frequency response and renewables smoothing – "sort of micro-responses to fluctuations in solar and wind". This initial 2MW/8MWh trial run helped inform China's 2017 energy storage strategy document, including the several, multi-hundred megawatt-hour flow battery projects green-lit for development over the next decade.

Proving and improving

As well as the bankability of the technology class itself, there is still the question of competition among the makers of these systems. How will they differentiate? For some, like Australia's Redflow, it's about using cheap, readily available components like plastic tanks. Conversely for others like Primus Power, a single-tank design and titanium electrodes are the touted improvements. As we heard in the last issue, ESS Inc is perhaps unique on the other hand for utilising saltwater and iron instead of vanadium or zinc bromine.

Primus Power's CEO Tom Stepien told Energy-Storage.news in 2017 that the decision to use titanium electrodes instead

From 2014's Primus Power EnergyPod (left) to the most recent third generation (right, with wind farm in background)

Credit: Primus Power

of graphite, as are used in other flow batteries, is due to the metal being "more expensive on a weight basis, but actually less expensive on an energy basis", and not subject to changing its composition over time due to corrosion. This time around, Stepien says that even including the titanium, the raw material costs of producing EnergyPods are low.

"The way I think about the cost, it's really simplistic at a high level: it's raw material plus processing that raw material. If you have a low raw material cost like we do, then because we have a single tank, we don't have a separator [membrane], we have such a head start," Stepien says.

Indeed, the Lazard LCOS analysis acknowledges that flow batteries designed using a single tank, single loop and no membrane could allow for "simpler and less costly designs".

"Our raw material cost in dollars per kWh is less than US$60, plastic, titanium, electrolytes, 60 bucks unprocessed. Today we are paying five to six times that to weld our steel, to injection mould the plastic and so on.

"We have a system that's US$50, US$60 times six – 400-500 bucks per kWh is the material cost of our completed Energy Pod. If you build a couple of hundred – it doesn't take 10,000, just a couple of hundred – that transformation cost is below two times. There's a line of sight to get below US$200 for that same unit. Raw material wins. If you want something cheap as dirt, get it as close to dirt as possible," he says.

The other question is whether flow batteries should continue to ride the tide of the energy storage market as it is today, gradually finding deployment as the need for long duration storage inevitably spreads in tandem with solar and wind. Navigant Research analyst Ian McClenny says that the redox pairs of vanadium and zinc-based chemistries "yield competitive, but lower power densities" in comparison with lithium-ion.

If flow batteries were to attempt to compete with lithium head-to-head, they would require the development of different chemistries that "yield higher power density and are safer", better separator, electrode materials and architecture to improve chemical conversion would still be needed, as would ongoing reductions in balance of system costs. Yet, the example of RedT's lithium-vanadium hybrid system shows, it might not have to be a straight shootout between the two technologies after all. Ironically, one of lithium-ion's 'weaknesses', offers the opportunity for flow to complement its more mainstream cousin.

"What has come now to the market – which is a fact – is that it's the cost of degradation on the lithium which is the problem for grid storage," McGregor says.

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"Trading using a [lithium] battery, you have to work out what the cost of that use is. With flow you don't have a cost because there is no degradation. [So] a flow solution is good for, yes, medium, long-term duration on the grid services but it's actually much more valuable for short term services. You use the lithium when you're making lots of money and the flow is for everyday use."

Vertical integration versus OEM

From a manufacturing standpoint, the different providers' strategies are almost as diverse as their technology offerings. VRB/Pu Neng, for instance, is 82% owned by US/Canadian mineral resources group Ivanhoe Capital, which is led by financier Robert Friedland and fits into the mining industry veteran's IPulse group of companies. Jim Stover says that Friedland's group had spotted potential to capitalise on its "upstream vanadium expertise", as well as a track record of working in China and purchasing Pu Neng in 2016 (the rebranding as VRB is currently ongoing, while the Chinese subsidiary will retain the Pu Neng moniker). While corporate headquarters are in Vancouver and other offices are in the US, the manufacturing takes place in China, near Beijing.

"It's important to be vertically integrated here, to produce a vanadium battery. Because the electrolyte typically is 30% to 50% of the cost of the battery, depending of course on the length of energy duration," Stover says, adding that VRB is preparing to present solutions for large-scale solar installations in the Middle East that involve an 8-13-hour energy storage duration.

"At that point, the electrolyte is maybe 70% to 80% of the cost of the battery so it's important to have that upstream vanadium electrolyte capability."

Conversely, Tom Stepien says that Primus Power "would be out of business if it built a factory" and like several others in the space, outsources manufacturing to a major contract OEM. Everything excluding the stack is made by Foxconn, the US$140 billion annual revenue assembly partner for Apple's iPhone. With this arrangement, Stepien claims Primus Power effectively "already has a Gigafactory".

"If you put enough billions of dollars in the Nevada Desert you can get the transformation cost [of lithium battery materials] low because you've got a lot of automation. This is not automated assembly. These are 2 metres by 2 metres by 2 metres; this is not a robotic, semiconductor-type manufacturing. You can add automation in a smart way but outsourcing manufacturing allows us to focus on our core."

Although Tom Stepien at Primus says it is "never of interest" to fully vertically integrate, earlier in 2018 the company netted investment from Anglo-American Platinum, which just happens to supply metals used as catalyst to the titanium electrodes of Primus' EnergyPod systems. The plating of zinc onto titanium electrodes and the rest of the stack's assembly takes place in the US. The stack and balance of plant and other parts made by Foxconn meet at an assembly centre in the US.

"We can deliver to Johannesburg at the same cost as we can deliver to LA with this regional integration, worldwide delivery model that we've developed. It's not our idea, other people have done that. We love that model. It makes a tonne of sense for young technology companies like us."

Jim Stover is confident the cost reduction trajectory for flow energy storage, while not as dramatic as that experienced by solar, will be at least competitive to lithium, despite the danger that the latter's popularity could "crowd out innovation" in other technologies.

"Lithium is on about 15% cost reduction per doubling of manufacturing capacity – [that's the] 'learning rate'. Solar is on about 23-25% per doubling and that's why it's come down so fast. We see ourselves – going back to 2010 or so, we see a similar progression of about 15- 16% reduction in cost per doubling in manufacturing capacity [for vanadium redox batteries]." ■