The revolution has already begun

Battery storage | One of the claims made about large-scale storage coupled with solar is that it is difficult to justify from a business-case perspective. But evidence is already emerging that if done right, intelligent battery solutions are already competitive, writes James P. McDougall

Credit: Younicos

Recently it's become fashionable to talk about the disruption brought on by the powerful combination of falling renewable energy and battery prices. In fact, it's fast becoming conventional wisdom that energy markets worldwide are about to be drastically reshaped. As anybody familiar with our company, Younicos, knows, it was precisely this notion that storage in general – and batteries in particular – would be a crucial driver of the transformative potential of renewables that led us to investigate just what sort of technologies and business models would be needed.

Ten years later, a number of business models are emerging. Many will become reality. However, the combination of utility-scale PV and batteries providing a new kind of solar base-load is what excites us at the moment. Why?

Disruptive price trend

For a start, there's the obviously disruptive price trend for all renewable power assets, but particularly for both solar PV and battery storage.

According to Bloomberg New Energy Finance, prices for photovoltaic power have fallen from approximately US$2 per Watt-peak to US$0.65/Wp in just six years – almost a quarter of the price. This means that this clean-sourced energy is more affordable and more attractive as a power source across all markets. Translate these numbers into actual energy costs, and they become even more impressive.

This year we saw PV record chasing PV record with prices as low as US$0.07 per kilowatt-hour in India. Not all places are as sunny, of course. But even the north is not as far behind as you may think: recently we've seen German utility-scale tenders at €0.085 (US$0.093). This is cloudy northern Europe we're talking about!

Add to that the recent spectacular drop in battery prices. Driven by the rapid expansion of battery manufacturing capacity for electric mobility, prices have come down almost 50% over the last five years. Tesla is now promising to sell "naked" lithium-ion batteries at US$250 per kWh of capacity at utility scale once its much hailed Gigafactory is operational in 2017. However, that's still some way off from the magic number of US$150/kWh that's regularly quoted. So, is all the excitement premature? We think not.

Business models are beginning to emerge that prove the viability of combining large-scale storage with solar generation.

Already competitive – if you do it right

For starters, it is overly simplistic to assume that once battery costs fall below a certain price point, everyone will start to use batteries overnight. This is not to say that batteries won't have a disruptive effect. They will. The point is that even at prices above US$150/kWh, the world is already changing fast.

In many applications intelligent battery solutions are already competitive today. It's been over a year since we inaugurated Europe's first commercial battery facility for regional utility WEMAG in north German Schwerin. Despite being systematically disadvantaged by the TSO "50 Hertz", the 5MW facility has not only met, but beaten all expectations so far.

Operating with only 4MW, it still exceeded its revenue target in the first year of operations and met the goals for 2015 at the end of August – with all revenue after that coming on top. Once allowed to operate at full capacity the investment could be repaid in as little as 7.5 years overall – and this is counting only revenues from providing primary frequency regulation power.

We, and others in the industry, have already proven that fully automated intelligent battery parks can provide several system services in parallel, and thus simultaneously tap into multiple revenue streams. This implies greater strain on the battery and thus shorter system life, but the right software can both maximise the lifetime and make the best trade-off between both continuously updated economic and technological parameters.

Towards a solar base-load

The drastic fall in prices for solar panels means that this clean-sourced energy is more affordable and more attractive as a power source across all markets. But to fully

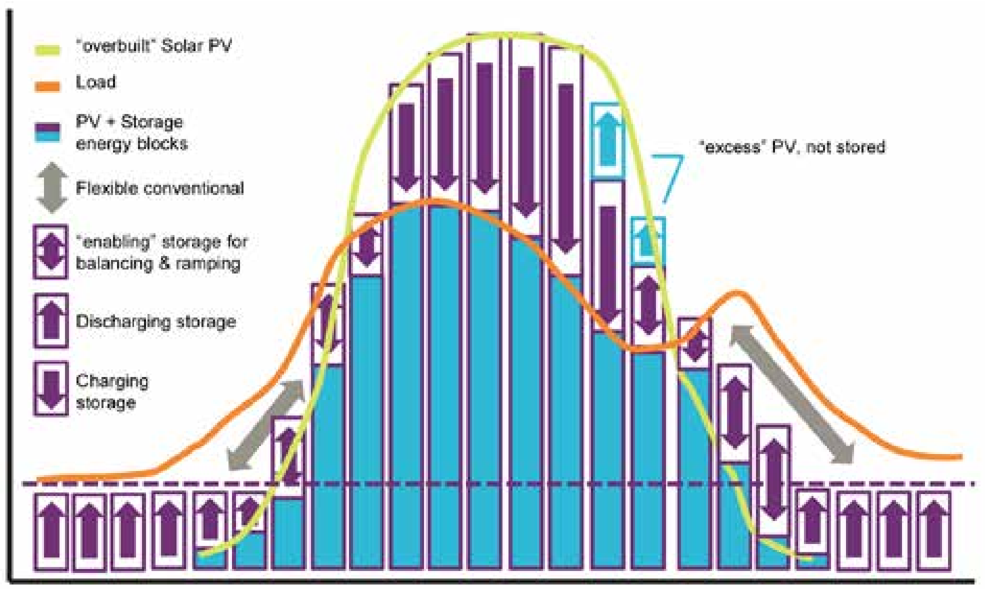

Figure 2. Illustration of utility PV-plus-storage model on 'good' solar days. Note that the main purpose of the storage is to provide predictable 'day(s)-ahead' blocks in a day-ahead market well as a certain minimum at night (on 'bad' days other renewable and/or conventional sources can take over larger shares of the individual blocks).

capture it, we need to come up with a way to effectively manage its integration on to a grid, which is used to blocks of power and a relatively stable load.

Battery storage is of course the ideal resource to directly manage the intermittency of solar power by providing instantaneous frequency response, voltage support and ramping control, allowing the solar output to integrate seamlessly into grid operations. But does that pay? And at which price?

Let's start with US$500/kWh for a plug-and-play system complete with the latest software and controls. Over the battery system's lifetime, that translates into a levelised cost of storage of US$0.15/kWh – or less, depending on how well you treat the battery.

Now, before we calculate further, it's important to understand that as long as PV panels are cheaper than batteries – and with prices for both dropping rapidly, that will remain the case for a while – it's neither economical nor necessary to store every kilowatt-hour of solar energy.

Particularly at a cost of only a few cents, sensible investors will choose to install (significantly) more solar than storage. Storing about a third to a quarter of all kilowatt-hours produced by a given PV power plant will suffice to smooth intermittent generation so as to provide predictable, and thus tradable, energy blocks during the day – as well as at night.

The diagram above illustrates this concept: on 'good' solar days some of the excess energy during the day is shifted into the night, thus providing power even through the dark hours. Importantly, the storage is also used to even out short-term fluctuations. With today's increasingly reliable weather forecasts solar energy can thus become tradable days ahead. Of course, for days with little solar energy, other renewable and/or conventional power sources can compete for some or all of these energy blocks. The point is not that sometimes the weather is bad for days, and in some regions even weeks, at a time. What matters is that the utility-scale PV-plus-storage model makes solar power just as predictable as conventional generation.

So what would it cost? Add it all up and you reach about €0.12 per kilowatt-hour. That translates into £80 (US$120) per megawatt-hour – for dispatchable solar base-load. A veritable bargain compared to the £92.50 no-risk, inflation-adjusted 35-year feed-in tariff EDF gets for the Hinkley Point power station in Somerset, UK. And that's discounting the fact that unlike nuclear power plants, operators of renewable generation assets are required to clean up after themselves – rather than leaving their waste for others to deal with.

Of course, much of this calculation hinges on rules and regulations – most importantly how to organise and price both critical system services and flexible back-up power.

To make the most of increasingly cheap renewable power generation, markets must become more flexible. Weather forecasts allow us to predict PV-plus-storage energy blocks days ahead with high certainty, allowing conventional back-up generation to be planned accordingly. As the uptake of renewables continues to increase, such generation will have to be much more flexible than today, leaving ever less space for inflexible generation with a high "must-run" requirement.

Islands show the way – and the challenges

To illustrate what I mean, it's very useful to look at closed grids, particularly islands, where both the challenges and the opportunities brought about by falling renewable energy generation and storage costs are already more visible.

Even with the drop in oil prices, replacing a large share of fossil energy produced by expensive, imported diesel is economically desirable in an increasing number of islands, but as we've been arguing for years – and others have found out painfully – the must-run requirements of thermal power stations mean that it's simply not possible to push the annual share of renewably produced energy beyond 30%. Why?

In traditional power systems, thermal engines not only produce energy, but also keep the grid stable through their so-called 'spinning reserve'. In essence, thermal units either increase or decrease their power output to match demand at all times. To do that, even the most flexible units typically need to run at a minimum of 40% of their maximum capacity. Naturally, the electricity thus produced is offloaded onto the grid – thus blocking it for clean energy.

The application of storage as part of the RE portfolio removes this need to have a fossil-fuel asset online and available, effectively replacing a 'spinning' resource with a 'non-spinning' resource – since the battery system can react instantly from a 'no-load' status – facilitating much higher limits on the maximum renewable energy output which can be supplied to the grid.

Of course, to enable the use of up to 100% of renewable energy in comparatively small island grids, such batteries must be able to cover the whole island load, which means that on an island with a 2.5MW peak load a 2.5MW battery system is required. Depending on the amount of renewables installed as well as the energy capacity of the battery, such systems will enable an annual share of renewables of more than 60%. Because of the comparatively high price of diesel fuel, such systems are economic on islands, but what about interconnected grids? Will we need an 80GW battery to back up Germany's 80GW peak load?

Interconnected grids

Firstly, it's important to understand that large, interconnected grids have much lower renewable shares than islands, where adding relatively little PV or wind generation capacity in absolute terms quickly translates into a high relative share. As of today, no large continental grid has had to deal with more than 10% annual share of renewables – for example Germany with its 25% share is part of the continental European grid, where the annual share of intermittent generation is between 7 and 8%. So in the case of interconnected grids, rather than going to 60% and more annual share of renewables, we're talking about starting to take renewable penetration beyond 10%.

Our calculations have shown time and again, and this has been validated by our experience of almost 100MW of storage in the field, that to reach the first 50% 1MW of storage can free as much as 10MW of space on the grid for renewables, implying a very large leverage effect of storage.

Secondly, even when considering to aggressively combine utility-scale PV and storage to take over a large part of energy provision, it's important to recall that we're talking about a clean base-load not peak-load. The point is that combining PV with storage enables utilities to offer predictable blocks of clean energy, complete with the option of turning to flexible conventional generation such as gas when it's clear that a given day will be cloudy.

Since there already is a grid with other producers, there's also no need for the battery systems to be fully grid-forming, which reduces system costs. This is not to say that the batteries co-located with solar will not have to provide critical system services – they just don't have to do it alone.

Clean balancing

In fact, the provision of system services is an opportunity for both PV and storage. For years, renewable energy resources have been unable to participate in the ancillary services markets, due to the variable nature of their supply. With the prospect of accompanying storage assets, we now see opportunities for RE resources to incorporate storage to enhance the value of their PPAs by making additional services available, such as the sale of ancillary services like frequency regulation, or the selling of peaking capacity to the utility.

In addition, the changing nature of the supply mix means that the nature of balancing services required by the grid is also evolving – much greater flexibility to respond to power supply fluctuations is now required from all balancing resources. Storage has an edge here over conventional plants which traditionally do not move quickly and require a period of time to ramp up or down to the requested output level.

On the other hand, the requirement to accommodate the 'must-run generation' of these conventional plants can result in renewable power output constraints, as a certain amount of minimum power generation must first be dispatched to maintain balancing service capability. This reliance on 'spinning reserve' from traditional plant essentially denies cheap renewable power to the market. As a clean, flexible, easily located resource with no must-run requirement, storage helps resolve these challenges by providing a new source of balancing services to the grid.

Rooftops?

But doesn't the same mathematics pencil out for distributed (residential) solar plus storage? Whereas on islands the utilisation of cheap local renewable resources is often limited by the need to have diesel generation back-up, rooftop or distributed solar is often restricted by the limitations of the local distribution feeders which are unable to accept export from distributed power resources beyond a certain output level. Undoubtedly many business models will flourish here, but at current prices utility-scale is closer to competitive edge than residential.

Residential PV plus storage is an exciting proposition, but demand here does not have the same price sensitivity as the utility case and thus won't grow quite as rapidly as prices fall. Of course, economic considerations are certainly also important in the residential case, but not quite as much. High prices will deter some people from making an investment, but the primary motive for getting rooftop solar plus storage is the seemingly universal desire to become "independent", even if all of these homes, very sensibly, still rely on the grid for final backup.

On the other hand, co-located utility-scale solar and storage will exploit economies of scale through better location, as well as lower investment and financing costs. It's also better suited to tap into the Swiss-Army-knife-like versatility of storage by exploiting various revenue streams for the provision of system services, whereas residential customers will have to add the cost of being grid connected to their calculation.

In any case, utility-scale solar PV and battery storage has a seemingly endless market to exploit. While increasingly attractive in already industrialised energy economies, it has even more to offer in fast-growing markets with rapidly rising energy needs, but poor infrastructure. Rather than build large and expensive thermal power plants that will only pay back over 30 years, along with the centralised grid infrastructure to match, why not spend months and put in place a clean solar-powered grid, backed up efficiently by batteries that also stabilise the grid far more effectively than inflexible thermal units?

Credit: Younicos

The quick ramp time of storage coupled with renewables generation gives it an edge over conventional power plants in responding to power supply fluctuations.

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