A steampunk vision: Prosumers and Frequency Control

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The electricity system is created as a giant rotating mass. Hundreds of fast-spinning turbines are elegantly joined together by three-phase electrical currents twisting along the transmission network – Australia has the longest in the world. They are synchronised at 3,000 rpm divided by some number of electrical windings, so that the passing of rotors over stators forms an alternating current at the 50 Hz grid frequency.

This is maintained with remarkable precision. Consumers provide the drag that slows the rotation, by drawing energy out of the system, while fossil-fuel or hydro generators – and more recently wind and solar generators – provide the acceleration. In the driver's seat is the system operator, the Australian Energy Market Operator (AEMO), which also has the parallel role of facilitating energy trading.

The accuracy of frequency control in any large electricity grid puts automobile drivers to shame: in Australia[1] any deviation beyond 49.85 Hz to 50.15 Hz raises eyebrows. Even in the case of a major generator or network failure, the mainland power system should maintain frequency between 49.0 Hz and 51.0 Hz, the equivalent of maintaining the revs in your car despite losing a cylinder. If the frequency goes below 47.0 Hz or above 52.0 Hz the system crashes.

In Tasmania there are slightly different standards, being a smaller system with special consideration for the dominant hydro generators.

In the aftermath of the September 2016 blackout in South Australia, there has been talk in the media and online about the role that consumers could play in preventing the occurrence of such events in the future. The idea is that many consumers with rooftop solar PV will install battery systems that are capable of a very fast response.

If given a suitable control signal, these personal battery systems would out-perform any existing generators in the market as first responders, providing

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[1] https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/Ancillary-services/Frequency-and-time-error-monitoring

short-duration emergency power to arrest a frequency decline. This gives time for larger generators to ramp up and do the heavy lifting.

These are "prosumers" or producing consumers, stepping up from their familiar role as passive power supplies during daylight hours, to become battery-enabled energy service providers available at any hour. For a suitable payment. There is also an implication, in the public discussion, that prosumers would be able to maintain their own power supplies should the power system fail, lessening the impact of a blackout.

Who are these prosumers though, to think they can have any influence on such a machine as this steampunk vision of the Australia's electric power system?

The idea conjures images of the Lilliputians holding Gulliver helpless on the ground with hundreds of tiny ropes and pin-prick weapons. Yet hold him they did, through the force of many.

And, like Gulliver, the power system is a benevolent giant, placing an unfortunate foot here and there, but generally trying to help the community to achieve the National Electricity Objective: cost-effective and reliable power.

Prosumers in the market

The system has traditionally been a one-way street, with consumers passively accepting the electricity supplied and paying the bill, albeit with occasional vocal upset over the amount, with accompanying political fallout.

That is undergoing rapid and radical change at present with the growth of the prosumer. With over 1.5 million residential rooftops, Australia has the largest single installed base of residential solar in the world, with most of these installations feeding some of that power into the grid.

Overlay this with the drive to transition to centralised large-scale renewable generation – with its markedly different characteristics to centralised fossil fuel generators – along with the increased variability of consumer demand, and this is clearly a system undergoing a high degree of flux.

Prosumers are already a significant proportion of the Australian community, and can exert considerable political leverage. However, the decision-making in our electricity system is difficult for non-specialists to access or even understand. Unsurprisingly, the system is dominated by incumbents who were the only game in town until very recently.

Also unsurprisingly, there are competing claims about whether prosumers are being subsidised by other consumers, or underpaid for the services they provide.

Meanwhile, the opportunities for active participation are just starting to be realised. Australia's total electricity generation capacity is 59 GW, with 5 GW of that being derived from rooftop solar PV, and steadily increasing.

The battery revolution

The traditional model to derive value from solar PV is to receive a feed-in tariff for net or gross generation, and offset the tariff for energy consumed. Feed-in tariffs (FITs) were well above the retail price of electricity, as they were intended as a support mechanism to drive uptake of solar PV.

As the cost of solar PV has plummeted, FITs have come down too, and they are now well below the retail price. This means that a unit of PV generation used behind the meter can now have a value five times higher that a unit of PV exported to the grid. The new players in the energy market find this intuitively wrong, and are looking for other ways to use the electricity.

The storage revolution is one of the responses to this mismatch between value in front and behind the meter. The proposition is easy to understand, and the economics are getting closer. That's where providing energy services can help prosumers – by improving the payback on their batteries.

Around the physical electricity system are wrapped retail and market functions that both determine who pays for what, and provide many of the feedback mechanisms that regulate the physical inputs. On the supply side, generators bid into the National Electricity Market to supply a certain amount of capacity, while prices send a signal to consumers to reduce or shift demand.

Yet it's important to recognise that prosumers have two things to trade: their energy and their power. While you can sell your generated energy to the grid, it is power that controls the frequency of the system as a whole. Take too much power and all the turbines slow down, produce too much and they speed up, with grid frequency tracking their speed.

Prosumers with batteries can ramp their power input or output very quickly and without affecting, at least in the short term, the electricity supplied to their household or business appliances. There is a dual opportunity going wanting here, for prosumers to begin profiting by offering stability to a fluctuating system.

Trading frequency

There's a market for frequency, or rather several, and a sufficient number of like-minded prosumers can help to manage the grid by using them – although that is no mean feat.

There are eight distinct Frequency Control Ancillary Services (FCAS) markets[2] with which the AEMO manages a competitive bidding process, in parallel with the wholesale or "spot" electricity market, to procure fast-responding power services to manage frequency variations.

Two are Regulation FCAS, up and down, by which generators equipped with a real-time link to the system operation centres, can have their output ramped up and down to manage ordinary fluctuations in frequency. These are due to uncontrolled variations in load and generation, including variable renewable generation. Situation normal.

Contingency FCAS, on the other hand, are to manage extreme events. The fastest ones are the 6-second first-responder FCAS which arrest the frequency in its

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[2] https://www.aemo.com.au/-/media/Files/PDF/Guide-to-Ancillary-Services-in-the-National-Electricity-Market.pdf

quick fall, or sometimes rise, after a failure somewhere in the system. Slower ones stabilise the frequency (60-second response) and then restore it back to the usual 50 Hz (5-minute response).

All large electricity systems in the world have a similar sequence of frequency control services. But the fastest services generally have the highest value because not all conventional generators are able to provide them.

Enter batteries. They are highly scalable, so small ones can do most of the things that big ones can do, with advanced power electronics interfacing them to the grid. Frequency response is challenging due to short timeframes. Some things are harder at small scale: measuring what the frequency is on a local distribution network with distorted voltage waves, or ensuring that the local network has capacity to deliver a power punch out to the transmission grid. But these are amenable to clever solutions and frequency services from customer batteries can aggregate up to a big contribution towards a stable grid.

Existing regulations, however, are barely keeping up with opportunities like this. It is possible, but not easy, to gather up and bid customer batteries in the FCAS markets.

One company that has taken up the challenge and offers the capability for FCAS participation to ordinary residential customers is Reposit Power. This ACT-based start-up offers a storage trading and control platform that is focused on high-performance residential batteries. By signing onto this and submitting control of their battery to Reposit Power's software, customers can for the first time, store their solar energy, manage their tariffs, and trade their batteries' capacity in the electricity market, all coordinated to achieve the highest revenue.

Reposit Power CEO Dean Spaccavento said the company had a vision that homeowners with energy systems could provide important services – and deserved to get paid fairly for their efforts.

"Opening the electricity market to households was not an easy task," Mr Spaccavento said. "We had to constantly push for change and convince people to challenge the status quo. We kept hearing that only big power stations could trade in the market and there were too many barriers for Reposit. But, despite many technical challenges, we achieved success for customers. They can now trade their stored capacity to the electricity market when it is needed most and get rewarded.

"We still have a fight ahead. But, it now clear that owners of PV and batteries have a big role to play in a clean grid."

Customers then receive trading benefits achieved by their batteries in the form of GridCredits that offset their electricity bills. This directly allows them to see how they're helping the grid and reducing the payback time for their battery installation.

The importance of bringing new, responsive power capacity to market cannot be overestimated. The South Australian blackout in September 2016 highlights that modern power systems, with large amounts of renewable generation, require new thinking to operate them effectively.

Could the blackout have been mitigated, if not prevented, had enough customer batteries been online and ready to respond? Well, no, not with present frequency regulation services in the Australian market, because the frequency fell too fast: from normal (50 Hz) to system collapse (47 Hz) in half a second.

There are moves afoot to redefine the FCAS markets and it is possible that they will include an "inertial", or immediate, response one day soon.

Inertia is the traditional way to keep the frequency bounded during these contingency events, but that language is becoming too imprecise. Physical inertia in spinning turbines is an eminently sensible way to "ride through" contingency events when nearly all the power is provided by spinning things.

In the new order this won't be the case – spinning turbines will only be operating when the non-spinning type aren't in action, and if your turbine isn't on, there is no inertia.

What is actually needed is the capability for fast response – seriously fast – in the order of a second and less. And batteries are the obvious choice to provide that.

When the worst happens

When all these measures fail and there is a blackout, prosumers have the option of mitigating the impact on their own premises, which is a better outcome for the system too. Backup power seems an obvious motivation for customers. After all, the largest battery installations in the world exist to supply emergency power to secure facilities and data centres.

Residential owners of energy storage will also want their lights to stay on when the rest of their street is blacked out. But mass-market storage systems are usually designed to store solar energy, not to provide backup power – although they could also do that with some extra wiring and control options.

The reason is safety. The grid connection standards vary significantly between countries and states, but one universal requirement is that when there is a problem with the grid, or when part of the grid is de-energised for maintenance, customer energy sources including batteries must be disconnected from it. This protects line workers from being electrocuted by wires they thought were inactive, and prevents fallen wires remaining live and endangering the public after storms and accidents.

The technology that implements this safety requirement is called anti-islanding protection because it prevents "islands" of power remaining when power is no longer being delivered by the grid. It must be implemented by all power conversion systems approved for mass-market sale and grid connection. This includes battery systems as well as solar PV generation. A combination of voltage, frequency, and impedance presented by the grid is typically used to detect when grid power is no longer present.

Backup capability can be designed in, though, as an additional feature, providing it is designed to ensure this can't inadvertently continue to send power outwards to the grid. The conservative approach is to energise only a selection of critical circuits so that the battery capacity can support a longer period without grid power. Many customers would be delighted if their lights, internet, entertainment, and main kitchen appliances continued to operate during a blackout. This would require modest additional wiring at the switchboard.

At present, there is no universal approach to battery connection for residential customers, and standards and accreditation bodies are engaged in the task of documenting recommended wiring systems and their benefits. Looking forward, this should include standards on how consumer storage can maintain islanded supplied safely during blackouts.

Conclusion

The steampunk power system we rely on, is undoubtedly an elegant machine. Yet as it moves to a new design, driven by new energy sources, another physical analogy may be a better description. Pilots used to mechanical controls for an aircraft's flaps were hesitant to trust "fly-by-wire" technology where control was programmed, with no mechanical connection from the stick to the flaps.

It was an understandable mistrust in an industry driven by experience to have a conservative viewpoint, but pilots quickly got used to it, and would be aghast if they got into a cockpit today and had to manually adjust those flaps during take-off and landing.

Now prosumers can fly-by-wire to participate in managing the power system and get better electricity deals as a result – for example, faster payback on their battery systems.

As electricity markets and grid companies get more familiar with the quality of services they can receive from prosumers, and particularly those with batteries, business models based on this idea will become commonplace – driven by demand from customers who, as it turns out, really like the idea of trading.