Going hybrid
Adding batteries to grid-connected solar

Going off-grid may not be for everyone; a better route may be to 'go hybrid', by adding batteries to grid-connected solar. Andrew Reddaway explores the options.

THE solar battery industry is on the verge of disruptive change. Traditionally, large batteries were only seen in houses at off-grid locations such as Moora Moora (see box on the solar hybrid training course held there, which I attended earlier this year and which provided input to this article).

For off-grid systems, reliability is crucial; failure prompts an emergency call to the solar installer, so such systems have been designed conservatively using proven lead-acid batteries.

Meanwhile, in towns and cities, grid-connected solar systems have gone mainstream. As feed-in tariffs for solar export have dropped far below the rates paid for grid electricity, householders are looking for ways to cut bills by making better use of their excess solar generation. One answer is to add batteries to create a hybrid system: a grid-connected solar system with batteries either for backup or load-shifting.

This article gives an overview of current hybrid technology and the options available for adding batteries to an existing grid-connected solar system.

Image: Bosch Power Tec

↑ Storage systems, such as the Bosch Power Tec BPT-S5 Hybrid, look more like appliances than battery systems.

Different batteries for hybrid

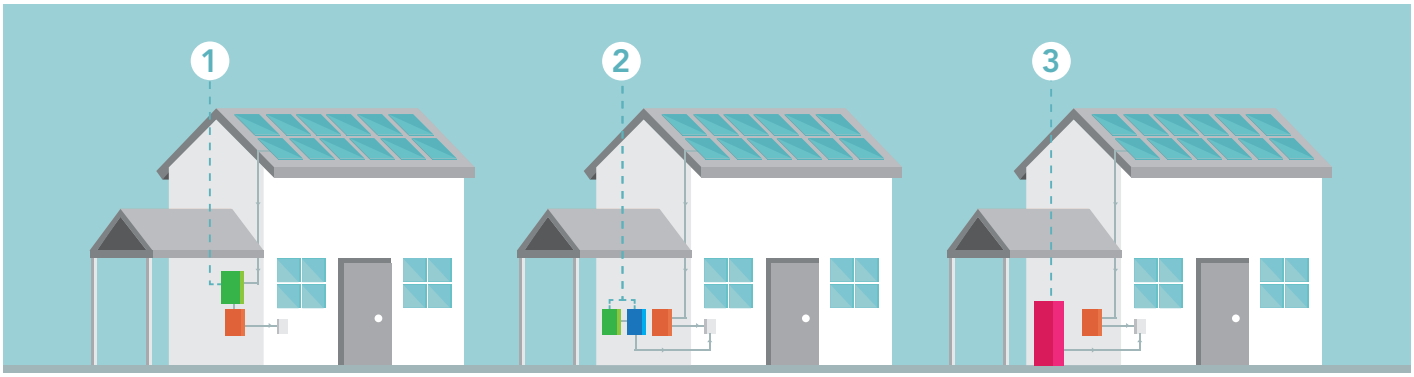
A hybrid solar system is tough on batteries. Unlike an off-grid system that may store enough energy to last multiple days, a hybrid system's entire usable capacity will be charged and discharged daily. This requires a battery that can handle fast discharge rates at high levels of efficiency. Lithium batteries fit the bill, and have already become dominant in consumer electronics, power tools and electric cars. Compared to lead-acid, they are also smaller, lighter, don't require monthly maintenance and don't emit hydrogen gas. The only things holding them back in the solar market are unfamiliarity and price.

The recently announced lithium Powerwall battery from Tesla is priced well below previous products and has a 10-year warranty. Traditional lead-acid batteries cannot compete with this new benchmark, so it's expected that systems will start to move away from them. Hybrid systems are now expected to become viable on pure economics in a few years or less. Early adopters are already installing lithium hybrid systems, as are some who value maintaining power during a blackout.

Option 1: Solar buffer battery

So how can a battery be added to an existing grid-connected system? The simplest concept is to connect it between the panels and the grid-interactive solar inverter, most likely wall-mounted next to the inverter. From a string of panels, current flows at, say, 400 VDC into the battery during the day. The voltage is regulated to the internal battery voltage, say 500 V. At night, DC current flows from the battery to the inverter and then to the house switchboard at 230 VAC. The inverter doesn't even know that a battery is present—as far as it's concerned the solar panels are still generating!

To work as a proper solar buffer, a sensor at the switchboard is also required. When the house is starting to import electricity



↑ Options 1, 2 and 3 for adding storage to an existing grid-connected solar system. The orange box is the existing grid-interactive inverter. In option 1, the batteries (green) are added between the solar panels and the inverter. In options 2 and 3, no changes are required to the wiring of the grid-interactive inverter; instead, a new circuit is added to the switchboard: In option 2, this connects the batteries (green) and a new inverter/charger (blue); in option 3, an all-in-one system (including batteries and inverter/charger in a fridge-sized box) is connected. Depending on the component housing, all these additions may require protection from the weather and ventilation.

from the grid the battery should discharge, and when the house is starting to export the battery should charge.

The advantage of this approach is that no new conversions from AC to DC are introduced. Costs are minimised as additional inverters aren't required, and efficiency is high. However, blackout backup may not be available, as a typical grid-interactive inverter shuts down when the grid is not present. An issue to check is whether the battery will interfere with the inverter's maximum power point tracker (MPPT). Also, how does panel generation bypass the battery when it's full? If the battery has a lower power rating than the total solar array, will the panel output be clipped?

It appears at least one of the Tesla Powerwall systems is designed to be installed this way (as far as the currently available specs imply, as of early May 2015). Another yet-to-be-deployed product is the Australian Sunsink. SMA sells a grid-interactive inverter with 2 kWh of lithium batteries included, although it is not yet available in Australia.

Option 2: AC-coupled inverter-charger

An alternative approach is to keep the battery separate from the existing grid-interactive inverter and wire it to the house switchboard. As the switchboard runs at 230 VAC, this is called an AC-coupled system. Batteries are DC, so an inverter-charger is required near the battery. The battery's nominal voltage is likely to be 24 V or 48 VDC.

One advantage of this method is that blackout protection can be provided by the inverter-charger. When the grid goes down, a high-quality hybrid system will step in so fast that house appliances are not disturbed by the changeover. As far as the grid-interactive inverter is concerned a blackout never occurred, so your panels can keep generating. Appliances can be powered by the total output of both the inverter-charger and the grid-interactive inverter (if the sun is shining).

To conserve the battery during a blackout, it is possible to have some high-usage household circuits switch off, such as the oven, air conditioner and pool pump. A petrol or diesel generator is relatively easy to add, with startup controlled by the inverter-charger. In fact, a good AC-coupled hybrid system has all the features to disconnect from the mains and go off-grid! However it may be under-sized to run the whole house full-time.

You can also exploit additional strategies to use the battery with such a system. For example, if you have cheap grid electricity in the middle of the night you could use it to charge the battery to cover a morning consumption peak. Another benefit of this method is that the existing solar system is not disturbed, avoiding potential remediation work where standards have changed since the original solar installation.

The main drawback of this approach is the cost of the smart inverter-charger. Also, electricity that goes through the battery requires an additional conversion from AC to DC and back again, reducing efficiency.

An issue to check is how the hybrid system regulates power from the solar panels during a blackout. Some inverter-chargers can communicate with the grid-interactive inverter, throttling its output when the battery approaches capacity. However, this feature may only be available with compatible models of grid-interactive inverter. If this is not possible, the system may not handle a large solar array.

If you're installing a grid-connect solar system now and considering adding batteries later, it's worth checking whether the inverter can communicate with any hybrid inverter-chargers.

There are many examples of AC-coupled inverter-charger hybrid systems, using, for example, Schneider Conext, SMA Sunny Island and the Australian Selectronic SP-Pro inverter-chargers.

Option 3: Self-contained appliance

This option uses an appliance with an inverter-charger in the top and lithium batteries in racks at the bottom, often called an 'all-in-one system'. Installation is simple—wheel it in, set it on the floor and wire it into the switchboard. The solar array may connect directly via a DC cable (DC coupled) or via a grid-interactive inverter (AC coupled). Ideally, battery capacity is expandable so you can start with a small capacity to minimise costs, see the effect on your bill and add

What about microinverters?

Currently it is difficult to add batteries to a microinverter solar system. Option 1 is not possible as electricity from the panels is AC. Options 2 or 3 are problematic as no microinverters can yet communicate with an inverter-charger. This will change when Enphase (the leading microinverter manufacturer) releases their own battery later this year.

additional cells as desired. If you move house, you can take it with you! Downsides to this option are cost, and finding a suitable place for the system. Examples include the Solari Energy SolaGRID, the Bosch BPT-S and the ZEN Freedom PowerBank. These all-in-one systems were covered in a buyers guide in *ReNew 128*.

Predicting the future

It's still early days for hybrid solar systems. Different concepts are competing for a small pool of early adopters and it's not yet clear which will become mainstream.

When adding batteries to an existing solar system, I expect Option 1 will be most popular due to relatively low equipment costs. For new hybrid installations perhaps Option 3 will dominate as it requires only a single device beyond the panels, reducing installation costs. Hopefully battery systems will settle on standard sizes as other home appliances have. A fridge shape seems optimal where space can be found in the garage or house; perhaps such spaces will be included as standard in future building plans. Longer, slimmer appliances may find a market along the inside wall of garages.

If your goal is to reduce electricity bills, it's a good idea to hold off on adding batteries until price drops flow through to mainstream products. If you have other motivations, there are solid hybrid systems available right now, at a price. Talk to an installer experienced in hybrid and off-grid.

If you're getting a standard grid-connected solar system, aim to keep your options open to add batteries later. When installers are quoting, ask them how batteries can be integrated. ✷

Further info:
ReNew 128: Energy storage system buyers guide (covers all-in-one systems)
ReNew 131: Battery buyers guide (covers separate batteries)
ReNew 128: Off-grid basics
ReNew 130: AC vs DC coupling
ReNew 122: Inverter buyers guide
ReNew 129: Inverter basics

Solar PV hybrid training course

Earlier this year I attended the Australian Solar Council's Solar PV Hybrid Training course. Below is a student's perspective as a guide to others considering this course.

Four days from 9am to 5pm were split between classroom lessons, hands-on exercises and special activities. No prior experience was required—attending with me were a mix of solar installers broadening their service offering, utility employees, university students and specialists in renewables and energy efficiency.

Classes were comprehensive, detailing the entire workings of a solar electricity system from the photovoltaic cells to calculating how much battery capacity is required for an off-grid house, to rule-of-thumb cost estimates. Concepts were illustrated with real-life examples, including common pitfalls such as poor planning, unrealistic expectations and commercial pressures.

I found Glen Morris's teaching style engaging and relaxed. Participant questions frequently sparked lively discussion among the whole group, giving useful insights into broader issues such as the electricity 'death spiral'. As a long-term off-grid solar installer, trainer and vice-president of the Australian Solar Council, Glen's depth of knowledge is outstanding. Outside class, we had many opportunities to pick his brains about specific issues. A solar installer who lives at Moora Moora assisted Glen, and an equipment manufacturer also gave a presentation.

Most hands-on exercises were held in a shed kitted out with solar panels, a wind turbine and a range of off-grid equipment. DC voltages were kept low, enabling all participants to join in safely. Working in a few groups, Glen assigned us tasks culminating in a small, off-grid solar system. Just like chefs in a kitchen, competition for tools was sometimes evident! Participants with electrical qualifications were given tasks in an operational equipment room that supplies electricity at 230V to a group of buildings. The gear in this room was impressive—manufacturers often supply Glen with new models for testing.

Other exercises included using devices to calculate the shade cast by a tree at different times of the year. We also toured the facilities at nearby inverter manufacturer Selectronic.

The course is held at Moora Moora Cooperative, an off-grid community located on Mount Toolebewong near Healesville, 70km from Melbourne. The community's heart is an old farmhouse, with members living in clusters of houses scattered in the surrounding bush.

One afternoon we toured some of the houses (including Glen's) to check out their off-grid systems. We saw a broad variety of approaches including micro-hydro, defunct wind turbines, passive solar, solar hot water and mini-grids servicing multiple houses.

Most course participants took advantage of the included accommodation: backpacker-style bunkrooms upstairs in the well-heated farmhouse. However one Melbournite stayed at a B&B in Healesville where his family was holidaying. A highlight of the week was the food; three meals plus morning and afternoon tea expertly cooked by a chef who lives in the community!

Andrew attended the course in exchange for advertising in *ReNew* and this course review. See www.cleanenergy.org.au/training/solar-pv-hybrid-training for course details.