BATTERY VALUE STREAMS

DISCUSSION PAPER

Qualitative identification of present day and future value streams for a large battery embedded in an office building power system

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<u>Important note about your report</u>

The sole purpose of this report is to provide an introduction to battery value streams in the present electricity market in Australia. This summary is provided for information only and is not to be relied upon for any commercial or investment decisions.

No warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report.

Circular Solutions

Circular Solutions is a specialised renewable energy consultant and contractor. Our services include:

- Concept development including feasibility, design, strategic planning, and regulatory advice;
- Project delivery as a turnkey or EPC contractor, as in house project and contract management for the owner, or as a fully financed (BOO) solution.

Our team are specialists in:

- Concept design and specification of micro-grid and island power systems;
- Detailed design and project delivery of renewable energy projects with significant experience in remote locations; and
- Systems integration and commissioning including thermal power and batteries.

Because we are a consultant and a contractor, we are uniquely placed to provide practical advice to our clients and partners based on current costs and on-site experience.

For more information about Circular Solutions, our team, capability and experience please visit our website www.circularsolutions.com.au.

To contact us to discuss your renewable power projects please email the team at info@circularsolutions.com.au.

Value Streams

PRESENT DAY VALUE STREAMS

The following value streams relate to revenues or savings that could be realize in the present day:

- Peak demand charge reduction (using batteries to discharge in times of peak demand and charge with solar or off peak);
- Demand response (AusGrid, the Sydney distribution network service provider is seeking participants in a demand response mechanism to defer nework upgrades);
- Time of use (discharging when the energy tariff is high and charging with solar or off peak power)
- Energy Reduction (if there is excess onsite generation, batteries allow the full value of that asset to be captured)
- Back up generation savings (reduced capex and maintenance of back up generators)

FUTURE VALUE STREAMS

The following value streams are not available with today's technology or energy markets without becoming a registered generator but are likely to be available in the near future.

- Grid resilience
- Wholesale hedge avoidance
- FCAS
- Energy arbitrage through retailers.

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Battery Value Streams

THE NATIONAL ELECTRICITY MARKET (NEM)

On the east coast of Australia, the balance between electricity produced by generators (supply) and the electricity consumed by residents and businesses (demand) is managed by the Australian Energy Market Operator (AEMO). AEMO manages one of the largest interconnected network in the world the National Electricity Market (NEM)

Energy Arbitrage

Every dispatch interval, the available large generators in the NEM advise AEMO how much capacity they want to supply and the minimum price that they are willing to sell that energy for. During each dispatch interval of the market, the National Electricity Market Dispatch Engine (NEMDE) dispatches sufficient generation capacity to meet the forecast demand. NEMDE will dispatch generation in merit order of cost. The highest cost offer to be enabled will set the market energy price. As a result of this market process, the energy price is dependent on demand.

The owners of large batteries can register as market generators to buy and sell power at the energy market price. Using this approach the battery owner could realize the full benefit of the difference between the highest and lowest energy price each day.

Frequency Ancillary Services (FCAS)

Frequency Ancillary Services payment is the mechanism that AEMO uses to control frequency in the NEM. There are two types of FCAS frequency control: Regulation FCAS for minor frequency changes, usually caused by normal changes in network demand; and Contingency FCAS for responding to major frequency changes such as trip of a generator unit or a transmission failure.

Frequency control service providers are enabled by cost merit order in a similar process to the energy market.

Regulation FCAS

Regulation FCAS is provided by generators, which are given signals by AEMO's Automatic Generation Control (AGC) to raise or lower to maintain the frequency in the normal operating band.

Contingency FCAS

Contingency frequency control services are proved by technologies that detect frequency deviations locally. Once enabled by the NEMDE they respond automatically to correct contingency frequency events without receiving additional signals from AEMO. Contingency FCAS providers include:

- Thermal generator governor response: where the generator governor reacts to the frequency deviation
- Load shedding: where a load can be quickly disconnected from the electrical system

- Rapid Generation: where a frequency relay will detect a low frequency and correspondingly start a fast generator (can act to correct a low frequency only).
- Rapid Unit Unloading: where a frequency relay will detect a high frequency and correspondingly reduce a generator output (can act to correct a high frequency only).

Voltage Control Ancillary Services (VCAS)

AEMO is also required to maintain the network voltage within specified tolerances. One method that AEMO uses to achieve the voltage requirement is Voltage Control Ancillary Services. VCAS is the engagement of plant that can generate or absorb reactive power. Typically synchronous condensers, capacitors or reactors are used.

Batteries have the potential to participate in VCAS because battery power converters are able to generate and absorb reactive power without supplying energy to the market.

Network Loading Control Ancillary Service (NLCAS)

NLCAS is used by AEMO to prevent overload of the inter-connectors between regions on the NEM. When flow across an inter-connector approaches its limits AEMO can use AGC to increase generation on the end of the inter-connector with net demand or it can use load shedding.

As with Regulation FCAS, batteries can participate in the same way as a generator by supplying energy on the downstream end of the line to decrease the flow.

Batteries and the NEM

Energy Arbitrage

The Hornsdale Power Reserve is registered generator and trades in the NEM wholesale energy market. RenewEconomy estimates that the system could have made up to $1 million dollars over the two day period shown in

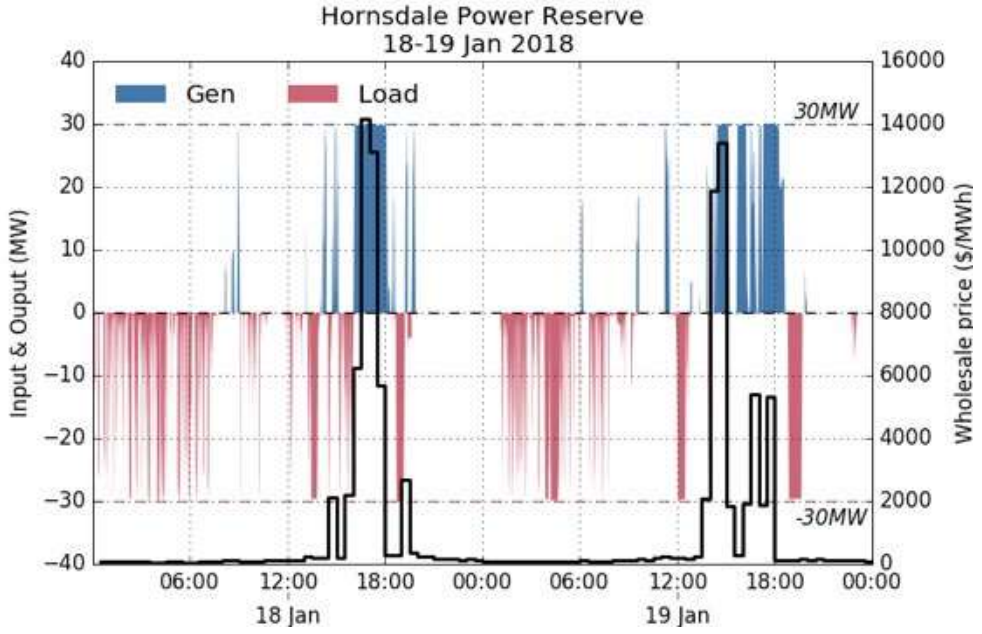

Figure 1.

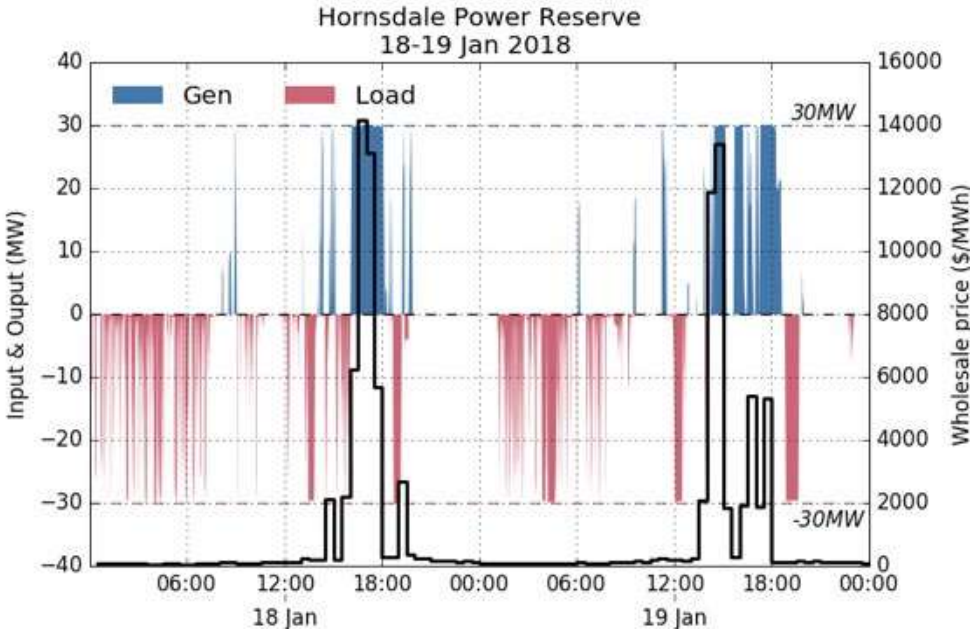

Figure 1 – Hornsdale Power Reserve energy arbitrage example (RenewEconomy: Dylan McConnell from Climate and Clean Energy College)

Regulation FCAS

Batteries are now increasingly being used for FCAS. One example is the Hornsdale Power Reserve 100 MW Tesla battery.

One of the main services that the battery has been providing is Regulation FCAS. A plot of the AEMO AGC signal and the battery output is shown in Figure 2. Batteries can effectively provide Network Loading Control Ancillary Services in the same way as Regulation FCAS.

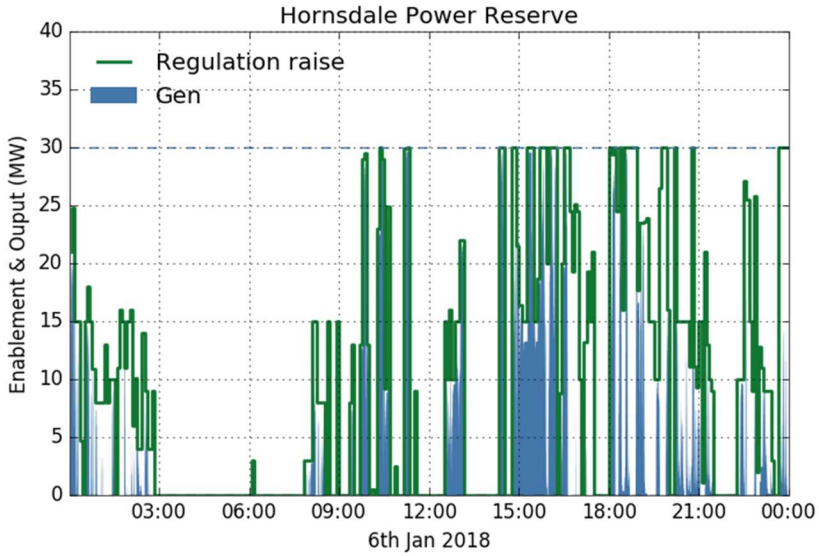

Figure 2 - Output of Horndale Power Reserve compared with enablement in the regulation raise FCAS market. [theconversation.com data from AEMO]

Contingency FCAS

The Hornsdale Power Reserve provided Contingency FCAS on 14 December 2017 when one of the major coal power generators tripped, see Figure 3.

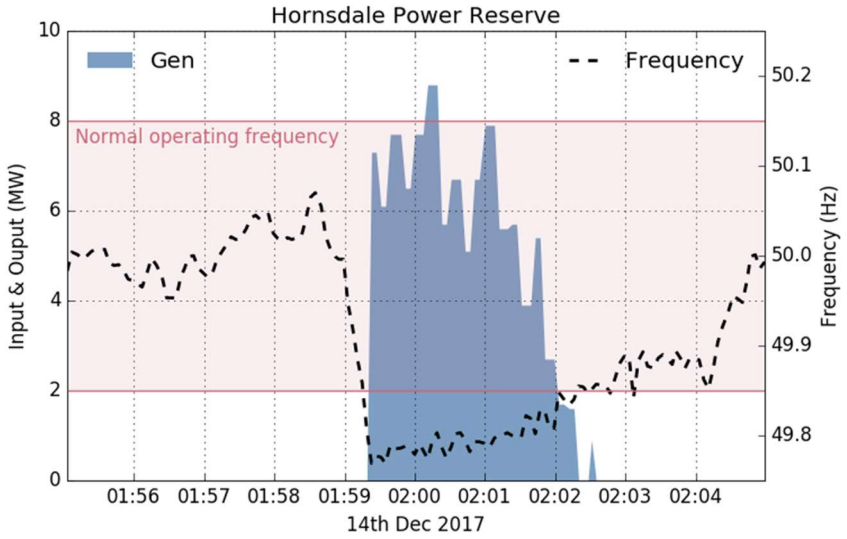

Figure 3 - The Hornsdale Power Reserve responding to a drop in system frequency. [theconversation.com data from AEMO'

TRANSMISSION AND DISTRIBUTION

In traditional electricity networks electricity is generated in large power stations then transported on high voltage network backbone known as the transmission system. When the power reaches a commercial or urban centre, the power is converted to a lower voltage before being transported to homes and businesses on supply reticulation called the distribution network.

The operator of the transmission network is a Transmission Network Service Provider (TNSP) and the operator of the distribution network is a Distribution Network Service Provider (DNSP). The NSW TNSP is TransGrid and the DNSP for the Barangaroo area is AusGrid.

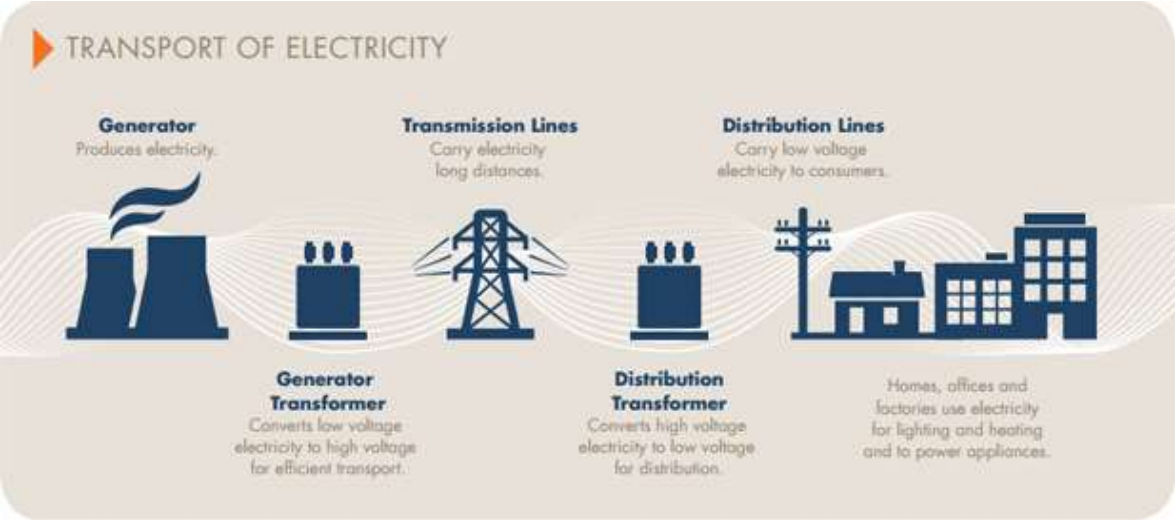

Figure 4 – Transport of Electricity (AEMO)

The role of the TNSPs and DNSPs is to maintain and operate a safe, reliable, sustainable and affordable network. Ahead of each regulatory period the network services providers (NSPs) submit a proposal for works expenditure and required revenue to meet their reliability objectives. Distributed energy system and advanced energy control technologies are providing new options for NSPs to achieve their reliability requirements. As these technologies improve they are becoming cost competitive with the traditional capital upgrade model. Solutions where the network services use alternate technologies rather than network upgrades to solve constraints are referred to as a non-network approach.

Non-network solutions include demand management solutions such as load curtailment or shifting, embedded generation and energy conservation measures to reduce load on the network.

Augmentation deferral, augmentation avoidance and network support

In Western Australia both Western Power and Horizon Power have trials in place in which they have supplied stand-alone power systems (solar, battery, diesel) to residents at the end of remote transmission lines. The trials have been successful to date and the total cost of supply install and operation of these systems being lower than the cost that maintenance and upgrade of the original line would have been. To date the consumers with stand-alone power systems have experienced less outages then their neighbours. On a larger scale, battery storage has been used to provide grid stability, reliability and lower energy costs on microgrids including Onslow, Coober Pedy, King Island and at the DeGrussa copper-gold mine in WA.

In a trial aimed specifically at deferring network augmentation costs, DNSP Endeavour Energy (Ausgrid equivalent) have installed grid support batteries at West Dapto near Wollongong. The installation of the 1MWh grid-connected battery is expected to reduce network investment by up to $1 million a year (RenewEconomy).

TransGrid and AusGrid Non-network solutions

There is a growing interest from NSPs to provide non-network solutions. In addition to direct capital expenditure projects such as the examples above, NSPs are beginning to run programs that incentivise consumers to assist in the resolution of network constraints.

TransGrid and AusGrid, the TSNP and DNSP servicing Barangaroo have been actively and jointly consulting with the community and planning non-network solutions for over four years. This process began with the Powering Sydney's Future consultation in 2014 and was continued in 2016 with a Regulatory Investment Test for Transmission (RIT-T) process. The RIT-T Project Assessment Conclusions Report (PACR) describe the purpose of the project as being undertaken "with a focus on alleviating the increasing risk to the supply of electricity to consumers from ageing electricity infrastructure in the Inner Sydney area. The overall RIT-T process is designed to directly engage with parties on the problem and proposed options being considered, both network and non-network, to address it [and] test the market for alternate and more efficient solutions" (TransGrid / AusGrid).

The conclusion of the RIT-T PACR are to implement non-network solutions to both delay significant network upgrades and to assist during the commissioning of the new assets. The non-network solutions recommended include 40-60MW of non-network capacity between 2018/2019 summer and 2021/2022 summer. The RFT for these solutions is expected in April 2018.

ELECTRICITY RETAIL

Medium sized consumers and generators are able to register as an energy market participant and buy and sell energy directly from the wholesale electricity market. However, most medium size energy choose not to register due to the compliance and technology requirements.

Buying and selling electricity through a retailer provides a barrier to the NSPs and the NEM. The electricity retailer offers a contract to buy electricity at pre-agreed tariffs. The tariff can be a flat rate or time of use (usually three rates: peak, shoulder and off peak). These tariffs are developed by the retailer based on their forecast of the average spot price in the wholesale energy market over the contract period, plus a risk margin, an operating margin and some cost to hedge their risk in the ASX energy futures market.

The tariff to feed any generated or stored energy back into the network is generally also a flat rate and is lower than the average energy market spot price.

The retailer's approach to tariffs protects consumers form exposure to the volatility of the wholesale market. This reduces the risk to the consumer of fluctuating energy prices, but it also restricts the ability to participate in the real time market and restricts the number of products available to the customer. It effectively shields the consumer from the maximum potential benefits of energy arbitrage or renewable energy storage.

The retailer will generally apply a capacity charge in the customer's electricity contract, which is a pass through of the NSP charges.