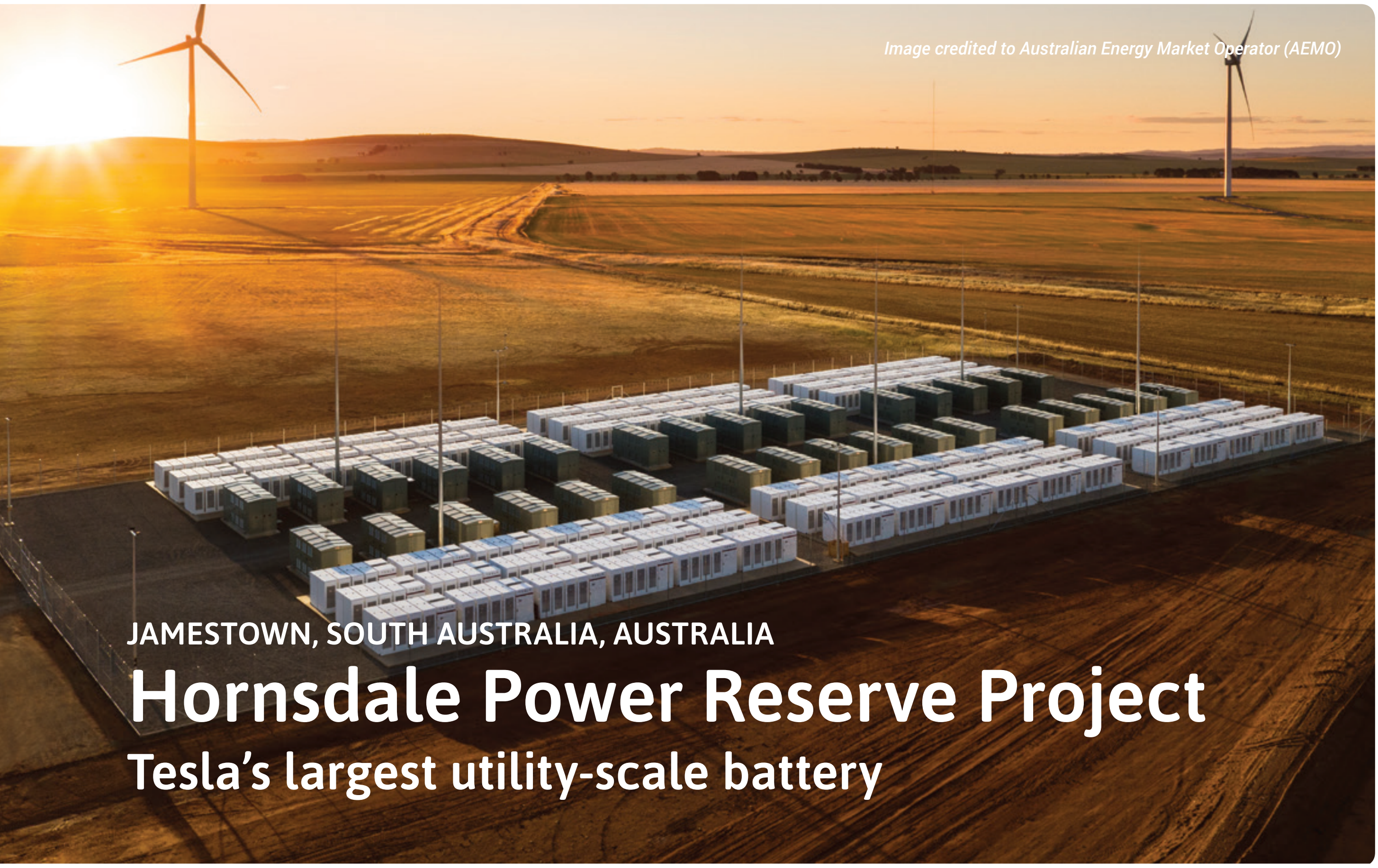

JAMESTOWN, SOUTH AUSTRALIA, AUSTRALIA

Hornsdale Power Reserve Project

Tesla's largest utility-scale battery

September 2019

PROJECT OVERVIEW

The Hornsdale Power Reserve (HPR) is the world's largest lithium-ion battery. The AUD 90 million[1] grid-connected 100 MW Tesla Powerpack system (the Battery) is located about 15 kilometres north of Jamestown, in South Australia.

Developed, owned and operated by Neoen, a French renewable energy company, the Battery's purpose is to contribute to the stabilisation and security of the South Australian electricity system, to further support the integration of renewable energy in South Australia, and to assist in preventing load-shedding events[2].

In addition to successfully supporting the security of electricity supply in South Australia, the Battery has also had the effect of reducing the cost of electricity grid stabilisation. The speed and accuracy with which the Battery can respond to changes in frequency has made it a significant competitor in the grid stability market, which has traditionally been dominated by conventional gas-fired generators. This increase in competition has resulted in a 57% cost saving (equivalent to approximately AUD 33 million) for electricity grid stabilisation services from Q4 2017 to Q1 2018, creating the potential for consumers to benefit from reduced power prices.

1 56 million euros in 2017, as reported by Neoen. Source: https://www.bloomberg.com/news/articles/2018-12-04/musk-s-outback-battery-sparks-new-projects-after-promising-run

2 Load-shedding is the process of deliberately switching off customers' power supply because there is not enough electricity supply to meet demand. In Australia, the Australian Energy Market Operator (AEMO) is the entity responsible for implementing a load-shedding event, for example, during a heatwave.

PROJECT DETAILS

- It is the world's most powerful battery; at the time of commissioning, the next largest was an 80 MW Tesla installation in Ontario, California.
- The Battery is helping to manage summertime peak load and reduce intermittencies and has improved the security of South Australia's electrical infrastructure.
- The Battery can respond to contingency events (which result in changes in electrical frequency) much faster than any conventional generator; it has a response time of a fraction of a second, compared to minutes for a gas or steam turbine, for example.
- It has the potential to prevent 200 MW of load-shedding in South Australia during a contingency event, such as generator failure[3].
- It has provided greater competition in the grid stabilisation services market:
  - It was the first time regulation frequency control ancillary services (FCAS) were offered by a technology other than conventional synchronous generation, such as coal and gas plants, in Australia's electricity market[4].
  - The cost of grid stabilisation services was 57% (AUD 32.7 million) lower in Q1 2018 than in Q4 2017, with a key driver being the introduction of the Battery to the market, increasing competition and replacing higher-priced supply from existing technologies[5].

CONTEXT

Australia's eastern states, including South Australia and Tasmania, are interconnected to form a National Electricity Market (NEM). The NEM is an interconnected electricity system where generators from one state can produce electricity consumed by another state, supplying electricity to nine million customers. The NEM is physically connected by transmission interconnectors that cross state boundaries.

In September 2016, large storms in South Australia caused major damage to homes and critical infrastructure, including more than 20 electricity transmission towers. The resulting faults in the transmission lines prompted several wind farms to power down. With that sudden loss of generation, South Australia immediately began drawing more power across the Heywood Interconnector from the state of Victoria. The increase in power being transmitted overloaded the interconnector and it was switched off causing a state-wide blackout across South Australia. Much of the state was without power for several hours, with full power not restored to all parts of the state until several weeks later.

Further supply interruptions and load-shedding events between September 2016 and February 2017 led the South Australian Government (the SA Government) into an intensive period of policy planning to address power supply concerns. In March 2017, the SA Government responded to the 'energy crisis' by announcing an AUD 550 million plan (the Energy Plan)[6] to improve energy security in the state, which included the construction of Australia's largest battery storage project.

Image credited to Australian Energy Market Operator (AEMO)

3 Aurecon, Hornsdale Power Reserve Year 1 Technical and Market Impact Case Study, 2018

4 AEMO, Initial operation of the Hornsdale Power Reserve Battery Energy Storage System, April 2018

5 AEMO, Quarterly Energy Dynamics, Q1 2018

6 It should be noted that, as of the March 2018 election, this Energy Plan has now been superseded by the new South Australian Government's energy strategy.

PROJECT TIMELINE

Key dates in the project timeline are shown below:

28 September 2016
Storms caused a significant and sustained state-wide power blackout in South Australia.

9 March 2017
A Twitter exchange between Tesla CEO, Elon Musk and Atlassian entrepreneur, Mike Cannon-Brookes, sparks increased interest in a battery solution. Elon Musk makes his "100 days from contract signature or it is free" promise.

14 March 2017
The SA Government announces an AUD 550 million Energy Plan to increase grid reliability that, among other objectives, includes building a 100 MW battery before the 2017/18 Australian summer.

16 March 2017
The SA Government opens a two-stage competitive procurement process for national and international companies interested in constructing the 100 MW battery, beginning with an Expression of Interest (attracting 79 proponents) followed by an Invitation to Supply for 14 shortlisted proponents.

6 July 2017
The Hornsdale Power Reserve (HPR) consortium, led by Neoen and using Tesla's battery equipment, is awarded the contract to build the Battery and the Project Agreement is signed.

29 September 2017
Grid connection agreement is signed with ElectraNet, the electricity transmission network operator, and approved by the Australian Energy Market Operator (AEMO). Elon Musk's 100-day deadline begins.

1 December 2017
The Battery is constructed and connected to the NEM, ahead of the 100-day promise[7].

18 December 2017
The first opportunity for the Battery to respond to a grid stabilisation issue arises when a coal generator in New South Wales shuts down. The Battery responds to the sudden loss of 689 MW of generation within a fraction of a second, faster than any other existing generation technology.

CONTRACTUAL STRUCTURE

The SA Government awarded the contract to develop the Battery to the HPR consortium in July 2017. The HPR consortium was contracted to design, finance, construct, commission and test the battery storage facility, and subsequently own, operate and maintain the Battery. Tesla is the battery technology and energy storage system provider. Neoen is the owner and operator of the project. The Battery was developed and operational in less than 100 days from contract signature, providing a new competitive source of energy and frequency control in South Australia. The project is registered and participates in the NEM as a scheduled and ancillary services generator and load.

The HPR consortium must deliver the following electricity services for 10 years under the Project Agreement with the SA Government:

- Provide system security services to maintain the security, integrity and stability of the South Australian electricity network
- Prevent certain load-shedding events
- Provide supply during critical peak periods
- Participate in ancillary services and wholesale electricity markets.

Tesla is party to the Project Agreement to ensure its commitments and obligations to the SA Government, established in the Contractor Industry Participation Plan, are captured. Tesla's agreement involves ongoing commitments to contribute towards South Australia's economic development. In addition, Neoen and Tesla also have separate agreements for the engineering, procurement and construction, and operation and maintenance of the Battery.

Financing and Funding

Over the life of the Project Agreement, the SA Government has agreed to pay AUD 41.8 million for the provision of battery storage services, from its Renewable Technology Fund of AUD 150 million. The SA Government makes monthly payments to the HPR consortium in line with the Project Agreement. In return, the HPR consortium grants the Government the exclusive right to a reserved power output capacity of 70 MW and a reserved energy storage capacity of 10 MWh. The remaining excess capacity in the Battery may be used by the HPR consortium to sell to the NEM and generate further revenue.

7 This timeframe is considered relatively rapid in the South Australian context. For comparison, the Battery Operating Agreement for the ESCRI Battery in South Australia was executed in September 2017, with commissioning and testing completed in April 2019. (ESCRI-SA Project Summary: The Journey to Financial Close, ElectraNet 2018; and https://www.escri-sa.com.au/about/ [accessed 11 July 2019])

A summary of the contractual structure is shown below.

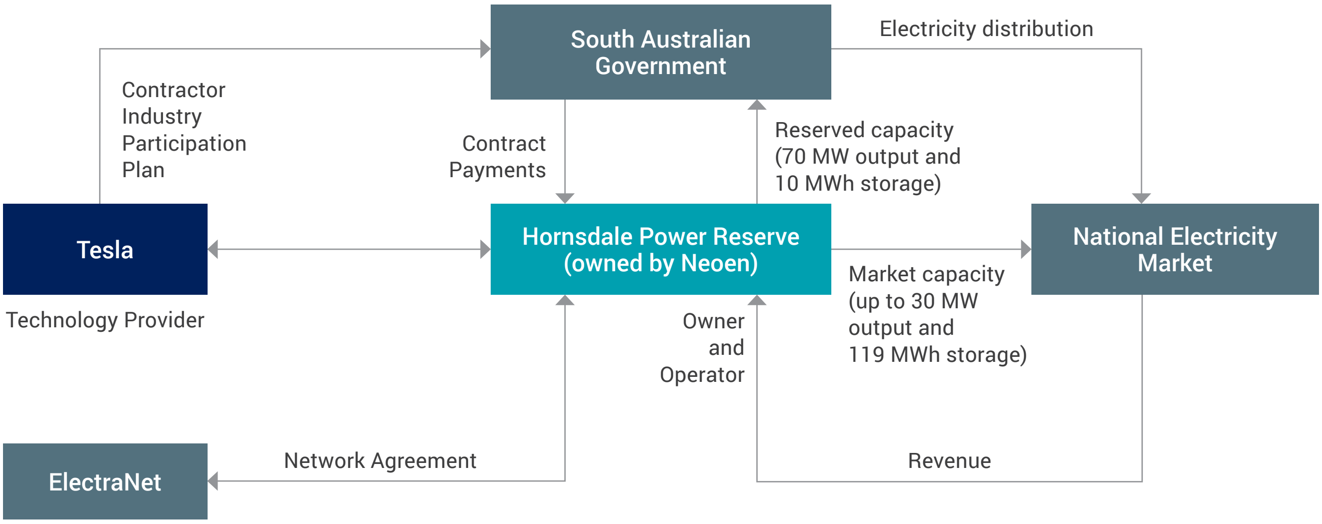

Figure 1 – Contractual structure of the Battery

Source: The Government (Auditor-General's Department), Global Infrastructure Hub analysis

BATTERY TECHNOLOGY

Features

The Battery uses Tesla Powerpack lithium-ion units and associated equipment. Each Powerpack is a direct current energy storage device containing 16 individual battery pods, similar to those used in Tesla's vehicles.

Approximately five Powerpacks provide one MWh of energy, hence the Battery comprises several hundred connected Powerpack towers.

The Battery provides enough electricity to power the equivalent of 30,000 homes, which is approximately equal to the number of homes that lost power during South Australia's major blackout in 2016. The Battery's 129 MWh capacity represents approximately 75 minutes of electricity at full discharge.

It shares the same 275 kV network connection point as the 300 MW Hornsdale Wind Farm, which is used as a charging source and delivers electricity during peak hours to help maintain system security.

Functions

A utility-scale lithium-ion battery such as the Battery may typically be expected to perform the following functions:

- Network security services, including frequency control ancillary services (FCAS) and Network Loading Control Ancillary Services (NLCAS)[8]
- System Restart Ancillary Services (SRAS)[9]
- Arbitrage (buying and selling electricity in the NEM to generate revenue)
- Peak shaving (reducing the amount of energy purchased at peak times)
- Block/load shifting (shifting energy consumption to another time period to avoid paying high energy prices)
- Renewable firming and smoothing (firming intermittencies and smoothing out minor variations in renewable energy output)

A utility-scale lithium-ion battery's primary difference compared with other technology types is the speed at which it can provide rapid response services to electricity grid contingency events, such as power outages or heatwaves. The Battery was chosen as a solution to South Australia's 'energy crisis' because of its speed and has proven itself by responding to contingency events as required since inception.

Due to its agile responsiveness, the Battery has also been included in a new control scheme called the System Integrity Protection Scheme (SIPS)[10].This is designed

8 FCAS are used by AEMO to help correct the supply/demand balance in response to minor changes in electricity load or generation. NLCAS are used by AEMO to control the flow on interconnectors, either by increasing generation or load-shedding.

9 SRAS are required to enable the power system to be restarted following a complete or partial black-out.

10 This scheme was implemented following a recommendation from AEMO to investigate the feasibility of developing such a scheme which would initiate, if necessary, load-shedding or generation tripping with a response time fast enough to prevent separation. Future South Australia-installed batteries may also be included in this control scheme. Recommendation 4 from AEMO's Third Preliminary Report on the Black System South Australia event, found at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Reports/2016/Integrated-Third-Report-SA-Black-System-28-September-2016.pdf

to reduce the likelihood of the South Australia power system separating from the rest of the NEM following a sudden increase in flow on the Heywood Interconnector. SIPS is intended to detect high flows on the Heywood Interconnector and trigger the Battery to start discharging at peak capacity as quickly as possible. The Battery's injection increases local power supply in South Australia, which reduces the required flows on the Heywood Interconnector, reducing the likelihood of it disconnecting.

In addition to the Battery's performance in delivering the services described above, a major benefit is its ability to reduce the costs associated with grid stabilisation, by promoting greater competition in FCAS, as discussed below.

MARKET IMPACT

Australia's National Electricity Market

The NEM is a wholesale electricity generation market, transporting electricity via high voltage transmission lines from generators to large industrial energy users and to local electricity distributors in each region, which then deliver it to homes and businesses. AEMO is responsible for managing the NEM to ensure power supply safely meets demand.

AEMO also manages electricity frequency and stability delivered to the NEM via FCAS. There are two types of FCAS provided to the NEM – regulation and contingency. Regulation FCAS enables continuous correction of generation/demand balance in response to minor deviations in load or generation. Contingency FCAS enables the correction of generation/demand balance following a major event, such as the loss of a generating unit, a major industrial load or a large transmission element. In Q1 2018, the Battery was enabled to provide regulation and contingency FCAS for 71% and 99% of the time, respectively.

Impact on FCAS Delivery

HPR's most significant market impact has been in the regulation FCAS market. For system security purposes, AEMO has historically required the local procurement of 35 MW of regulation FCAS in South Australia at times when the separation of the state from the Heywood Interconnector is a credible contingency. During these times, South Australian FCAS prices have been very high–approximately 20 to 50 times the normal average price–due to the limited supply of these services in the state.

Aurecon has estimated that the additional regulation FCAS cost due to this local procurement requirement approached AUD 40 million over 2016 and 2017[11], before the Battery was operational. In October 2018, AEMO determined that the procurement of the 35 MW was no longer required due to the Battery providing added competition and reduced FCAS prices, and the implementation of other system strength requirements.

AEMO pays for FCAS according to how quickly it is delivered, on a scale tied to three response rates–six seconds, one minute, and five minutes. The Battery provides a response time of approximately 100 milliseconds. This ability to deliver FCAS faster than conventional generation technology boosted competition in the market, resulting in a 57% (AUD 32.7 million) reduction in FCAS costs in Q1 2018 compared with Q4 2017. Such a cost reduction ultimately leads to potentially lower electricity prices for end users.

Despite the Battery's speed and precision in response compared with conventional synchronous generation, regulation FCAS arrangements in the NEM do not currently recognise differences in the quality of service delivery. All regulation FCAS are essentially considered to be equal and interchangeable, and providers are paid the same price per MW of enabled service, regardless of performance.

REGULATORY IMPLICATIONS

Current FCAS market arrangements could be modified to specifically recognise the rapid and accurate response capabilities of lithium-ion batteries, enhancing their ability to drive cost reductions to the broader energy market.

Some overseas markets have established new frequency control services with very short delivery time requirements that are typically only fulfilled by batteries. For example, the PJM Interconnection, which operates in the eastern United States[12], has established two separate regulation products, one of which is allocated only to batteries, and has introduced performance metrics for the provision of regulation services that include a payment multiplier for higher performance.

11 Aurecon, Hornsdale Power Reserve Year 1 Technical and Market Impact Case Study, 2018

12 Originally named for Pennsylvania-New Jersey-Maryland (PJM), the Interconnection now serves Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia and the District of Columbia.

Further reading:

https://hornsdalepowerreserve.com.au/

https://arena.gov.au/assets/2019/02/hornsdale-power-reserve.pdf

https://www.aemo.com.au/-/media/Files/Media_Centre/2018/Initial-operation-of-the-Hornsdale-Power-Reserve.pdf

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