Initial operation of the Hornsdale Power Reserve Battery Energy Storage System

April 2018

Important notice

PURPOSE

This paper provides an overview of the initial period of operation of the Hornsdale Power Reserve Battery Energy Storage System (HPR), focusing on its participation in frequency control ancillary services (FCAS) markets, since it was commissioned in late 2017.

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VERSION CONTROL

Version	Release date	Changes
	5/4/2018	

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1. Background

The Hornsdale Power Reserve Battery Energy Storage System (HPR) is located near Jamestown, north of Adelaide in South Australia.

The HPR battery is rated at 100 megawatts (MW) discharge and 80 MW charge, and has a storage capacity of
129 megawatt hours (MWh). This capacity represents approximately 75 minutes at full discharge.

The HPR shares the same 275 kilovolt (kV) network connection point as the 300 MW Hornsdale Wind Farm.

1.1 Services provided by the Hornsdale Power Reserve

The HPR provides a range of services under commercial agreements between the South Australian Government, Tesla (the battery technology provider), and NEOEN (the operator of the Hornsdale Wind Farm). The services are summarised below. AEMO is not a party to these agreements.

1.1.1 Energy arbitrage

Under normal conditions, 30 MW of the battery's discharge capacity is made available to NEOEN for commercial operation in the National Electricity Market (NEM). Of the battery's total 129 MWh energy storage capacity,
119 MWh may be used for this mode of operation.

1.1.2 Reserve energy capacity

The remaining 70 MW of battery discharge capacity is reserved for power system reliability purposes.

This 70 MW reserve capacity has not been dispatched to date. Under arrangements with the South Australian government, this capacity is offered into the NEM at the Market Price Cap, ensuring this component of the HPR will not be dispatched ahead of other generation in South Australia.

1.1.3 Network loading control ancillary services (NLCAS)

The HPR is included in a new control scheme – the System Integrity Protection Scheme (SIPS) – which is intended 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[1]. This control scheme was developed by ElectraNet and reviewed by AEMO, and it is being implemented by ElectraNet under the NLCAS framework.

The SIPS control scheme is intended to detect high flows on the Heywood Interconnector and trigger the HPR to start discharging at 100 MW as quickly as possible. This control scheme may also undertake controlled load shedding in South Australia, to further reduce the likelihood of loss of the Heywood Interconnector.

Future South Australia-installed batteries may also be included in this control scheme. A key feature of this control scheme is the very rapid response that can be achieved using battery systems.

The South Australian NLCAS requires 10 MWh of the HPR's total energy storage capacity to be reserved for the control scheme. It is expected to be fully commissioned in the second quarter of 2018.

1.1.4 Frequency Control Ancillary Services (FCAS)

The HPR is registered to provide all eight FCAS services[2], and actively participates in all eight FCAS markets. AEMO provided input into the design of the frequency controls, considering the battery's high performance capabilities, to maximise power system security benefits.

[1] This occurred on 28 September 2016, leading to the black system event.

[2] Regulation FCAS is enabled to continually correct the generation/demand balance in response to minor deviations in load or generation. There are two types of regulation FCAS (raise and lower). Contingency FCAS is enabled to correct the generation/demand balance following a major contingency event, such as the loss of a generating unit or major industrial load, or a large transmission element. Contingency services are enabled in all periods to cover contingency events, but are only

This paper summarises the HPR's performance to date in providing FCAS services, and highlights potential learnings for future battery storage developments and their participation in frequency response markets.

2. Participation in FCAS markets to date

2.1 Regulation FCAS

AEMO's central Automatic Generation Control (AGC) system can be used to control the HPR, and this is the normal control arrangement most of the time. AGC control allows AEMO to send a new MW set-point to the battery at a rate of up to once every four seconds.

This enables the HPR to provide regulation FCAS in South Australia. This market has seen high prices for this service for the two years prior to the battery becoming operational.

Regulation FCAS incrementally adjusts the output of the battery up or down, away from an underlying energy dispatch target, to correct slow moving frequency changes across the NEM. Up to 30 MW of the battery's output capacity is available for provision of regulation FCAS.

This is the first time regulation FCAS has been provided in the NEM by any technology other than conventional synchronous generation.

The neighbouring Hornsdale Wind Farm has also recently trialled operation under AGC control to provide regulation FCAS, and further trials are planned for other wind farms in the NEM.

2.1.1 Quality of regulation FCAS delivery

Data available to AEMO demonstrates that the regulation FCAS provided by the HPR is both rapid and precise, compared to the service typically provided by a conventional synchronous generation unit. Figure 1 and Figure 2 compare the accuracy and response speed of a large conventional steam turbine (Figure 1) and the HPR (Figure 2) to AGC set-point control targets for frequency regulation over a one-hour period.

occasionally used (if the contingency event actually occurs). There are six types of contingency FCAS, to raise and lower in three different time scales (fast or 6 seconds, slow or 60 seconds, and delayed or five minutes).

Figure 1 Accuracy and speed of regulation FCAS response – large conventional steam turbine

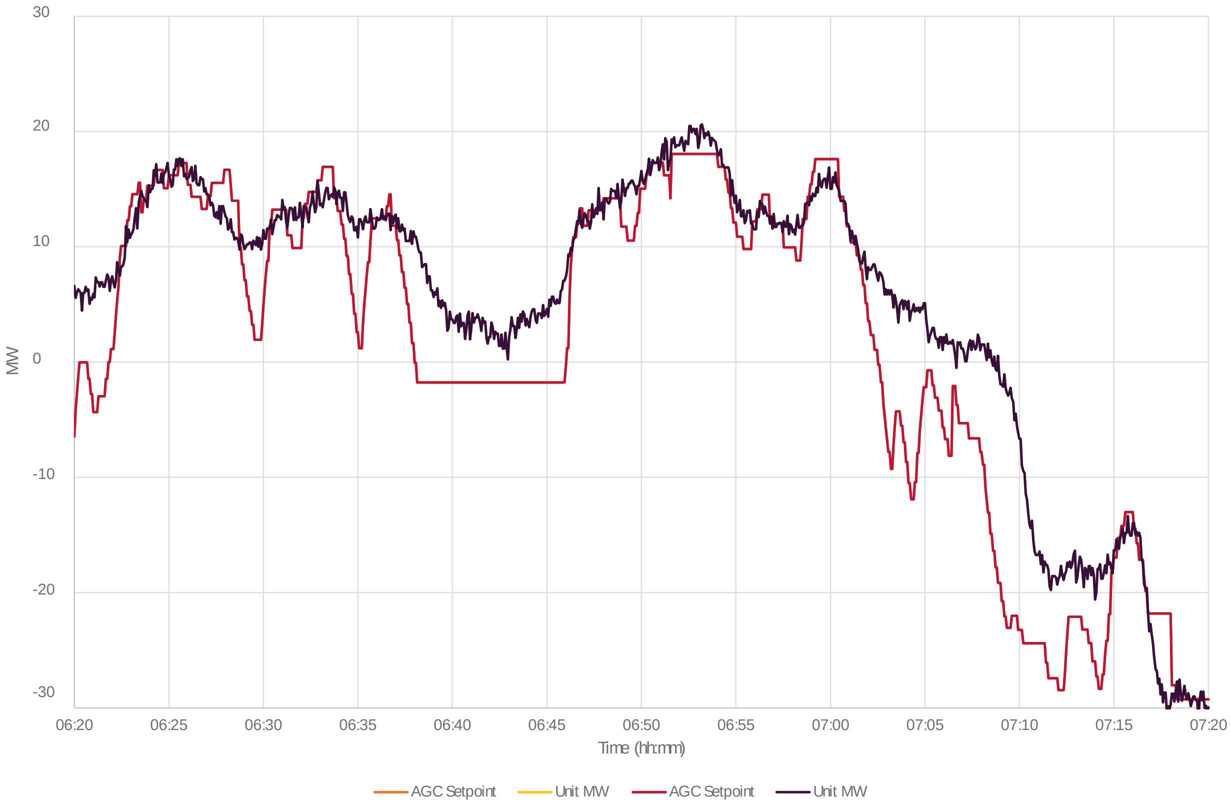
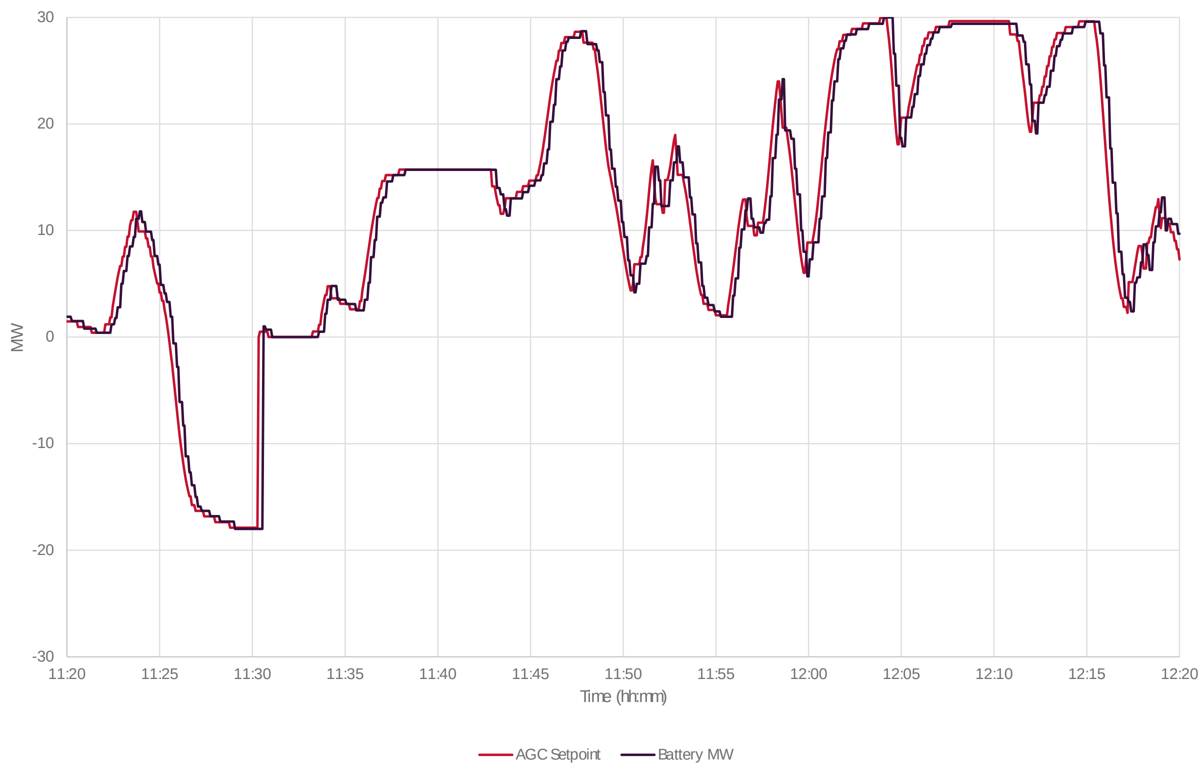


Figure 2 Accuracy and speed of regulation FCAS response – Hornsdale Power Reserve



While experience shows that the HPR is capable of providing very high quality regulation FCAS, regulation FCAS arrangements in the NEM do not currently recognise differences in the 'quality' of service delivery.

The Market Ancillary Services Specification (MASS), which specifies each market ancillary service, and how it is to be quantified, does not address performance requirements for regulation FCAS. All regulation FCAS is essentially considered to be equal and interchangeable, and providers are paid the same price per MW of enabled service, regardless of performance.

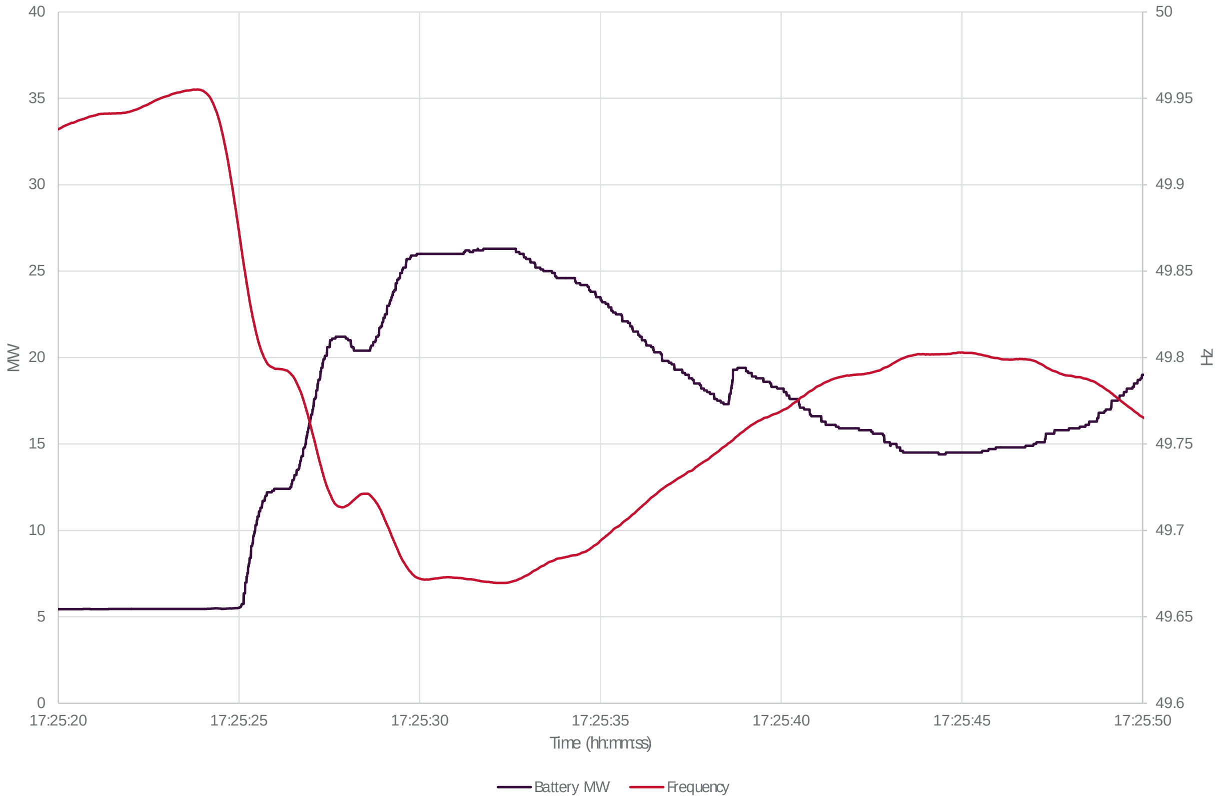
2.2 Contingency FCAS

The HPR has been configured to provide a contingency FCAS response at all times, irrespective of FCAS market outcomes, using the full technical operating range of the battery.

Because major frequency deviations in the NEM are (fortunately) rare, actual full delivery of this service has not yet been demonstrated.

An example of the HPR's actual response to the trip of 689 MW of generation in New South Wales on 18 December 2017 is shown in Figure 3 below. This is fully consistent with the expected response.

Figure 3 Hornsdale Power Reserve response to trip of generation in New South Wales, 18 December 2017



Commissioning tests and simulations confirm that the HPR is capable of responding more rapidly to a contingency event than conventional synchronous generation. As noted above for regulation FCAS, due to the way the MASS assesses contingency FCAS capability, HPR's high response capability is not recognised or rewarded differently to the service provided by conventional synchronous generation.

3. Learnings for future large batteries

Operation of the HPR to date suggests that it can provide a range of valuable power system services, including rapid, accurate frequency response and control.

The funding arrangements for the HPR meant there was a focus on ensuring all its capabilities were fully utilised to maximise power system security for South Australia. This included engagement with AEMO when control settings and operating arrangements were determined, in a way that would not typically occur for other generation development (where the project developer is responding to existing market signals and arrangements).

Future development of batteries outside of South Australia might not result in the provision of similar services, due to the way FCAS are currently quantified and rewarded, as well as the voluntary nature of participation in the FCAS market, and in frequency control arrangements more broadly.

Where other large batteries are established under government incentive schemes, there could be a role for a more prescriptive provision of system security services, to maximise the benefits to the power system such devices can provide.

Current FCAS market arrangements could also be modified to specifically recognise the rapid and accurate response capabilities of batteries, and therefore enhance their ability to earn income from providing them.

3.1 Changing how frequency response is assessed and paid for

Batteries, and some other inverter-based technologies, have demonstrated that they are capable of rapid delivery of a large and sustained response to a change in frequency. In some circumstances this can be particularly valuable, such as following a large disturbance, or when the power system is operating with low inertia.

The current methods for assessing and commodifying frequency response involve performance assessment against a slow moving change in frequency, and do not therefore recognise, or reward, the more rapid response capabilities of batteries, and some other inverter-based technologies.

In some overseas markets, new frequency control services with very short delivery time requirements have been established, which are typically only fulfilled by batteries.

Modified regulation market arrangements at PJM Interconnection

PJM Interconnection operates part of the United States' power system, covering 13 eastern states and the District of Columbia. It is 3-4 times larger than the NEM in terms of installed generation capacity and annual energy consumption, but much smaller geographically.

PJM runs an hourly market for regulation services, which are used for the slow correction of system frequency and the control of tie-line flows with neighbouring power systems. PJM has identified similar differences in the quality of regulation response available from batteries, compared to conventional generation sources, to those AEMO has observed and noted in this paper.

As a result, PJM has:

- Established two separate regulation products, one of which is allocated only to batteries.
- Introduced performance metrics for the provision of regulation services that include a payment multiplier for higher performance.

Either or both of these concepts could be used in the NEM, although, due to differences in the underlying market designs, it may not be possible to directly translate PJM's approach to the NEM.

Care would be required in establishing new markets, or modifying the assessment of frequency response capabilities in the NEM, to consider the current complex interactions between the dispatch of FCAS and energy in the NEM, the potential need to maintain technology neutrality, and the potential for limited competition in the delivery of any newly defined services.

AEMO will work with industry to undertake formal consultation on the necessary modifications to the MASS.