Preliminary Report Non-Credible Separation Event South Australia – Victoria on 16 November 2019

December 2019

A preliminary operating incident report for the National Electricity Market. Information as at 09:00 29/11/2019

Important notice

PURPOSE

AEMO has prepared this report to provide preliminary information about the non-credible separation of South Australia from the National Electricity Market (NEM) which occurred on 16 November 2019.

DISCLAIMER

The information in this report is preliminary in nature and subject to confirmation. Acquisition and analysis of data by AEMO is incomplete and the initial findings may therefore change. Any views expressed in this report are those of AEMO unless otherwise stated, and may be based on information given to AEMO by other persons.

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VERSION CONTROL

Version	Release date	Changes
#1	18/12/2019	Original Release

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Executive summary

Event summary

At 18:06:47 (EST) on 16 November 2019, two 500 kV transmission lines in Victoria were disconnected simultaneously due to spurious signals from telecommunications equipment that caused the maloperation of protection equipment on both circuits. This non-credible contingency event resulted in the disconnection of the South Australian region from the rest of the National Electricity Market (NEM) power system for nearly five hours, and disconnection of electrical supply to the Alcoa Portland (APD) aluminium smelter in Victoria for nearly three hours.

This preliminary report provides information on:

- The cause of the event to the extent known at the point in time when this preliminary report was compiled.
- The performance of the power system during the event.
- Actions taken by AEMO to manage power system security.
- Market pricing during the event.

This preliminary report is based on data sourced and provided up to 17:00 Friday 29 November 2019. Information, data and observations in this report can change or be refined as new information and analysis becomes available.

Unless otherwise noted, all times in this report are Eastern Standard Time (EST).

Next steps

AEMO's investigation of the events of 16 November 2019 is ongoing. The investigation will seek to establish:

- Detailed cause of the event based on validated data and investigations.
- Operation of communication and protection equipment.
- FCAS response of generators and batteries enabled to provide FCAS.
- Synchronous and asynchronous generator and battery responses, including distributed resources. This will include a comparison to responses predicted by simulation models.
- Market response.
- Recommended actions for mitigation and improvement.

Investigation of this event requires AEMO to collect and analyse data from registered participants in the NEM to assess the cause and effects of the event, as well as the individual and combined responses of equipment in the power system at both the transmission and distribution level. Initial data requests were issued on 18 and 19 November 2019 and, under the National Electricity Rules (NER), registered participants have up to 20 business days to respond to AEMO. Further information may have to be requested following the initial data analysis.

Given these considerations, a timeline for publication of the detailed investigation report is yet to be determined, but unlikely to be before March 2020.

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Tables

Figures

1. Pre-event conditions

This section describes the relevant power system and environmental conditions immediately before the simultaneous opening of the Heywood-Alcoa Portland-Mortlake and Heywood-Alcoa Portland-Tarrone 500 kilovolt (kV) lines at 18:06:47 on 16 November 2019 (the event).

1.1 Weather

The weather conditions for Saturday 16 November 2019 near the VIC-SA Heywood interconnector were relatively cool, with Mt Gambier station in SA recording a minimum temperature of 3.4°C and maximum of 15.5°C, and a small amount of rainfall. Similar conditions were seen at Dartmoor station in VIC. There were low to moderate winds during the day and associated moderate wind generation in both regions that evening. Throughout this period there were also ongoing bushfires in NSW.

Weather warnings summary for 16/11/2019:

- SA: No wind warnings or severe weather warnings. Fire incident warning forecasts for 16/11/2019: Dorset Vale and Carey Gully.
- VIC: Marine wind warning: Strong winds for Central Coast, Central Gippsland Coast, East Gippsland Coast.
- No Thunderstorms forecast for SA nor VIC.

Weather was not a factor in the separation event of 16 November 2019.

1.2 Pre-event system configuration

The National Electricity Market (NEM) power system was in a secure operating state prior to the event in all regions. No abnormal operating conditions were present in either Victoria or South Australia at the time of the event.

There were no network outages or works in the vicinity of the Heywood interconnector between Victoria and South Australia at the time of the event.

A planned outage of a static var compensator (SVC) at Para near Adelaide was under way at the time of this incident. This resulted in some reduction in maximum transfer limits on the Heywood interconnector.

1.3 Regional demands

Table 1 lists operational demand in all NEM regions measured at 18:05 on 16 November 2019. This is the last measurement of operational demand prior to the event.

Table 1 **NEM operational demands at 18:05 on 16 November 2019 (MW)**

Region	Demand (MW)
Queensland	7,835
New South Wales	7,673
Victoria	4,858
South Australia	1,256
Tasmania	1,310

1.3.1 Alcoa Portland (APD) smelter load

The load at APD is supplied directly from the Victorian 500 kV transmission network near Heywood. The smelter load immediately prior to the event was 494 megawatts (MW).

Portland Wind Farm connects to the NEM through the APD switchyard. When Portland Wind Farm is generating, its output partly offsets the APD load. Output of Portland Wind Farm immediately prior to the event was approximately 53 MW.

1.3.2 South Australia generation mix

Total generation from grid-scale resources in South Australia shortly before the event was around 1,538 MW.

This generation was split almost equally between synchronous generation and inverter-based resources (IBR), including wind, transmission-connected solar photovoltaic (PV), and grid-scale batteries.

Table 2 shows the breakdown of generation, measured at 18:05 on 16 November 2019.

Table 2 **Synchronous generation output at 18:05 on 16 November 2019 (MW)**

Synchronous generation	Initial MW
Pelican Point	211
Ladbroke Grove 1	42
Osborne	179
Torrens Island B3	162
Torrens Island B4	164
Total	758
Inverter Based Resources	Initial MW
Wind	753
Transmission-connected PV	18
Grid batteries	9
Total	780

For the IBR in SA just prior to the event:

- All wind farms registered in South Australia were operating at the time of the event.
- Of the three solar farms currently registered in South Australia, only the Tailem Bend Solar Farm was generating. The Bungala 1 and Bungala 2 Solar Farms were not generating at the time of the event.
- The Lake Bonney Battery Energy Storage System (BESS) was out of service at the time of the event. The Dalrymple and Hornsdale BESS were in service.

1.3.3 South Australia synchronous inertia

The total inertia of synchronous generation in South Australia at the time of the event was approximately 6,500 Megawatt-seconds (MW.s).

1.3.4 Distributed PV generation

Output of distributed PV generation in South Australia for the half-hour ending 18:00 was estimated to be approximately 221 MW. This is not included in the totals above.

1.4 Heywood and Murraylink interconnectors

Table 3 below shows the market targets and limits for the Heywood interconnector in the five-minute dispatch intervals (DI) immediately prior to, and after, the event.

Table 3 **Heywood Interconnector flow targets**

DI ending	Initial MW	Target MW	MW Flow Limit
18:10	-286	-241	-420
18:15	-3	-55	N/A (no interconnector)
18:20	-3	0	N/A (no interconnector)

High-speed monitoring data shows the instantaneous MW flow on the Heywood AC interconnector was approximately -307 MW (flow in the South Australia to Victoria direction) at 18:06:47, immediately prior to the event.

The Murraylink HVDC interconnector between Victoria and South Australia was out of service for maintenance at the time of the event.

1.5 South Australia FCAS enablement

There were seven sources of frequency control ancillary services (FCAS) enabled within South Australia for the DI ending 18:10, these were:

1. Aggregated demand response provided by Enel X
2. Aggregated Tesla virtual power plant (VPP)
3. Dalrymple Battery Energy Storage System (BESS)
4. Hornsdale Power Reserve (HPR) BESS
5. Pelican Point combined cycle gas turbine (PPT CCGT)
6. Torrens Island B unit 3, and
7. Torrens Island B unit 4.

The enablement of each source is shown in Table 4.

Table 4 **Enablement of FCAS in South Australia. DI ending 18:10**

FCAS type	Enel X	Tesla VPP	Dalrymple BESS	HPR BESS	PPT CCGT	Torrens B3	Torrens B4	Total MW
RREG				23	30	40	25	118
R6	4	1	23	63	13	15	15	134
R60	4	1	23	19	13	30	30	120
R5		1	23	41				65

FCAS type	Enel X	Tesla VPP	Dalrymple BESS	HPR BESS	PPT CCGT	Torrens B3	Torrens B4	Total MW
LREG				40		14	15	69
L6		1	1	40				42
L60		1	1	19		10	10	41
L5		1	1	40				42

FCAS was enabled in South Australia prior to this event to meet global NEM requirements for frequency control, as there was no identified credible contingency event that would cause the South Australian region to separate from the rest of the NEM power system. AEMO does not enable FCAS pre-emptively to manage islanding of a region resulting from a non-credible event, as occurred on 16 November 2019.

2. Initial event

This section describes the non-credible contingency event that initiated the islanding of the South Australian region.

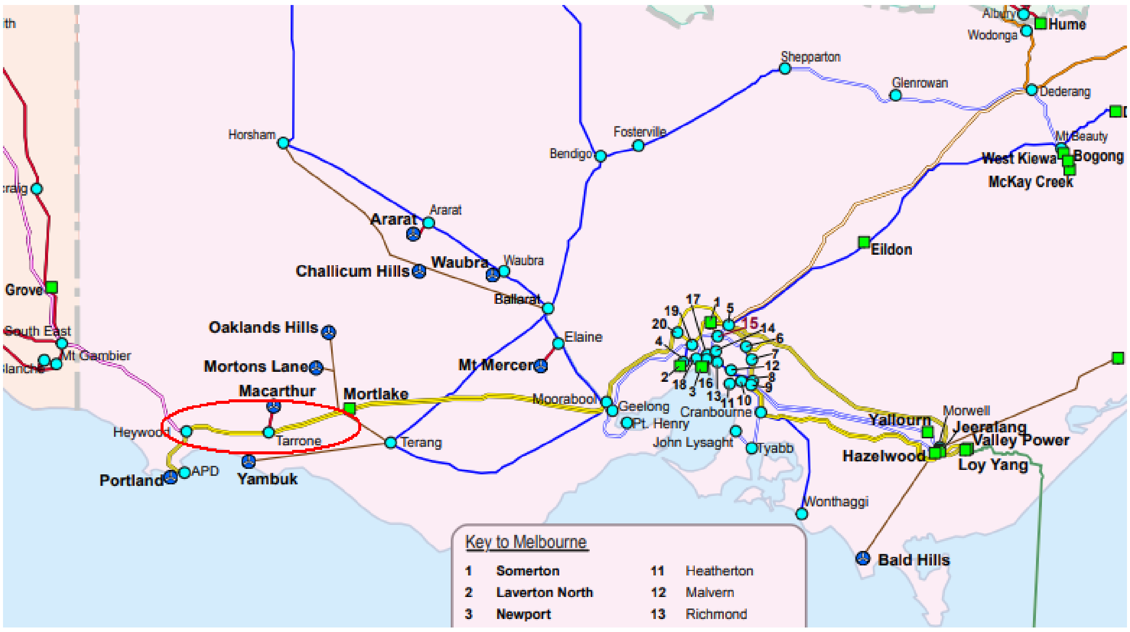
2.1 Simultaneous loss of multiple 500 kV lines in Western Victoria

Based on SCADA data available to AEMO, the following 500 kV transmission lines in Western Victoria simultaneously opened at 18:06:47 on 16 November 2019:

- Heywood – Alcoa Portland - Mortlake 500 kV line (HYTS–APD-MOPS 500 kV line).
- Heywood – Alcoa Portland - Tarrone 500 kV line (HYTS–APD-TRTS 500 kV line).

Figure 1 shows the location of the affected 500 kV lines in Victoria.

Figure 1 Victoria transmission system



At 18:06:47 there was a direct disconnection of all electrical supply to the APD 500 kV switchyard, and disconnection of the South Australian region from the rest of the NEM at Heywood.

High speed monitoring data shows no evidence of any initiating disturbance immediately prior to this event. It appears the cause of this event can be assessed as a 'clean' disturbance, without the influence of voltage disturbances or behaviour of generation.

2.2 Cause of non-credible disconnection of transmission lines

AusNet Services owns and operates the majority of Victoria's electricity transmission network. AusNet Services owns and operates the lines impacted in this event.

During the event, AusNet Services advised AEMO that disconnection of two 500 kV lines was due to maloperation of a communication multiplexer which caused the X unit protections on both of the affected transmission lines to erroneously detect faults and cause the opening of circuit breakers at each terminal on both lines. The mal-operating equipment needed to be isolated before the 500 kV lines could be restored to service, allowing restoration of supply to APD, and reconnection of South Australia to the rest of the NEM.

The communication multiplexer has two channels, consistent with regulatory requirements for protection and control system design to incorporate duplicated independent protection schemes and communication facilities with diverse paths. To date AEMO has not identified any anomalies in the operating and maintenance regime.

AusNet Services is continuing its investigation to determine the root cause of the simultaneous failure of both channels of a communication multiplexer.

3. Post-disturbance

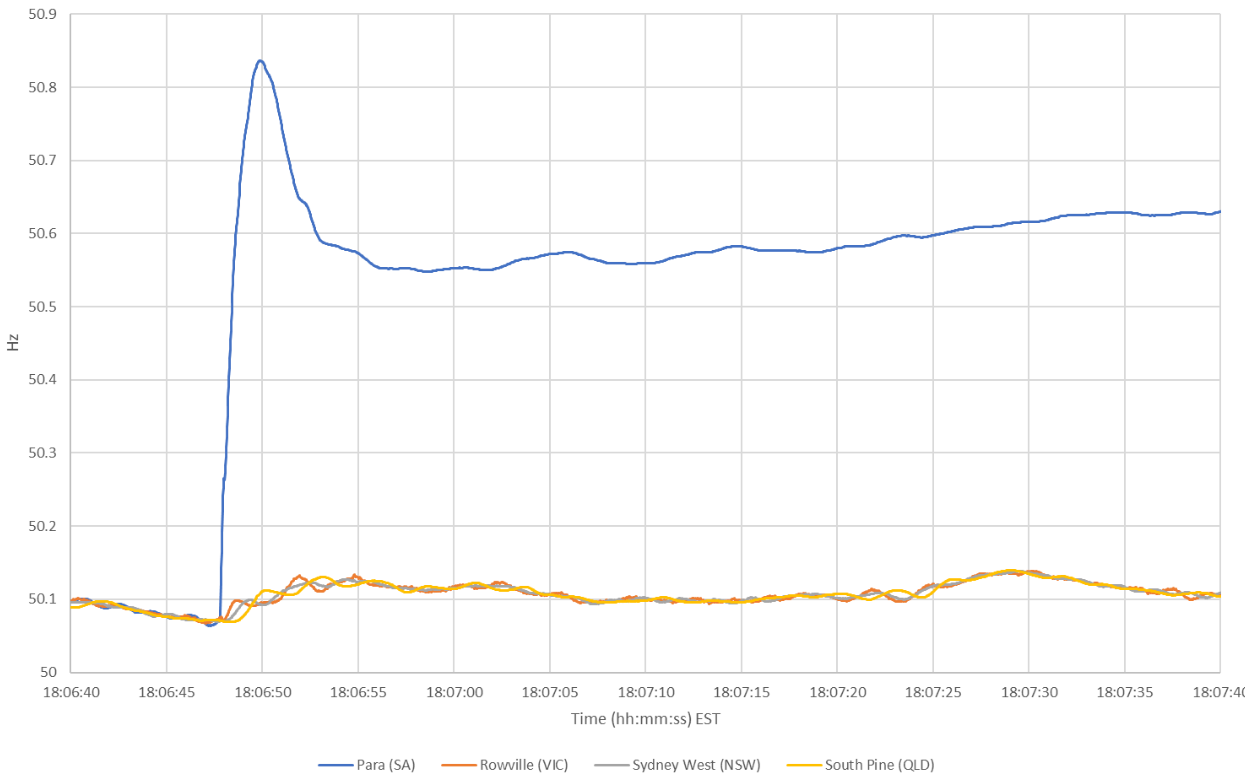
This section describes the responses of the power system, including connected equipment relevant to the event described in section 2.

3.1 Initial system response

Figure 2 shows frequency in South Australia and the rest of the NEM immediately following South Australia separation. Frequency in South Australia:

- Peaked at approximately 50.85 Hertz (Hz), settling at around 50.6 Hz approximately 2 seconds after the initial separation.
- Remained below 51.0 Hz, where generation protection in SA triggers an over frequency generation shedding (OFGS) scheme.

Figure 2 Frequency in South Australia and the NEM following separation

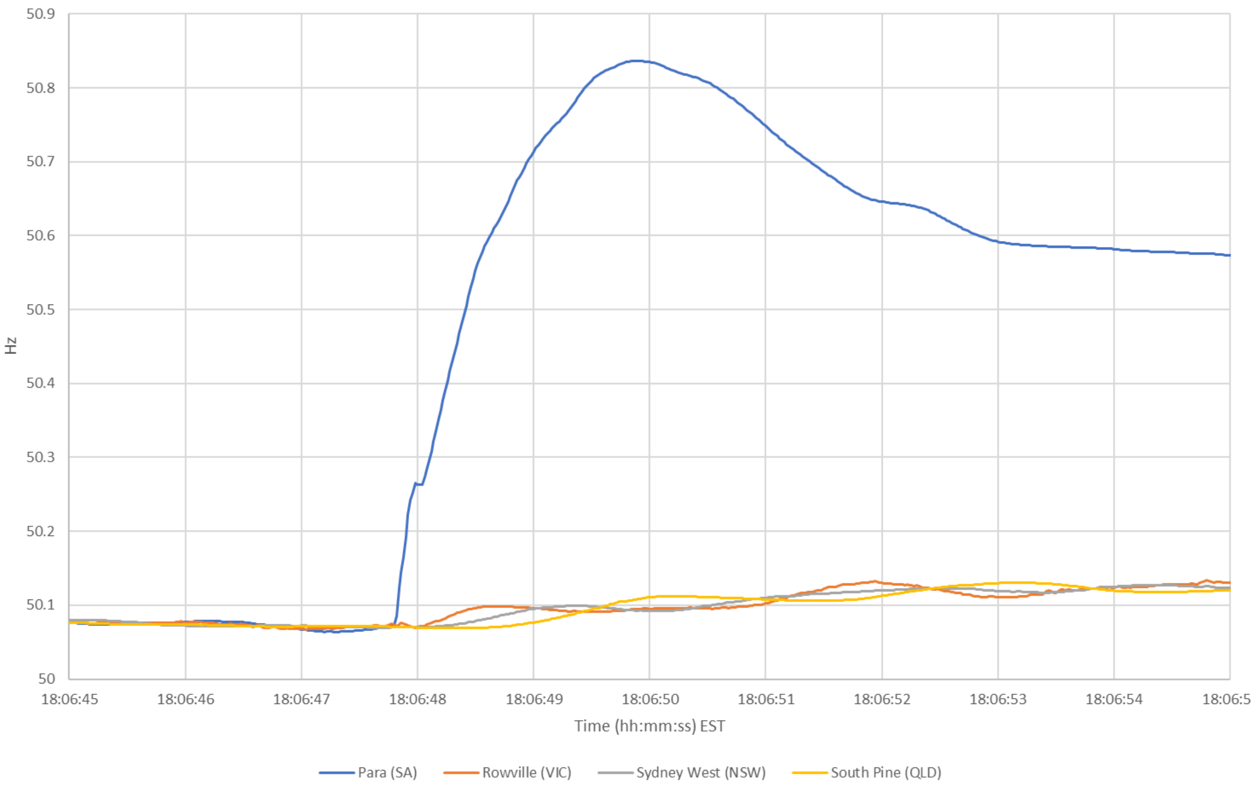


The frequency outcome in South Australia met the frequency operating standard for an islanding event.

Figure 3 shows frequency immediately following separation. It shows that immediately following separation, frequency in South Australia increased at a measured rate of around 1.15 Hz/sec. This rate of change of frequency (RoCoF) is consistent with the level of synchronous inertia in South Australia at the time of the event, and the loss of MW export.

This level of RoCoF was not sustained. A range of resources in South Australia rapidly responded to the high frequency condition, removing excess MW from the islanded region and reducing the rate of frequency change.

Figure 3 Frequency in South Australia and the NEM immediately following separation



3.1.1 Frequency outside South Australia

The effect of the event on NEM frequency outside of South Australia was negligible as the loss of MW infeed from South Australia was mostly offset by the loss of load at APD.

3.2 Generation response

In South Australia, a sudden loss of around 300 MW of export (equal to around 20% of system generation), coincident with sudden islanding under conditions of relatively low power system inertia, presented a significant challenge for frequency control in the region.

To arrest the rise in frequency, generation in South Australia needed to reduce (or load needed to increase) by around 300 MW. For this event, sufficient response was delivered rapidly enough to prevent frequency from rising above 51 Hz, the level at which protection schemes on some generation in South Australia begins to operate.

The level of frequency response delivered in this event exceeded the amount required to be delivered from the enabled contingency lower FCAS services in South Australia.

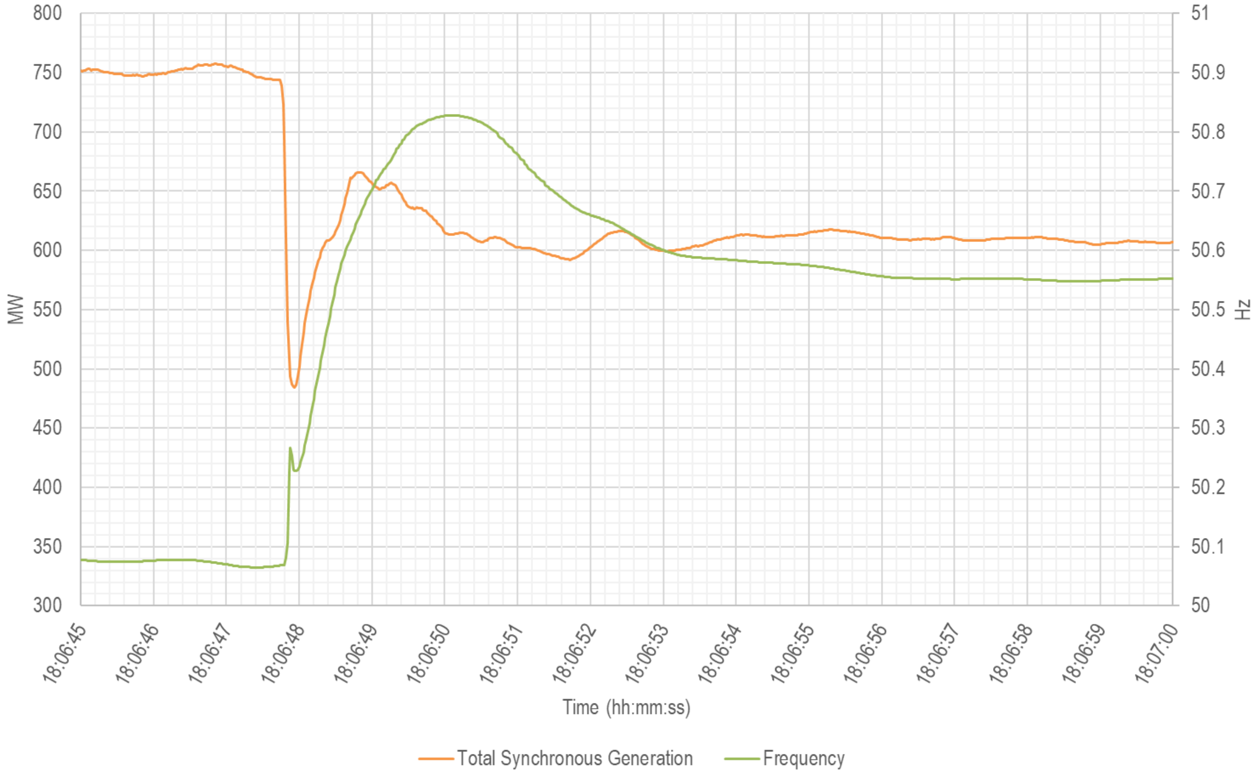
The response of generation in South Australia is reported by technology type in the sections below.

3.2.1 Synchronous generation

Figure 4 shows the aggregate response of the synchronous generation in south Australia listed in Table 2. This figure indicates that synchronous generation collectively reduced by around 140 MW. Much of this response was delivered prior to the frequency peak, when it is most important.

The response was unevenly shared between the online synchronous units, with some contributing no sustained response.

Figure 4 **Synchronous generation response**



3.2.2 Wind generation

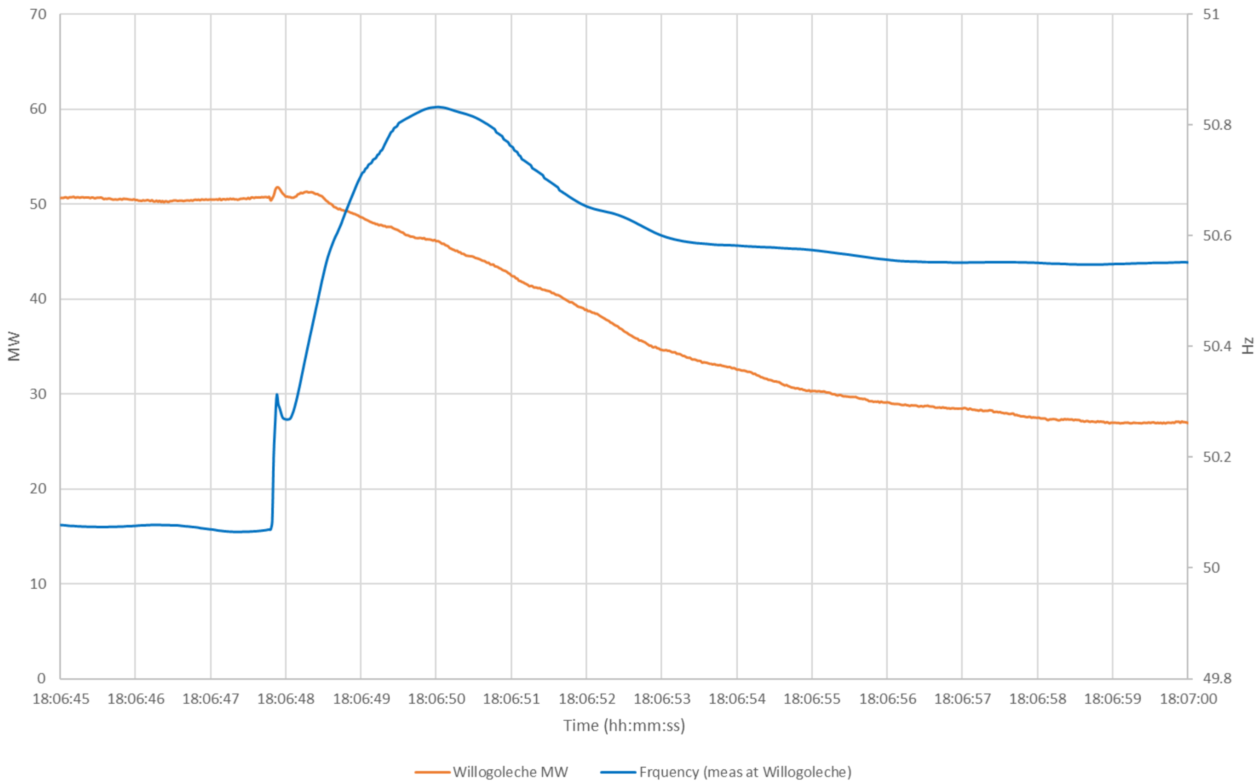
The response of wind generation in South Australia to this event varied. Most South Australian wind farms did not show any material or sustained change in output in response to the frequency change in South Australia, remaining close to their pre-disturbance outputs.

Based on data available to AEMO, Lincoln Gap and Willogoleche Wind Farms showed a relatively rapid and controlled reduction in output in response to the frequency increase, which in aggregate contributed to arresting the rise in frequency. This is shown in Figure 5 and Figure 6.

AEMO expects that Hornsdale Wind Farm would also have reduced output, although at the time of compiling this preliminary report, data is not yet available to confirm this.

Figure 5 Lincoln Gap Wind Farm response

Figure 6 Willogoleche Wind Farm response

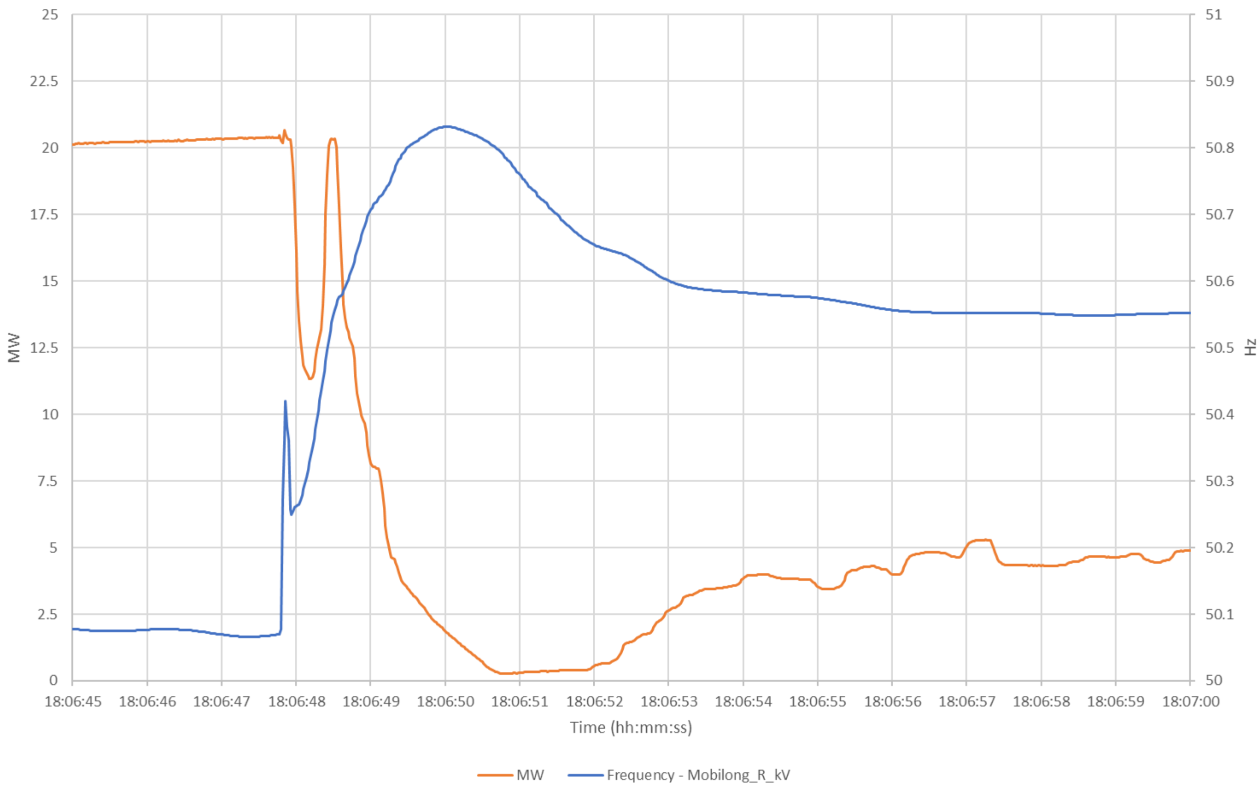


3.2.3 Transmission-connected solar generation

The 95 MW Tailem Bend facility was the only transmission-connected solar farm in operation in South Australia at the time of the event. Its output at the time was around 20 MW, due to the fairly low solar irradiance at 18:06.

As shown in Figure 7, Tailem Bend showed a rapid reduction in output, which contributed to arresting the rise in system frequency.

Figure 7 Tailem Bend Solar Farm response



3.2.4 Grid-scale batteries

South Australia has three grid-scale batteries:

1) Hornsdale Power Reserve - 100 MW/129 MWh – in service at time of event.
2) Dalrymple BESS - 30 MW/8 MWh - in service at time of event.
3) Lake Bonney BESS 25 MW/52 MWh - not in service at the time of the event.

The Hornsdale and Dalrymple BESS both provided a rapid change in output in response to the frequency change, which assisted in arresting the frequency rise. Due to the different size and control strategies employed, the response characteristics were somewhat different. The difference between the two response characteristics can be seen in the two plots in Figure 8 and Figure 9.

Hornsdale Power Reserve, shown in Figure 8, currently uses a simple proportional frequency response characteristic, with the base MW point of the battery also under central AGC control.

The Dalrymple BESS, shown in Figure 9, includes a form of 'virtual synchronous generator' functionality.

Figure 8 Hornsdale Power Reserve response

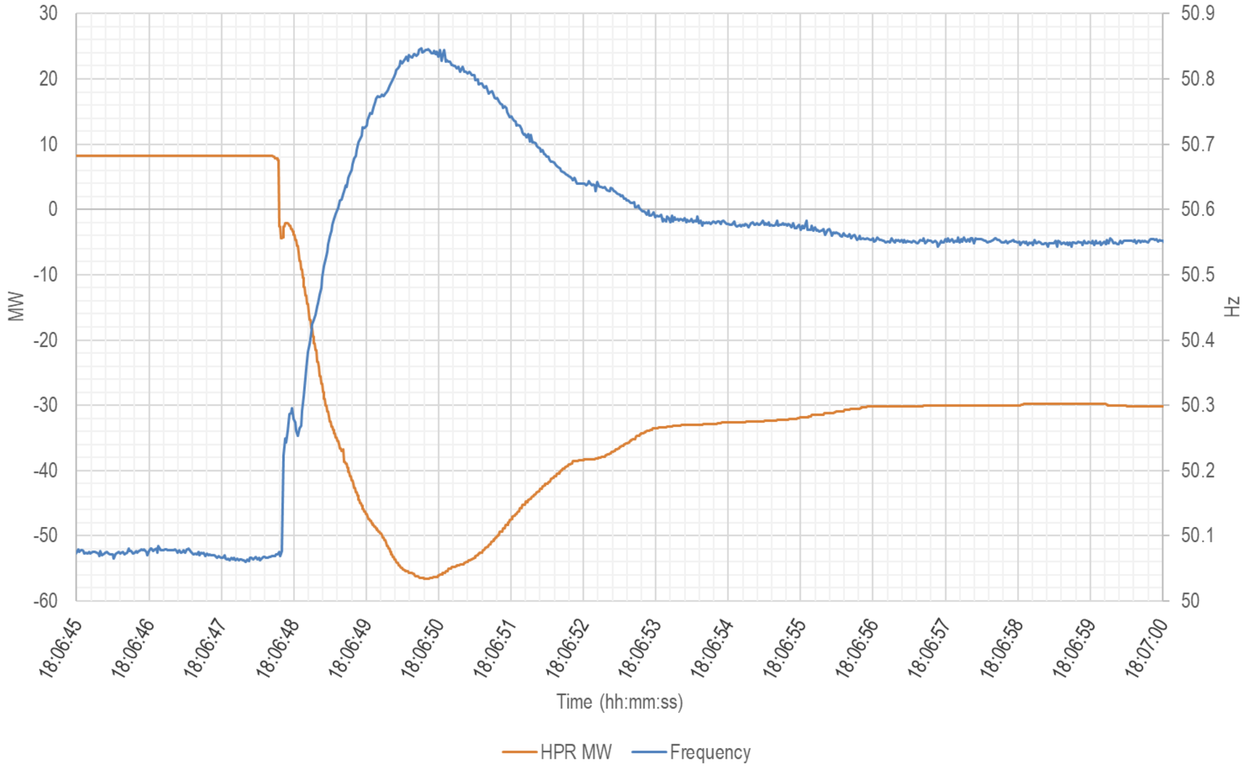
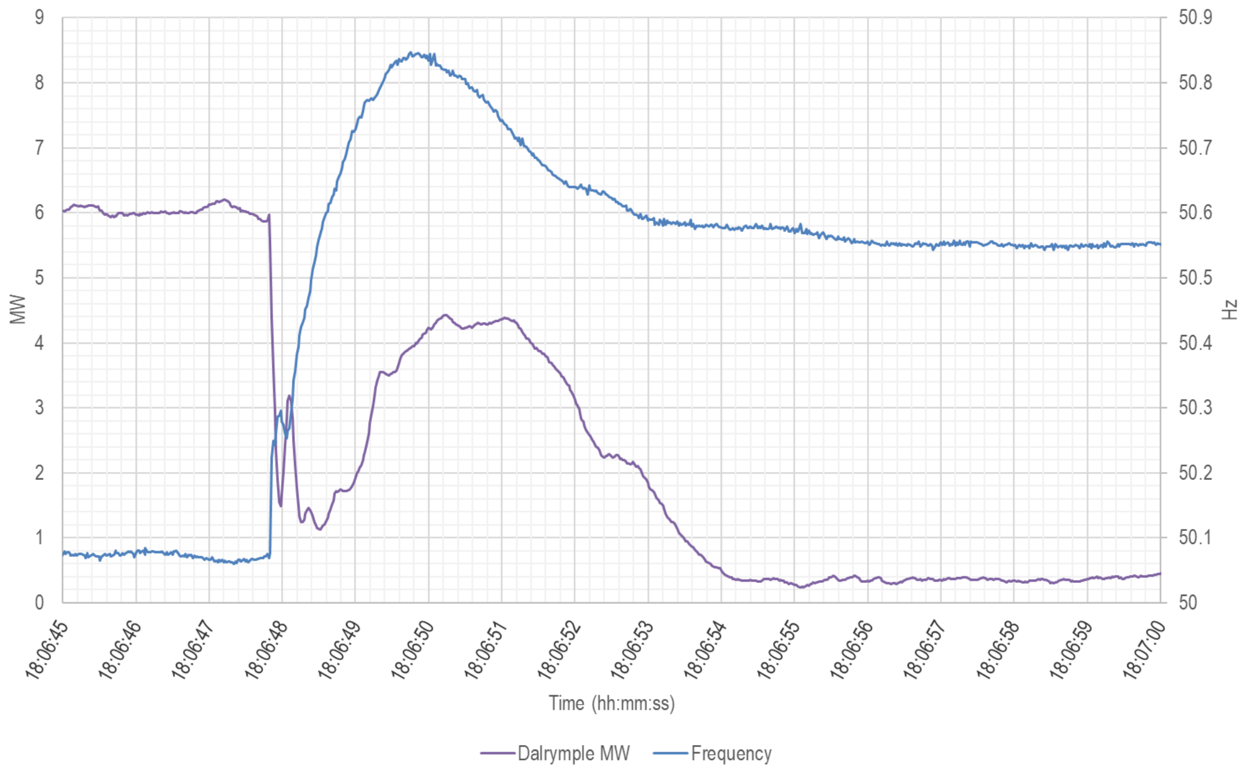


Figure 9 Dalrymple Battery response



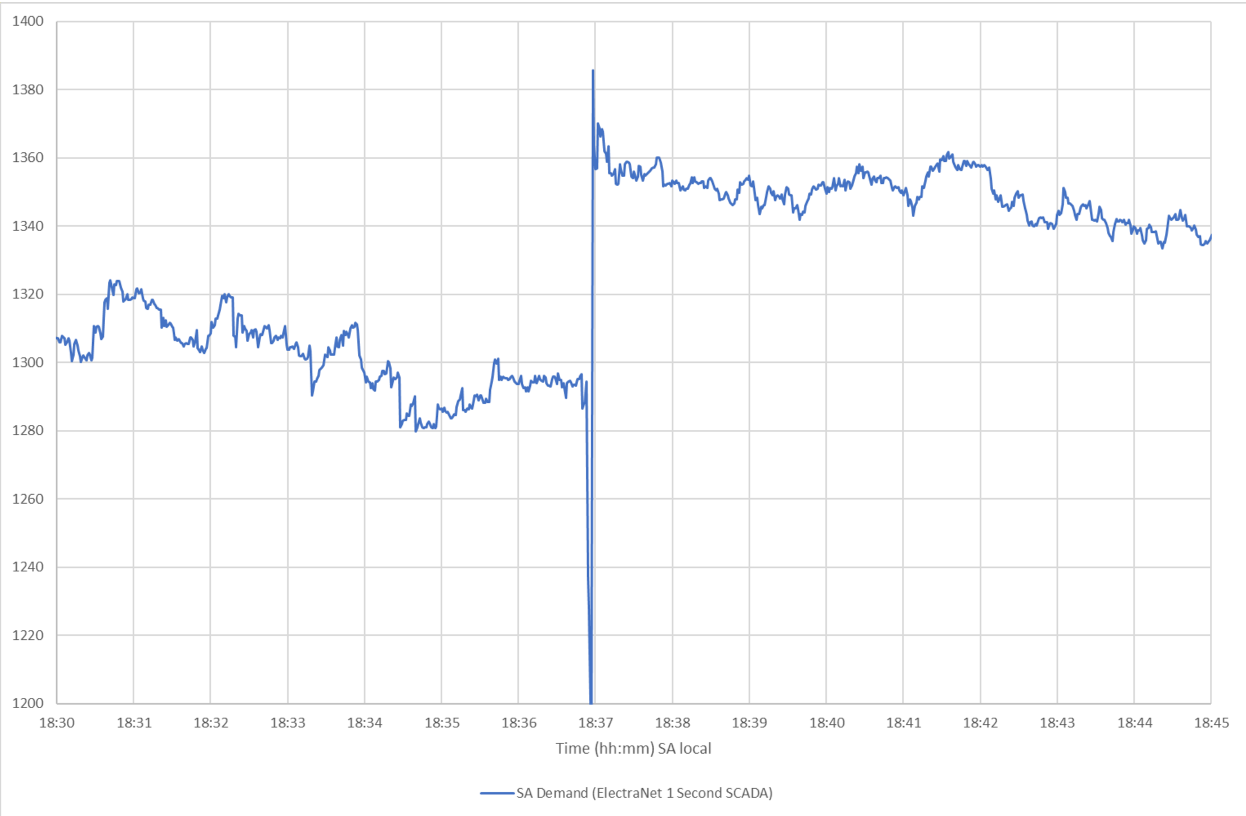
3.2.5 Distributed PV

Detailed data on the response of distributed PV in South Australia to this disturbance was not available at the time of preparing this preliminary report.

Distributed PV installed since 2015 is required to reduce output in response to the magnitude of frequency change that occurred in this event. Total distributed PV output in South Australia was estimated at over 200 MW at around the time of this event.

As shown below in Figure 10, there is some evidence of an increase in operational demand across South Australia immediately after the event. The role of distributed PV in this outcome is unclear at this time.

Figure 10 South Australia regional demand (from SCADA) prior to and after separation



3.2.6 South Australia Virtual Power Plant (VPP)

South Australia currently has a VPP formed from the aggregation of approximately 650 units of 5 kW PV + storage (3.25 MW). The response of this particular VPP is shown in Figure 11. Note the scale of this plot is only 1.4 MW

Figure 11 South Australia VPP response

While currently very small in size, this response demonstrates the potential performance and future importance of VPP technology as it scales.

3.3 Ongoing system frequency performance

South Australia was islanded for 291 minutes, or nearly five hours, with re-synchronisation ultimately occurring at 22:57. This is the longest period of ongoing islanded operation for South Australia since the start of the NEM in 1998.

Frequency performance in the islanded South Australia region and the rest of the NEM for the first 15 minutes of islanding, and for the full islanded periods, is shown below in Figure 12 and Figure 13.

These two figures show that the requirements of the NEM frequency operating standard for an island system were met for this event.

Figure 12 Frequency in first 15 minutes of separation

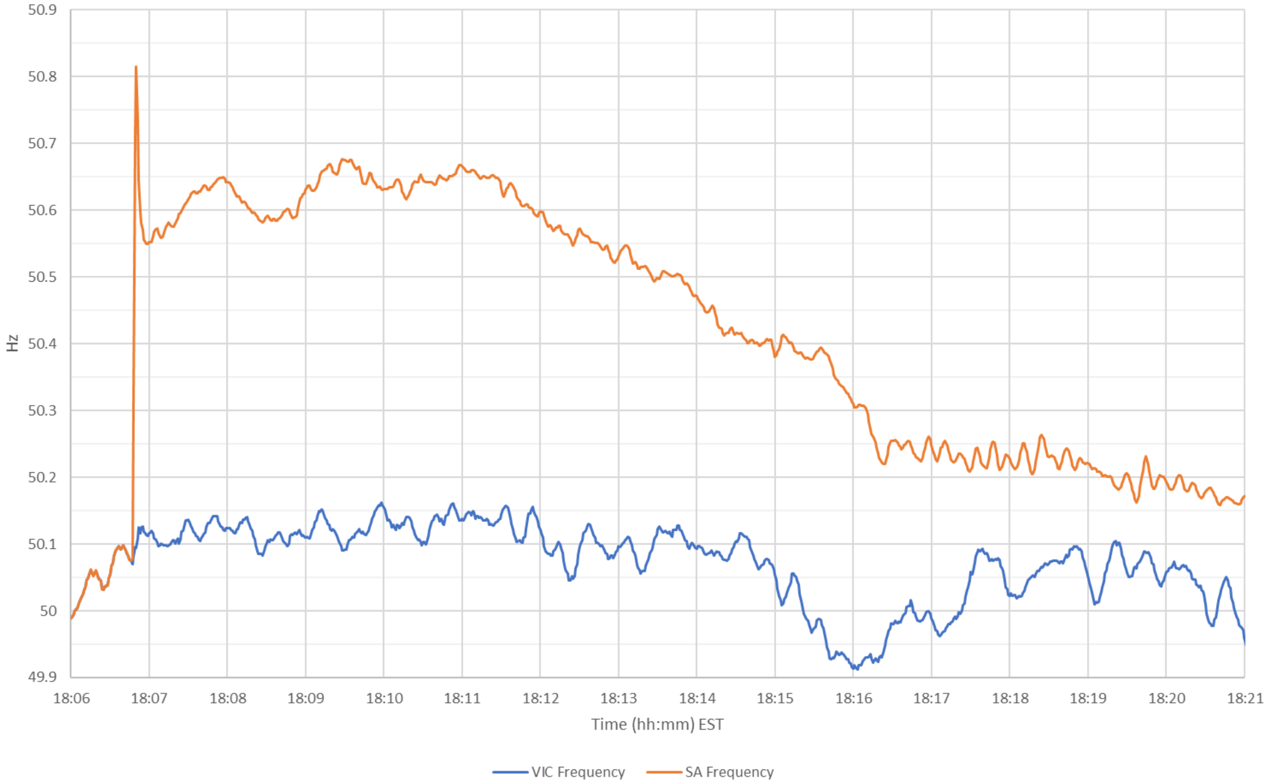
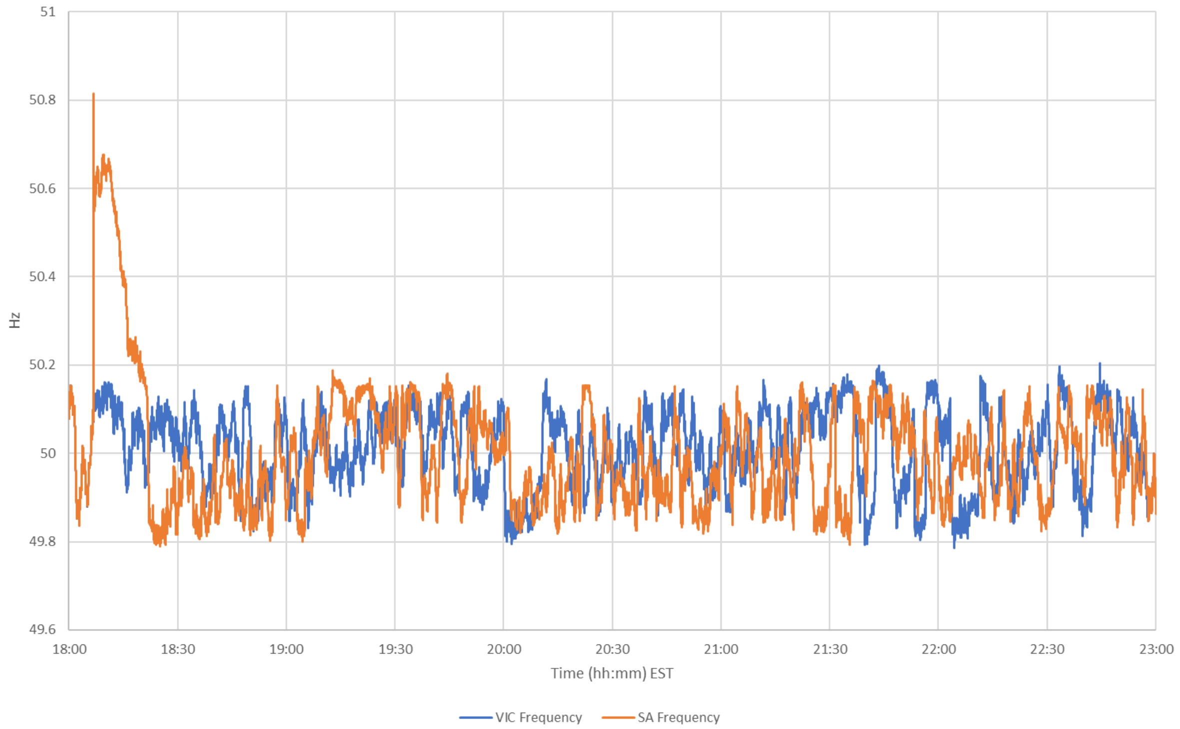


Figure 13 Frequency during full separation period



4. Actions taken to manage power system security

This section describes the steps taken or initiated by AEMO to return the power system to a secure operating state and maintain power system security after the event, until South Australia was reconnected to the NEM via the Heywood interconnector.

4.1 Constraints for a South Australia island

Network and FCAS constraints to manage the South Australia island were invoked at 18:09.

As a result, network and FCAS constraints for the South Australia island were picked up in the NEMDE dispatch run that occurred at 18:15, producing dispatch targets for the DI ending 18:20.

The target flow on the Heywood interconnector was set to 0 MW accordingly in the DI ending 18:20.

4.2 Automatic Generation Control (AGC) reconfiguration

AEMO's AGC system was reconfigured for the South Australian island at 18:09.

From this time onwards, South Australia was managed by AGC as a separate secondary frequency control area.

Any units dispatched to provide regulation FCAS in South Australia were controlled in response to a frequency signal measured within South Australia from this time.

Prior to this time, frequency control in South Australia post-separation was entirely dependent on primary frequency control from generation within South Australia.

4.3 Reduction in Olympic Dam load

The Olympic Dam load, at around 180 MW, is the largest load in SA. A single credible transmission contingency can result in disconnection of this load at any time. When South Australia is islanded, a large volume of contingency lower FCAS is required to control the rise in frequency that would result from a subsequent credible trip of this load. This requirement for contingency lower FCAS is further increased under low system inertia conditions in South Australia, due to the more rapid response requirement under these conditions.

To address ongoing violations of contingency lower FCAS constraints for trip of this load, at 18:54 AEMO directed[1] ElectraNet to reduce load at Olympic Dam to 130 MW. Load reduction commenced around 19:30, and load was reduced to 130 MW by 20:05.

[1] See Market Notice 71208

4.4 Lake Bonney and Canunda Wind Farms

Due to low system strength conditions in a South Australian island, and the relatively remote connection points of the generation, the Lake Bonney (Stage 1, 2, and 3) and Canunda Wind Farms are not permitted to generate when South Australia is islanded.

Lake Bonney Stage 2 and Stage 3 Wind Farms are registered as semi-scheduled, and can be constrained via the central dispatch system after an islanding event. Generation at these two sites was reduced to zero within 15 minutes of the initial islanding event.

Lake Bonney Stage 1 and Canunda Wind Farms are non-scheduled, and therefore cannot be controlled via the central dispatch process. Manual communication with wind farm operators was required to reduce output.

Lake Bonney 1 generation reached zero around 19:31.

A direction[2] was issued to Canunda Wind Farm at 19:35 to reduce output to zero, and generation reached 0 MW at 19:51.

4.5 Ongoing management of the region while islanded

As described above, establishment of a secure island in South Australia initially required management of FCAS and system strength requirements. Once these requirements were addressed, the South Australia island was assessed as being in a secure operating state for the rest of the islanded period.

No further contingencies occurred, and frequency in South Australia met the requirements specified in the NEM frequency operating standard for an islanded region.

Operational focus was first on restoration of supply to APD, then on resynchronisation of Victoria and South Australia, however this could not proceed until the 500 kV lines in Victoria were restored to service by AusNet Services.

4.6 Reclassifications

During this incident the communication multiplexer whose maloperation initiated this non-credible contingency event was isolated.

As a result, AEMO did not reclassify a recurrence of this non-credible contingency event as credible.

[2] See Market Notice 71227

5. Restoration

5.1 Restoration of 500 kV lines in Victoria

The restoration times for the 500 kV lines are listed in Table 5, and are based on AEMO SCADA voltage measurements.

Table 5 **Victorian 500 kV line restoration times**

Line	Restoration time
HYTS–APD-TRTS 500 kV line	22:25
HYTS–APD-MOPS 500 kV line	20:55

HYTS=Heywood Terminal Station, TRTS=Tarrone Terminal Station, MOPS=Mortlake Power Station

5.2 Restoration of APD load

All electrical supply to the APD site was interrupted at the start of the incident at 18:06:47, resulting in disconnection of all load at the site. This also disconnected the Portland Wind Farm, which is connected through this site.

Based on AEMO SCADA data, first electrical supply to the APD site was available at 20:55, allowing load restoration to commence from this time.

Restoration of smelter auxiliary load commenced shortly afterwards, with the first major potline load restored at 21:39. AEMO SCADA data indicates that full restoration of site load to near pre-event levels did not occur until nearly 12 hours after the initial disconnection.

Figure 14 below shows measured load at the APD site during this event.

Figure 15 provides a comparison of this event with the restoration of APD load following a similar supply interruption on 1 December 2016. This 2016 event resulted in significant ongoing disruption to smelter operation.

Figure 14 APD site load 16th November 2019

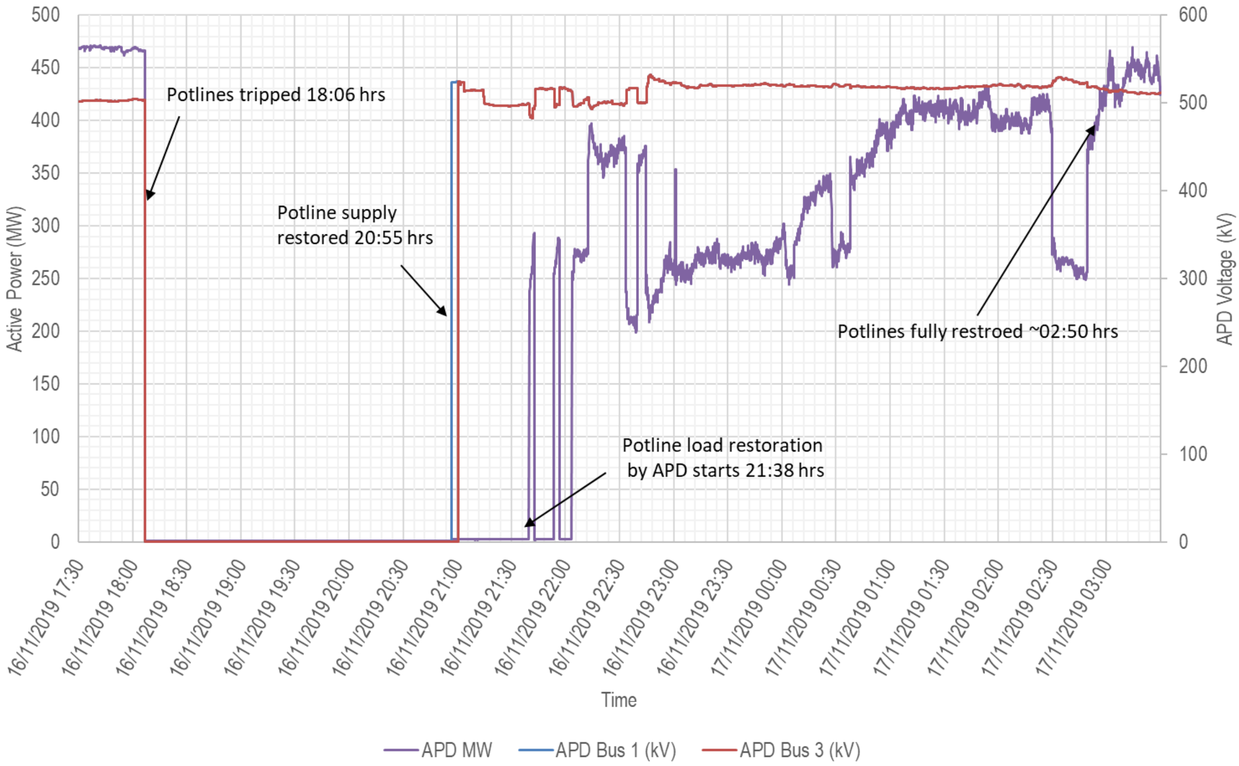
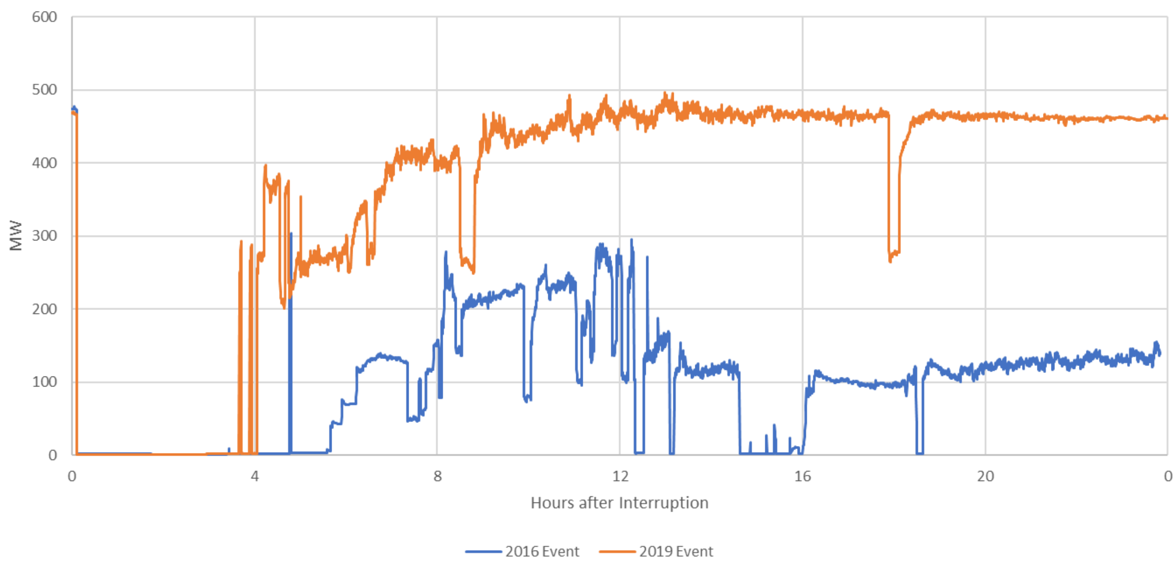


Figure 15 APD load restoration – 2019 vs 2016



5.3 Resynchronisation of Victoria – South Australia systems

The 275 kV supply to Heywood from South Australia remained available following the initial separation via the still-energised 275 kV lines from South East Switching Station (SESS) in South Australia.

AEMO data shows the Heywood switchyard remained energised from the 275 kV system throughout this event, with Victoria and South Australia disconnected at the 500 kV voltage level at Heywood.

As listed in Table 5, 500 kV electrical supply to Heywood was first available at 20:55.

Following restoration of load at APD, initial attempts to re-synchronise Victoria and South Australia at the 275 kV voltage level at Heywood were unsuccessful. Difficulties have been experienced previously with attempting to resynchronise Victoria and South Australia at Heywood due to the varying frequency of the two separated regions. This was also experienced during the most recent prior separation event on 25 August 2018 and highlighted the requirement for increased frequency control across the NEM.

At 22:38, AEMO requested ElectraNet to transfer the open end of the Heywood - SESS lines to SESS, to allow synchronisation at the SESS end of the lines to be attempted.

Managing a range of high voltage conditions at Heywood at this time, at both 275 kV and 500 kV levels, resulted in some further delays to re-synchronisation between Victoria and South Australia.

Victoria and South Australia were ultimately re-synchronised at around 22:58 at the SESS end of the Heywood – SESS lines.

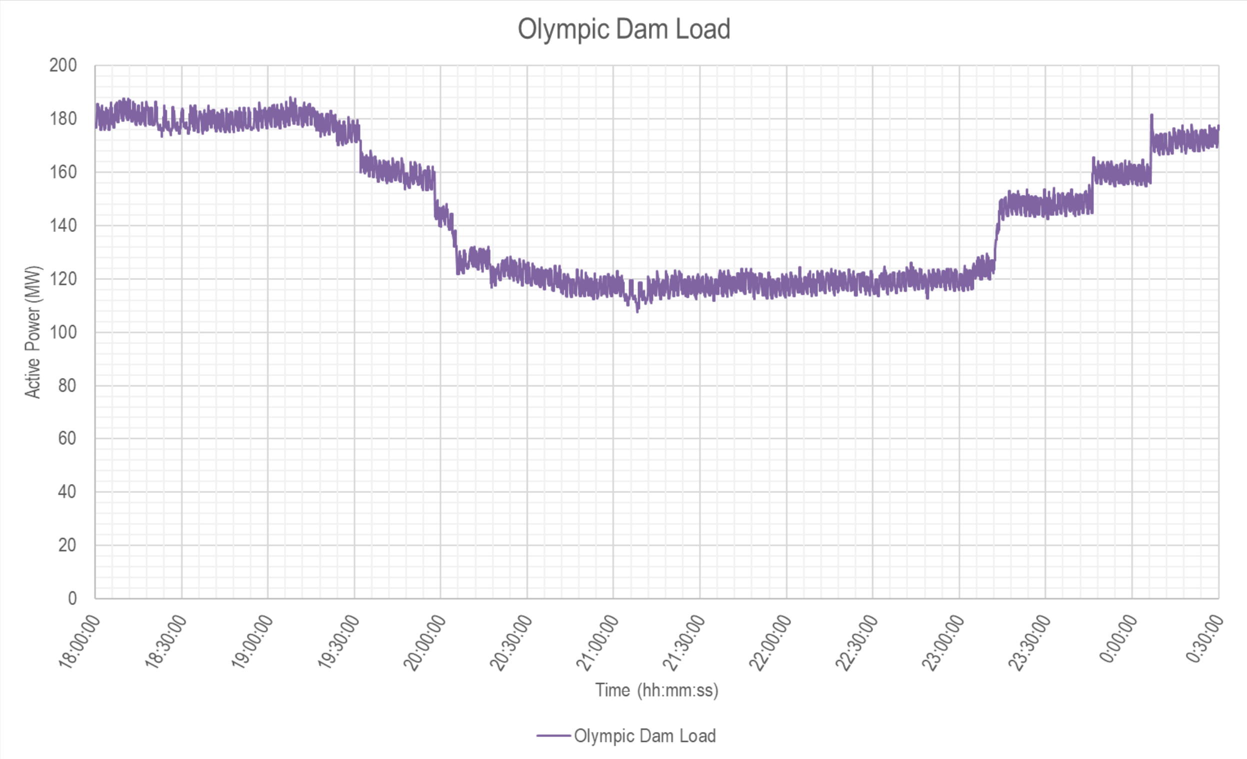
5.4 Restoration of Olympic Dam load

At 22:58, following resynchronisation, AEMO notified ElectraNet that the direction to reduce Olympic Dam load to 130 MW was cancelled[3], and load could now be increased as required up to maximum demand.

Load at Olympic Dam was restored to near pre-event levels by around 00:08 on 17 November 2019, as shown below in Figure 16.

[3] See Market Notice 71263

Figure 16 Olympic Dam load



6. Market operation

6.1 Energy and FCAS market operation during separation

The energy and FCAS markets operated according to bids and offers, consistent with power system conditions at the time of the event. During directions issued to Canunda, AEMO implemented intervention pricing which had a minor impact on prices in South Australia. AEMO will separately report on the direction as part of its normal reporting processes.

6.1.1 Energy prices

Energy prices in South Australia initially fell, while energy prices in other mainland regions initially rose, because South Australia was exporting energy to Victoria at the time of the separation. The trip of the Heywood interconnector left generation in South Australia producing more power than was being consumed within the region. This required a reduction in generation to restore the supply-demand balance in the electrically-islanded region. The reduction in generation caused a fall in the regional energy price because of the effective decrease in demand. Conversely, the trip of the Heywood interconnector created an effective fall in supply in the rest of the NEM, and a consequent increase in price.

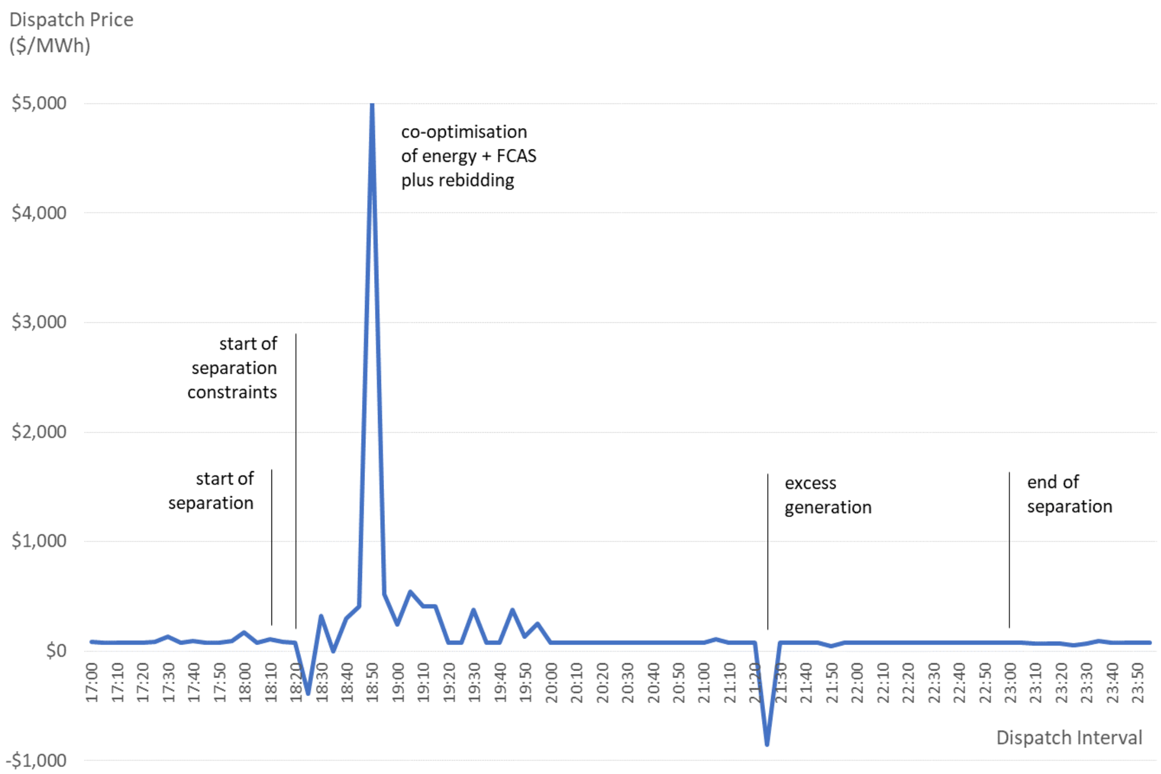
South Australian energy prices during the remainder of the separation event were more variable than they were for the periods on 16 November 2019 when the region was connected. Dispatch prices are shown in Figure 17.

In particular there was a price spike in DI 1850 and a price trough in DI 2125. Energy prices were – in the circumstances – unexceptional at all other times during the separation event.

- The South Australian energy price increased to $5,000/MWh in DI 1850 (resulting in a spot price of $1,078.17/MWh for TI 1900). This was due to a combination of co-optimisation between the energy and FCAS markets and rebidding. All the available R6 providers in SA that also produce energy were dispatched below their maximum availabilities in the energy market so they could be enabled to meet the local R6 requirement during this DI. This led to the energy price being set by Snowtown 1 Wind Farm, who had recently rebid all their capacity to $5,000/MWh. The SA R6 price also rose to $11,351.64/MWh in DI 1850.
- The South Australian energy price fell to -$856.01/MWh in DI 2125 (resulting in a spot price of -$72.13/MWh for TI 2130). This was due to relatively high wind generation at a time when the online thermal generation could not reduce its energy output further due to a combination of self-dispatch, ramp rate limitations, and co-optimisation between the energy and FCAS markets.

The Heywood interconnector was restored before the nightly hot water load pickup in DI 2335.

Figure 17 **South Australia Dispatch Prices**

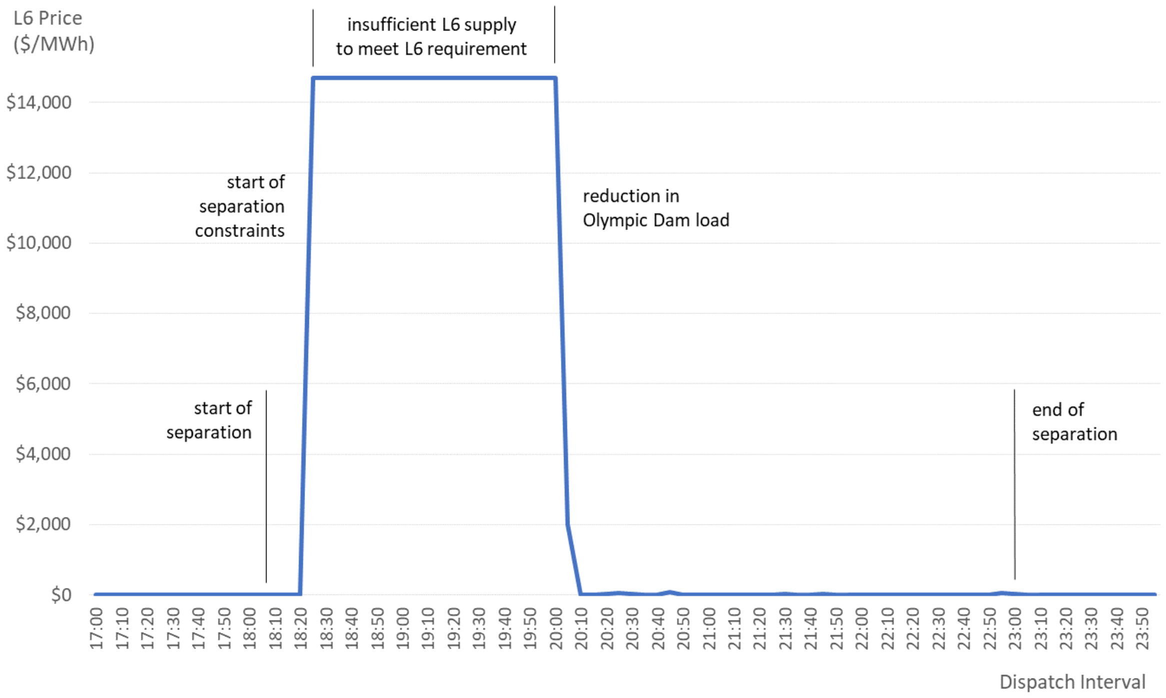


6.1.2 FCAS prices

Local FCAS requirements in South Australia were established from dispatch interval (DI) 1820. This resulted in South Australian FCAS prices being notably higher than in other mainland regions. L6 FCAS prices are shown in Figure 18.

In particular, both L6 and R6 prices reached the maximum price cap (MPC) of $14,700/MWh during the separation event when there was insufficient supply to meet the local requirements. The direction to reduce load at Olympic Dam relieved the inability of SA L6 suppliers to meet the local requirement from DI 2005, and from that time the L6 prices fell accordingly. However, R6 suppliers in the region were periodically unable to meet the local requirements, or were enabled at MPC, towards the end of the separation event, with an attendant impact on prices.

Figure 18 South Australia L6 Prices



7. Next steps

AEMO will continue its investigation into the root cause of the South Australia separation event on 16 November 2019, and relevant power system responses and recovery.

An overview of the activities and areas for further investigation is provided in the table below. A date for publication of AEMO's final incident report will be confirmed once all information and data has been collected and reviewed.

Table 6 **Next steps – summary of activities**

Area	Analysis to be performed
Root cause	AEMO will work with AusNet Services to understand the root cause of the hardware maloperation and recommend any remedial action as necessary.
FCAS	Assessment of the performance of the enabled FCAS providers and recommendations for any future changes to FCAS requirements.
AEMO actions	AEMO will review and report on its actions surrounding the event and restoration.
Generator performance	AEMO will assess the performance of generating units against their performance standards, and against available simulation models. AEMO will also assess the response of distributed generation sources such as co-generation units and rooftop PV, as available.
Network performance	AEMO will assess the performance of the transmission and distribution networks, relevant control schemes and protection equipment.
Mitigation measures	AEMO will explore potential mitigation measures and develop recommendations for the future.
Long term implications	AEMO will examine the implications of this event and recommend future work to improve the operation and resilience of the NEM power system.

For AEMO to complete its review and prepare a final incident report, the following should be noted:

- Under clause 4.8.15 of the NER, registered participants have 20 business days to provide data and information in response to a request from AEMO. AEMO issued initial requests on 18 and 19 November 2019 to registered participants whose facilities are thought to have been affected by the event.
- AEMO will undertake detailed modelling and analysis of the responses of power system equipment.
- Additional data or information may need to be requested from participants following initial analysis and modelling.

Glossary

This document uses many terms that have meanings defined in the National Electricity Rules (NER). The NER meanings are adopted unless otherwise specified.

Other terms and abbreviations used in this document are listed below.

Term	Definition
AGC	Automatic generator control system
APD	Alcoa Portland
BESS	Battery energy storage system
DI	Dispatch interval (5 minutes ending at the given time)
EST	Eastern standard time
FCAS	Frequency control ancillary service
HYTS	Heywood Terminal Station
Hz	Hertz
IBR	Inverter-based resources
kV	kilovolt
L5	Delayed lower (5 minute) contingency FCAS
L6	Fast lower (6 second) contingency FCAS
L60	Slow lower (60 second) contingency FCAS
LREG	Lower regulation FCAS
MW	Megawatt
MWh	Megawatt hour
MW.s	Megawatt-second
NEM	National Electricity Market
NEMDE	NEM dispatch engine
NER	National Electricity Rules
OFGS	Over frequency generation shedding
R5	Delayed raise (5 minute) contingency FCAS
R6	Fast raise (6 second) contingency FCAS
R60	Slow raise (60 second) contingency FCAS
RoCoF	Rate of change of frequency
RREG	Raise regulation FCAS
SCADA	Supervisory control and data acquisition

Term	Definition
SESS	South-east switching station
SVC	Static var compensator