FINAL REPORT – SOUTH AUSTRALIA SEPARATION EVENT, 1 DECEMBER 2016

REVIEWABLE OPERATING INCIDENT REPORT FOR THE NATIONAL ELECTRICITY MARKET

Published: **28 February 2017**

AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

INCIDENT CLASSIFICATIONS

Classification	Detail
Time and date of incident	0016 hrs on 1 December 2016
Region of incident	Victoria
Affected regions	Victoria and South Australia
Event type	Transmission equipment
Generation impact	9 MW of generation was lost as a result of this incident
Customer load impact	703 MW of customer load was lost as a result of this incident
Associated reports	Preliminary report published on 8 December 2016

ABBREVIATIONS

Abbreviation	Term
Hz	hertz
kV	kilovolt
MW	megawatt
ms	millisecond
NER	National Electricity Rules
NEM	National Electricity Market
pu	per unit

IMPORTANT NOTICE

Purpose

AEMO has prepared this final report in accordance with clause 4.8.15(c) of the National Electricity Rules, using information available as at the date of publication, unless otherwise specified.

Disclaimer

AEMO has been provided with data by Registered Participants as to the performance of some equipment leading up to, during, and after the separation event in accordance with clauses 3.14 and 4.8.15 of the Rules. In addition, AEMO has collated information from its own systems.

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.

Accordingly, to the maximum extent permitted by law, AEMO and its officers, employees and consultants involved in the preparation of this report:

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1. OVERVIEW

This report is AEMO's final report in relation to a reviewable operating incident[1] that occurred on 1 December 2016 in Victoria.

AEMO published a preliminary report on 8 December 2016. This final report provides:

- New information on the initial fault and the associated protection and control scheme operation.
- Further analysis of the frequency in South Australia (SA) and the need for AEMO to issue directions to participants in South Australia to manage power system security.

This event is not related to the SA black system event that occurred on 28 September 2016.

As this was a reviewable operating incident, AEMO is required to assess power system security over the course of this incident, and assess the adequacy of the provision and response of facilities and services and the appropriateness of actions taken to restore or maintain power system security.[2]

This report is prepared in accordance with clause 4.8.15(c) of the National Electricity Rules (NER). It is based on information provided by AusNet Transmission Group Pty Ltd (AusNet), Alcoa Portland Aluminium Pty Ltd (APD), ElectraNet and from AEMO's energy and market management systems.

All times in this report are AEST unless otherwise noted. In December, local time in South Australia is AEST plus 30 minutes, and local time in Victoria is AEST plus 60 minutes.

AEMO has concluded that:

- The trip of the Moorabool–Tarrone 500 kilovolt (kV) transmission line was the result of equipment failure.
- All protection and control schemes operated correctly and as expected.
- The frequency standard in SA was met.
- The under frequency load shedding (UFLS) scheme in SA operated as expected.
- Pelican Point Power Station did not provide fast raise (R6) frequency control ancillary services (FCAS) immediately after the separation event as required. AEMO is working with Engie to determine the reasons for this.
- AGL was unable to provide the high speed data to enable AEMO to analyse the delivery of fast raise (R6) FCAS from the Torrens Island generating units. AGL advised the data could not be provided due to a software problem with their data recorders. AGL has since advised that the software problem has been resolved. AEMO will confirm this with AGL.
- The non-delivery of FCAS did not have a material impact on the outcome of this incident.
- The power system was not in a secure operating state after this incident for a period of four hours and twenty minutes. AEMO took all reasonable steps to return the power system to a secure operating state. The actions taken by AEMO were appropriate and in accordance with the NER and published procedures.
- There was a delay in synchronising the Victoria and South Australia networks, due to a software issue associated with AusNet's control system.

At 0016 hrs (AEST[3]) on 1 December 2016, a fault on the Moorabool (MLTS) to Tarrone (TRTS) 500 kV transmission line in Victoria resulted in the loss of the Heywood interconnection between SA and Victoria.

At the time of the incident, SA was only connected to the Victorian network via one 500 kV Heywood Interconnector circuit, because the second circuit, which is normally connected, was out of service due to planned equipment maintenance arranged by AusNet Services.

[1] See NER clause 4.8.15.
[2] See NER clause 4.8.15(b).
[3] Australian Eastern Standard Time (Market Time).

A second outage, arranged by Alcoa Portland, meant there was no redundant electricity supply to the Alcoa Portland Aluminium Smelter (APD) at the time of the incident.

The disconnection of the Moorabool–Tarrone 500 kV transmission line resulted in the loss of approximately 230 megawatts (MW) of load in SA and the disconnection of all load at the APD (473 MW).

Generation at Macarthur wind farm (6 MW) and Portland wind farm (3 MW) was also disconnected as a result of this incident.

All SA load was restored within 89 minutes (by 0145 hrs). Supply was made available to APD within three hours and 14 minutes (at 0330 hrs), but APD advised AEMO they were not ready to commence load restoration. At 0447 hrs, APD advised AEMO they were ready to restore load and AEMO gave APD permission to restore all load.

To stabilise the separated SA power system, AEMO directed ElectraNet to reduce supply to BHP Billiton's Olympic Dam site to approximately 100 MW, under a 2015 protocol agreed by AEMO and BHP Billiton for such events. Prior to the event, BHP Billiton's Olympic Dam site was consuming approximately 170 MW. The duration of this reduction was three hours and seven minutes.

2. PRE-EVENT CONDITIONS

Immediately prior to the incident, there were two planned outages:

- Outage of the Heywood No. 2 500 kV busbar. This outage resulted in only a single connection from Victoria to SA via the Heywood Interconnector. The request for this outage was submitted by AusNet via AEMO's public Network Outage Schedule on 22 August 2016. The outage commenced at 0600 hrs on 30 November 2016 with an eight-hour recall time. Further information on this outage was provided by Market Notice on 31 October 2016.[4]
- Outage of the Heywood–APD No. 2 500 kV transmission line. This outage resulted in load to APD being supplied via a single connection. The request for this outage was submitted by APD[5] via AEMO's public Network Outage Schedule on 7 November 2016. The outage commenced at 0630 hrs on 28 November 2016 with a two-hour recall time.

Both outages were due to be completed by 1600 hrs on 1 December 2016.

The combination of these two outages resulted in the de-loading of the Mortlake–Heywood–APD 500 kV line. In accordance with normal operational practice, AEMO then de-energised this line to control voltages on the transmission network in the local area.

The Murraylink interconnector was in service and operating normally.

Refer to Appendix A, Figure 5 for a diagram of the power system prior to the incident.

To maintain the power system in a secure operating state during these outages, AEMO invoked the constraint sets shown in Table 1.

Table 1 Constraint sets invoked

Constraint set	Description
V-HYMO	Out = Heywood to Mortlake No2 500kV line
V-HYTX_M12	Out = Heywood M1 or M2 500/275kV Transformer
V-HY_500BUS	Out = Heywood No1 or No2 500kV bus
F-I-HYSE	FCAS requirements
F-V-HYMO	FCAS requirements

These constraint sets included constraint equations to:

- Limit flow on the Heywood Interconnector to ensure the rate of change of frequency (RoCoF) in SA after a credible separation would not exceed 1 hertz per second (Hz/sec).

[4] Refer to Market Notices 55515.
[5] The outage was submitted by AusNet on behalf of APD.

- Limit generation at Mortlake to 0 MW.
- Ensure 35 MW of raise and lower regulation FCAS was enabled in SA.

The power system was in a secure operating state immediately prior to the incident.

The operational demand in SA was 1,386 MW and was supplied by a combination of 865 MW of thermal generation, 85 MW of wind generation, and 463 MW of import from Victoria (217 MW via Heywood and 223 MW on Murraylink). The online inertia in SA prior to the event was 7,785 MW.s.

Table 2 shows the contingency raise FCAS enabled in SA just prior to the event. These contingency raise services were not specifically enabled to meet any requirement in SA, but were part of the overall NEM requirement to cover the loss of the largest single operating generating unit in the National Electricity Market (NEM).

Table 2 Contingency FCAS in SA

Service	Amount enabled (MW)
Fast raise	52
Slow raise	85
Delayed raise	39

The frequency operating standard for SA following a separation event is 47–52 Hz, based on previous notification by the Jurisdictional System Security Coordinator for SA. On that basis, AEMO has determined that no contingency raise FCAS is required for the credible loss of the Heywood Interconnector if flow is towards SA, because frequency will be maintained above 47 Hz by the operation of UFLS and the 1 Hz/sec RoCoF limit applied under credible contingency conditions.

3. INITIATING FAULT

At 0016 hrs, a single phase to earth fault occurred on the Moorabool–Tarrone 500 kV transmission line, causing the following events:

- The Moorabool–Tarrone Line tripped at both ends.

The trip of the Moorabool–Tarrone line severed the interconnection to SA via the Heywood Interconnector and left the load at APD connected to the SA network via the HYTS–TRTS–APD 500 kV line. At this stage the Macarthur wind farm was still connected to TRTS and generating 3 MW, and the Portland wind farm was connected to APD and generating 6 MW. Refer to Appendix A, Figure 6 for a diagram of the power system immediately after the fault.

Approximately 400 milliseconds (ms) after the initial fault, the Emergency APD Potline Tripping Scheme (EAPTS)[6] operated to disconnect the APD load from SA.

- The EAPTS at HYTS operated. TRTS Line No. 1 Bus 500 kV circuit breaker (CB) at HYTS opened (CB 210), disconnecting the APD load from HYTS
- The loss of supply to APD and TRTS resulted in the disconnection of the Macarthur and Portland wind farms.

Although supply to APD had been disconnected at this stage, a number of other protection operations occurred at APD. These protection operations had no impact on the outcome of this event:

- The HYTS No. 1 Line 'X' protection operated in Zone 1 and opened the HYTS No. 1 line CB at APD. Normally this protection would be blocked by the VT supervision function when there is a loss of voltage on all three phases. In this case, the VT supervision was inhibited due to the detection of negative phase sequence currents due to the system configuration at the time.
- As the CB Fail function associated with the HYTS No. 1 Line CB at APD had been set to a zero time delay, a trip signal was sent to HYTS to open CB 214 at HYTS.

[6] Refer to Appendix B for a description of this control scheme.

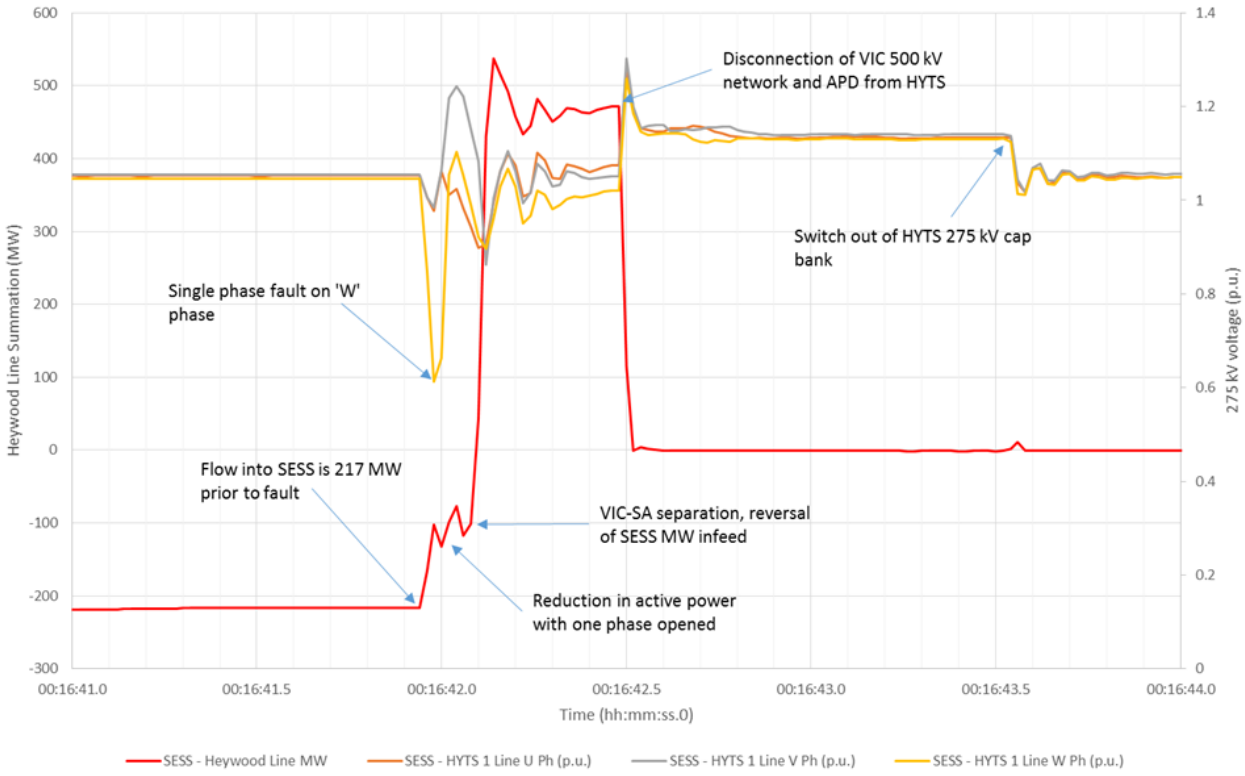
Approximately one second after the initial fault, the TRTS No. 1 Line No. 2 Bus CB at MLTS auto-reclosed in an attempt to restore the line. As the fault had not cleared, the TRTS No. 1 Line No. 2 Bus CB tripped again and remained open.

All protection and control schemes operated as expected for the type of fault and fault location.

The fault sequence is shown in Figure 1. The power flow on the Heywood Interconnector was initially 217 MW towards SA. Immediately after the faulted line tripped, the power flow reversed with 480 MW flow from SA to supply the load at APD. After approximately 400 ms, AEMO's EAPTS operated to disconnect the load at APD and the flow from SA reduced to zero.

Refer to Appendix A, Figure 7 for a diagram of the power system immediately after the event.

Figure 1 500 kV transmission line – Moorabool to Tarrone conductor fault 1 December 2016



The sudden loss of supply to SA resulted in the frequency falling to 48.23 Hz. South Australia Power Networks' UFLS scheme operated to shed around 190 MW of load in SA. There was also an additional load reduction of around 40 MW that was not associated with operation of the UFLS scheme.[7] The UFLS scheme operated as expected.

No generation in SA tripped or reduced output as a result of the separation event.

Based on data from the protection relays, the fault was estimated by AusNet to be in the vicinity of Tower 238, approximately 103 km from MLTS. AusNet conducted a line patrol between towers 230 and 244 did not identify any probable cause of the fault. The Moorabool–Tarrone line was re-energised at 0646 hrs, but tripped immediately.

AusNet conducted a further line patrol via helicopter later the same morning. At around 0930hrs, a broken conductor in the blue phase quad conductor bundle was located approximately mid-span between towers 284 and 285. The failed section of conductor was replaced, along with the spacers at the break location and either side. The Moorabool–Tarrone line was returned to service at 2132 hrs on 1 December 2016.

[7] Advice from ElectraNet is this load reduction occurred at Prominent Hill in the northern part of the state. Neither ElectraNet nor AEMO are aware of any load shedding scheme (frequency or voltage) in this area.

AusNet has not been able to determine the cause of the conductor break.

As a result of this incident, AusNet has conducted an audit of the assets associated with the Moorabool–Tarrone and similar lines in the area to mitigate any risk of a similar fault occurring. AusNet will conduct further maintenance or repairs if required.

4. FREQUENCY RESPONSE IN SOUTH AUSTRALIA IMMEDIATELY AFTER ISLANDING

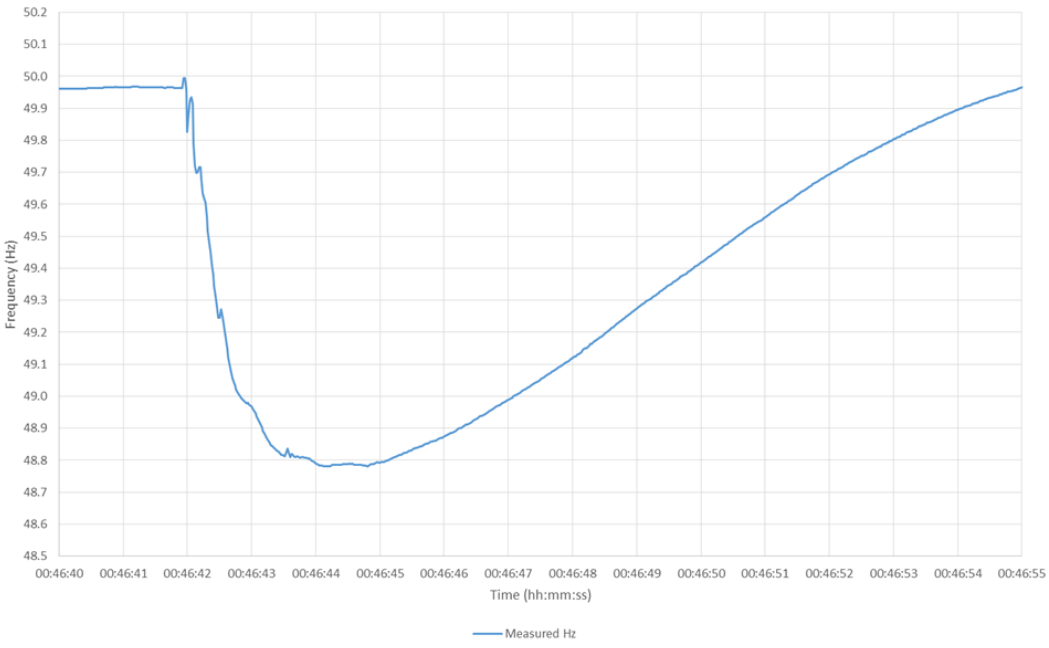
This section provides information on the frequency response immediately after SA was separated from Victoria.

4.1 Frequency standard

The frequency operating standard for a separation event in SA is operated at a wider band, and requires the frequency to remain above 47 Hz and recover to above 49 Hz within two minutes and above 49.5 Hz within ten minutes.

Figure 2 shows the frequency in South Australia immediately after South Australia was separated from Victoria. The frequency fell to a minimum of 48.78 Hz and recovered to within the normal frequency operating band after 11.5 seconds. The frequency operating standard was met for this event.

Figure 2 SA frequency immediately after islanding (time scale in local SA time)



4.2 Rate of change of frequency

When SA is at risk of islanding as the result of a single credible contingency resulting in the loss of the Heywood Interconnector, AEMO is required to ensure that the RoCoF in SA immediately after the occurrence of the credible contingency is no higher than 1 Hz/s. This limit was implemented in January 2015 to ensure reliable operation of the UFLS.

AEMO manages this by limiting the flow towards South Australia on the Heywood Interconnector depending on the amount of inertia in South Australia. The maximum allowable continuous flow across the Heywood Interconnector when South Australia is at risk of islanding for a single credible contingency is 250 MW.

In this incident, there was no loss of the Heywood Interconnector itself. The fault in Victoria resulted in the disconnection of the in-feeds to the Heywood Interconnector. It is not always possible to manage the power

system to avoid RoCoF exceeding 1 Hz/sec at any time post a credible contingency, given the range of possible credible Victoria–SA separation points that can all exist at once, and the large loads and generation than can exist between these various separation points.[8]

The actual RoCoF in South Australia was ~1.2Hz/s. This was greater than the 1 Hz/s limit as a result of the APD load being temporarily connected to South Australia immediately after the fault in Victoria.

4.3 Contingency FCAS

Table 3 shows the generating units in South Australia that were enabled to provide fast raise contingency (R6) FCAS for dispatch interval ending 0020 hrs. Generating units enabled for R6 FCAS are expected to commence delivering this service when the frequency falls below the normal frequency operating band of 49.85Hz.

Table 3 Generating units enabled to provide fast raise contingency (R6) FCAS

Generating unit	R6 FCAS enabled (MW)
Pelican Point	17
Torrens A1	4.52
Torrens B2	5
Torrens B3	15
Torrens B4	10.18
Total	**51.7**

As noted in Section 2, while contingency FCAS was not specifically enabled in South Australia as part of the planned outages associated with this event, any generating units in South Australia that were enabled would be expected to deliver the enabled service if the frequency in South Australia fell below 49.85 Hz. As noted in Section 4.1, the frequency in South Australia fell to a minimum of 48.78 Hz.

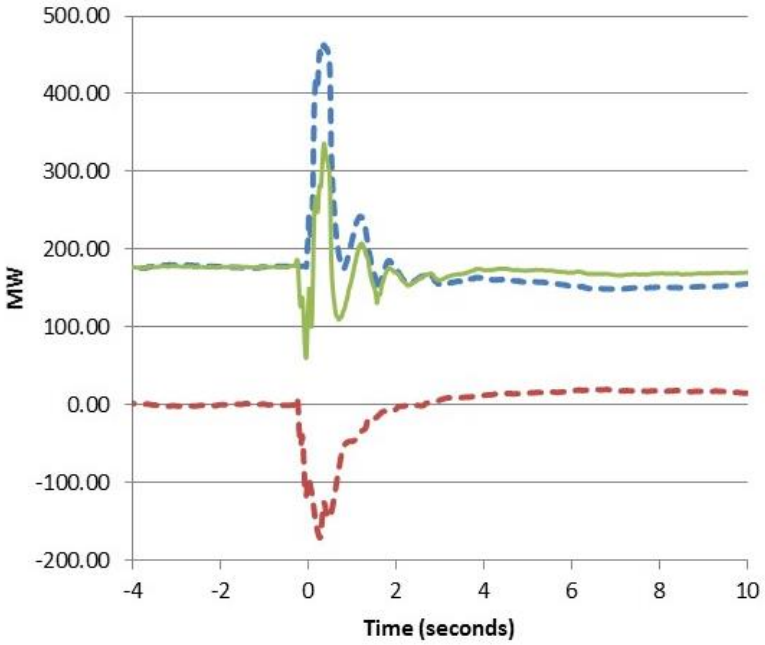
Clause 3.11.2(f) of the NER requires generators must install and maintain equipment to monitor and record the delivery of FCAS. Clause 3.11.2(h) of the NER requires generators to provide this information to AEMO if requested. AEMO requested the operators of all FCAS enabled generating units in South Australia to provide this information.

4.3.1 Pelican Point

Figure 3 shows the response of Pelican Point Power Station to the frequency deviation in SA. While there was an initial response from the unit, this response was not sustained over six seconds as required by the Market Ancillary Service Specification. The blue trace in Figure 3 is the pre-adjusted output, the red trace is the correction for inertial response, and the green trace is the resultant output after the inertial response has been removed.

[8] The Heywood Interconnector connects Heywood substation in Victoria and South East substation in South Australia.

Figure 3 R6 response from Pelican Point Power Station



4.3.3 Torrens Island

AGL was unable to provide the data required, due to a software fault with their high speed monitoring system. AGL has advised AEMO that the software fault has been repaired, and a further upgrade to the software is planned to occur shortly.

As the required high speed data has not been provided, AEMO has not been able to analyse the delivery performance of R6 FCAS enabled on the Torrens Island generating units.

Even if the R6 FCAS enabled in South Australia had been fully delivered, the response would not have been sufficient to prevent the frequency falling below 49 Hz, the point at which automatic under frequency load shedding occurs. AEMO has estimated that around 460 MW of R6 FCAS would be required in South Australia to prevent the frequency falling below 49 Hz. As noted in Section 4.1, the frequency standard for South Australia allows the frequency to fall to minimum of 47 Hz for a separation event and the frequency standard was met.

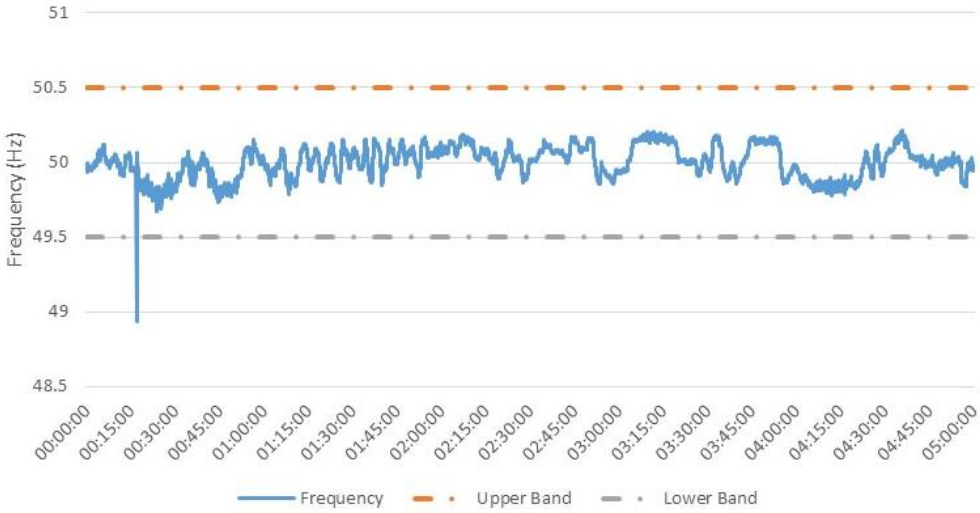
As the SA frequency recovered to within the normal frequency operating band within approximately 11 seconds, there was no requirement for the generating units enabled for slow raise (R60) and delayed raise (R5min) FCAS to deliver this service.

4.4 Regulation FCAS

As part of the outage planning process, AEMO enabled 35 MW of raise and lower regulation FCAS in SA. Regulation FCAS is required to ensure frequency can be controlled to within the normal frequency operating band for island operation of 49.5 to 50.5Hz.

Figure 4 shows the frequency in SA during the period of islanding. This amount of regulation FCAS was sufficient to manage frequency in the islanded SA power system. There were no material issues with frequency control in SA while operating as an island.

Figure 4 South Australia frequency during island operation



5. RESTORATION

Immediately after the incident, AEMO's efforts were directed towards stabilising the islanded SA network and restoring the lost SA and APD loads as fast as possible. The restoration sequence is shown in Table 4.

Table 4 Restoration sequence

Time	Action
0054 hrs	AEMO gave permission to restore all load in SA.
0117 hrs	APD recalled the APD-Heywood No2 500kV line outage.
0130 hrs	Direction issued to South Australia generator to provide additional R6 FCAS.
0131 hrs	The planned outages of the Mortlake–Heywood– APD 500kV line and the Heywood busbar were confirmed as recalled.
0145 hrs	All load restored in SA.
0210 hrs	Direction issued to ElectraNet to reduce load at BHP by 45MW to reduce the requirement for L6 FCAS.
0230 hrs	Direction issued to South Australia generator to reduce output to reduce requirement for R6 FCAS.
0250 hrs	Direction issued to ElectraNet to reduce load at BHP by a further 15 MW to reduce the requirement for L6 FCAS.
0330 hrs	Connection restored to APD via the Mortlake– Heywood– APD 500 kV line.
0339 hrs	AEMO advised APD that supply was available to APD. APD advised AEMO they were not ready to commence load restoration at this time.[A]
0357 hrs	Heywood No. 2 500 kV busbar returned to service via the Mortlake–Heywood–APD 500 kV line.
0407 hrs	AEMO gave permission to re-synchronise Victoria and SA via the Heywood Interconnector.
0420 hrs	AusNet Services advised AEMO that synchronisation had been delayed due to an unexpected switchgear problem at HYTS.
0441 hrs	Victoria and SA successfully synchronised. Heywood Interconnector in service via the Mortlake–Heywood–APD 500 kV line.
0447 hrs	APD advised AEMO they were ready to restore load. AEMO gave permission to APD to restore all load.
0453 hrs	Direction to generator 1 was cancelled.
0456 hrs	Direction to reduce supply to BHP's Olympic Dam site was cancelled.
0459 hrs	Direction to generator 2 was cancelled.
1018 hrs	Heywood–Tarrone–APD 500 kV line returned to service.
2132 hrs	The faulted Moorabool–Tarrone 500 kV line was repaired and returned to service. Both connections to the Heywood interconnector in service.

A AEMO received similar advice from APD at 0404 hrs, 0425 hrs, 0435 hrs, and 0446 hrs.

5.1 Synchronising delays

At 0407 hrs, AEMO gave permission to AusNet to carry out switching to re-synchronise the Victoria and SA networks. At 0420 hrs, AusNet became aware that a remotely controlled isolator at the Heywood terminal station had failed to close correctly. The isolator was successfully closed by field staff at Heywood at 0424 hrs.

AusNet advised AEMO at 0435 hrs that, although the Mortlake to Heywood line had been returned to service and the 500kV No. 2 bus at Heywood energised, the synchronising data required to allow the AusNet control room operators to close the 275kV circuit breaker at HYTS and synchronise Victoria and SA was not available on the AusNet operators' control screens due to a software issue. As such, AusNet could not carry out the switching required to synchronise the Victoria network to the SA network.

AEMO gave clearance to AusNet and ElectraNet to carry out switching to enable synchronising at the South East substation in SA instead. This involved switching by ElectraNet to de-energise the Heywood to South East No. 2 275 kV line from the South East substation in SA. AusNet then energised this line from Heywood, and ElectraNet then carried out the synchronising function at South East substation to restore the line to service. Victoria was synchronised to SA at 0441 hrs.

These issues resulted in a delay in re-synchronising of approximately 11 minutes.

AusNet has subsequently made changes to their control systems to ensure all necessary synchronising data is available to the operators.

5.2 Recall of planned outages

The planned outages of the Heywood busbar and the Heywood–APD line involved several parties – AEMO, AusNet, and APD. While AEMO has the responsibility to recall outages impacting power system security, the lines of communication are not as clear as they need to be. While this did not delay the restoration process in this instance, AEMO proposes to consult with NEM participants to develop procedures to ensure clear lines of communication and responsibility are in place in relation to recalling outages.

6. OPERATION OF SA WHEN ISLANDED

This section provides information on how AEMO managed frequency control in SA for the period where SA was separated from Victoria.

SA was able to be operated successfully as an electrical island with no synchronous connection to the NEM grid. During this time, the direct current (DC) non-synchronous connection through Murraylink remained connected and supplying power to SA.

When SA was islanded from Victoria, AEMO invoked constraint sets to enable contingency FCAS in SA at 0025 hrs. Contingency FCAS when operating SA as an electrical island is required to maintain the frequency operating standards within the region, and to prevent further load shedding if another contingency were to occur.

From 0030 hrs, constraints associated with the provision of R6 FCAS and fast lower contingency (L6) FCAS violated, indicating a shortage of these services. The shortage of contingency FCAS meant the power system in SA was not in a secure operating state. AEMO must take all reasonable actions, including intervention if necessary, to return the power system to a secure operating state within 30 minutes.

Appendix C provides details of the violating constraints.

Not all generating units in SA are able to provide contingency FCAS. The only generating units registered to provide contingency FCAS are the large thermal generating units at Torrens Island, Pelican Point, and Osborne.

Table 5 shows the generating units that were in service at the time of this event, the registered R6 and L6 FCAS capability, and the amount of R6 and L6 FCAS enabled for the dispatch interval ending 0030 hrs.

Table 5 Available and enabled fast FCAS (MW)

	Registered R6 capability	Available R6 capability	R6 enabled	Registered L6 capability	Available L6 capability	L6 enabled
Torrens A1	10	10	10	10	10	10
Torrens B2	20	20	20	20	20	20
Torrens B3	20	20	20	20	20	20
Torrens B4	15	15	15	15	15	15
Pelican Point	35	17[9]	17	35	17	17

As Table 5 shows, all available R6 and L6 FCAS was enabled. At 0045 hrs, Torrens Island A1 rebid all of its R6 capability as unavailable.

Any off line generating units that had the capability of providing either R6 or L6 FCAS would not have been able to be started in time.

The requirement for R6 FCAS is determined by the size of the largest generating unit that could be lost as a result of a single credible contingency. To manage the shortage of R6 FCAS, at 0130 hrs AEMO issued a direction to a generating unit in SA to increase the supply of R6 FCAS. The Generator complied with the direction. At 0230 hrs, AEMO issued a direction to a generating unit to reduce its output to reduce the size of contingency risk, and hence reduce the requirement for R6 FCAS. This is in accordance with AEMO's Power System Security Guidelines procedure.[10] The Generator complied with the direction. No other sources of R6 FCAS were available.

Despite the above actions, AEMO was not able to source sufficient R6 FCAS to completely cover the potential loss of the generation at Pelican Point Power Station. Constraint equation F_S+PPT_R6_1 continued to violate until SA was reconnected to Victoria via the Heywood interconnection.

The reason for this is, no additional R6 FCAS was available, and the output of Pelican Point Power Station could not be further reduced to reduce the FCAS requirement. This means the power system was not in a secure operating state for the duration of this event, a period of approximately four hours and twenty minutes.

The requirement for L6 FCAS is determined by the size of the largest load that could be lost as a result of a single credible contingency. To manage the shortage of L6 FCAS, at 0210 hrs AEMO directed ElectraNet to reduce the largest industrial load in SA. AEMO issued a second direction to ElectraNet at 0250 hrs to further reduce this load. ElectraNet complied with both directions.

This reduced the requirement for L6 FCAS, and was in accordance with an agreed protocol between AEMO and BHP Billiton. All directions were cancelled as soon as the interconnection to Victoria was restored. These directions will be covered in detail in a directions report to be published at a later date.

7. MARKET INFORMATION

AEMO is required by the NER and operating procedures to inform the market about incidents as they progress. This section assesses how AEMO informed the market[11] over the course of this incident.

For this incident, AEMO was required to inform the market on the following matters:

- Prompt advice of the occurrence of a major power system contingency.[12]
  - AEMO issued Market Notice 55958 at 0031 hrs (15 minutes after the event) to advise that the SA region was separated from the rest of the NEM.
- Constraints invoked with interconnector terms on the left hand side.[13]

[9] The reduced availability of R6 and L6 FCAS at Pelican Point is due to only one of the gas turbines being in service.
[10] SO-OP 3715.Section 5.7
[11] AEMO generally informs the market about operating incidents as they progress by issuing Market Notices.
[12] NER clause 4.8.3 and section 23 of the Power System Security Guidelines (SO_OP 3715).
[13] For short-term outages, AEMO is required to notify the Market of variances to interconnector transfer limits. AEMO, *Power System Security Guidelines,* Section 22.

  - AEMO did not publish a market notice to advise the market which constraints had been invoked for this event. AEMO believes sufficient information was available to the market based on the market notice advising of a separation event, and that any constraints invoked as a consequence were visible to the market via the dispatch process. However, AEMO accepts that a specific market notice should have been published in accordance with procedures. AEMO will review its internal procedures to market notices are published when required.
- Issue a Market Notice advising that AEMO has issued a direction or clause 4.8.9 instruction[14]
  - AEMO issued Market Notice 55973 at 0234 hrs to advise that directions had been issued to participants in the SA region. Market Notice 56015 was issued at 0502 hrs to advise that the directions to SA participants had been cancelled.

8. CONCLUSIONS

AEMO has assessed this incident in accordance with clause 4.8.15(b) of the NER. In particular, AEMO has assessed the adequacy of the provision and response of facilities or services, and the appropriateness of actions taken to restore or maintain power system security.

AEMO has concluded that:

- The trip of the Moorabool–Tarrone 500kV transmission line was the result of equipment failure.
- All protection and control schemes operated correctly and as expected.
- The frequency standard in South Australia was met.
- The UFLS scheme in South Australia operated as expected.
- Pelican Point Power Station did not provide fast raise (R6) FCAS immediately after the separation event as required. AEMO is working with Engie to determine the reasons for this.
- AGL was unable to provide the high speed data to enable AEMO to analyse the delivery of fast raise (R6) FCAS from the Torrens Island generating units. AGL advised the data could not be provided due to a software problem with their data recorders. AGL has advised that the software problem has been resolved. AEMO will confirm this with AGL.
- The non-delivery of FCAS did not have a material impact on the outcome of this incident.
- The power system was not in a secure operating state after this incident for a period of four hours and twenty minutes. AEMO took all reasonable steps to return the power system to a secure operating state. The actions taken by AEMO were appropriate and in accordance with the NER and published procedures.
- There was a delay in synchronising the Victoria and SA networks, due to a software issue associated with AusNet's control system.

9. PENDING ACTIONS

Table 6 Pending actions

Action	To be completed by
AEMO will review the delivery of fast raise (R6) FCAS with Engie.	31 March 2017
AEMO will consult with APD, AusNet, and other network service providers in all NEM regions to ensure clear lines of communication and responsibility are provided in relation to recalling outages.	30 June 2017
AEMO will review its internal procedures and training to ensure market notices are published when required.	30 June 2017

[14] Section 5 of the Intervention, Direction and Clause 4.8.9 Instructions procedure (SO_OP 3707).

APPENDIX A. NETWORK DIAGRAMS

The diagrams below show the relevant section of the Victorian 500 kV transmission network before and immediately after the Moorabool–Tarrone line tripped, and after the EAPTS had operated. Some circuit breaker information has been omitted for clarity.

Figure 5 Prior to fault

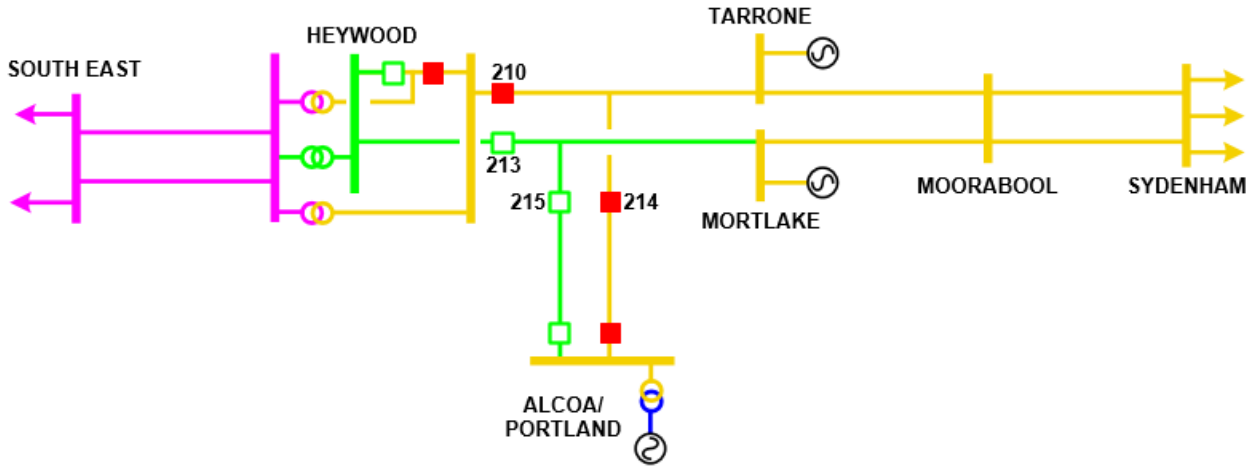


Figure 6 Immediately after fault

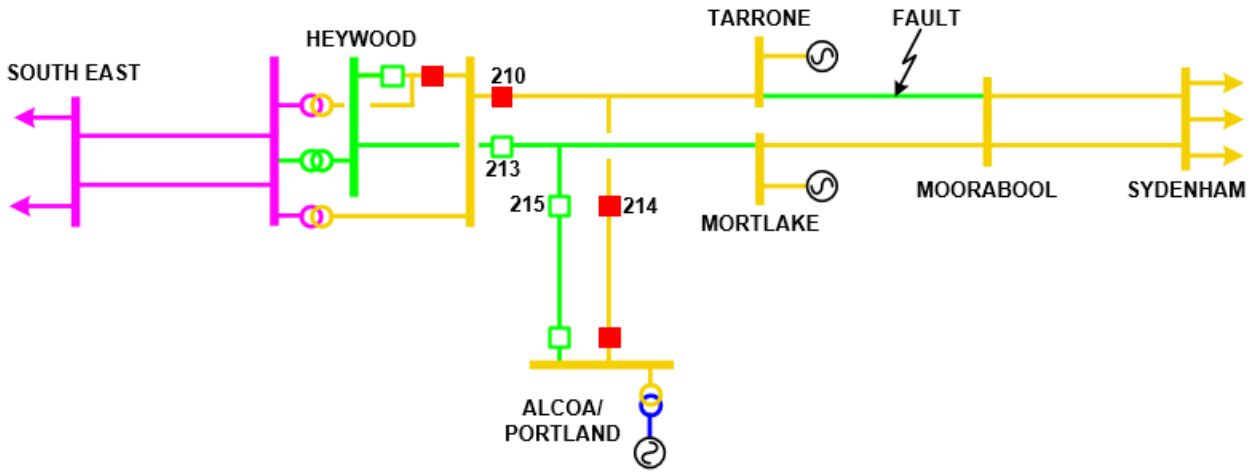
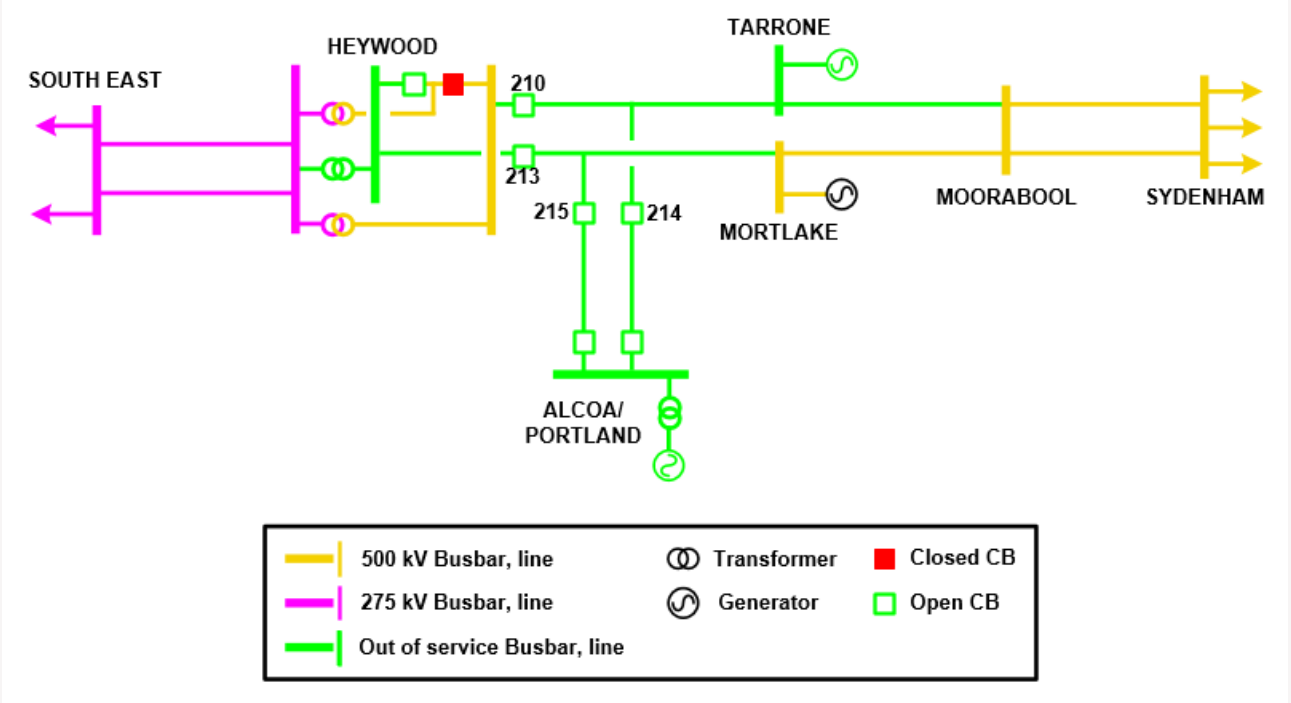


Figure 7 After operation of EAPTS control scheme



APPENDIX B. EMERGENCY APD POTLINE TRIPPING SCHEME (EAPTS)

The Emergency APD Potline Tripping Scheme is in place to ensure the APD load is not fed from SA after the loss of the transmission connection between Moorabool and Heywood.

The scheme detects the loss of the 500 kV connection between Moorabool and Heywood, leaving SA supplying the APD load. This condition may not be capable of supporting the load. The control scheme performs two tests to determine if operation is required.

- Test 1:
  - A sudden reduction in active power flow towards Heywood on the transmission lines from Mortlake and Tarrone of more than 280 MW, and
  - An increase in flow from South Australia across the 500/275 kV transformers at Heywood of greater than 200 MW, and
  - The frequency at Heywood as measured on the transmission lines to South Australia is below 49.7 Hz for more than 100 ms.
- Test 2:
  - A sudden reduction in active power flow towards Heywood on the transmission lines from Mortlake and Tarrone of more than 280MW, and
  - The voltage on both 500 kV busbars at Heywood is less than 400 kV for greater than 400 ms.

If either of the above conditions is met, then the APD load is disconnected by opening Tarrone Line No. 1 bus 500 kV CB (CB 210) and the Mortlake Line No. 2 bus 500 kV CB (CB 213) at Heywood.

For this particular event, the requirements for Test 1 were met.

APPENDIX C. VIOLATING FCAS CONSTRAINTS

Table 7 shows the FCAS constraints that violated during this event, and the amount of violation in MW.

Table 7 FCAS constraint violation

Time	F_S++QPS_R6_1	F_S++TIB2_R6_1	F_S++TIB2_R6_2	F_S++TIB3_R6_1	F_S++TIB3_R6_2	F_S++TIB4_R6_1	F_S++TIB4_R6_2	F_S+HL_TG_R6_1	F_S+PPT_R5	F_S+PPT_R6_1	F_S+TL_L5_OD	F_S+TL_L6_OD
01/12/2016 00:30		-93	-11	-99	-40	-103	-58			-35		-52
01/12/2016 00:35	-1	-90		-89		-99	-34			-75		-37
01/12/2016 00:40		-87		-87		-87				-68		-36
01/12/2016 00:45		-78		-85		-68				-77		-52
01/12/2016 00:50		-73		-74		-55				-85		-42
01/12/2016 00:55		-49		-47		-55				-83		-38
01/12/2016 01:00		-19		-15		-28				-73		-31
01/12/2016 01:05		-2		-1		-15				-83		-26
01/12/2016 01:10										-85	-2	-42
01/12/2016 01:15										-94	-8	-57
01/12/2016 01:20										-81	-8	-55
01/12/2016 01:25										-71		-53
01/12/2016 01:30										-70		-50
01/12/2016 01:35									-13	-71	-10	-52
01/12/2016 01:40										-51	-20	-78
01/12/2016 01:45								-16	-25	-63	-25	-95
01/12/2016 01:50									-16	-70	-24	-91
01/12/2016 01:55									-9	-61	-27	-95
01/12/2016 02:00										-42		-63
01/12/2016 02:05										-61		-50
01/12/2016 02:10										-72		-12
01/12/2016 02:15										-64		-12
01/12/2016 02:20										-70		
01/12/2016 02:25										-76		
01/12/2016 02:30										-77		
01/12/2016 02:35										-77		
01/12/2016 02:40										-28		
01/12/2016 02:45										-18		
01/12/2016 02:50										-16		
01/12/2016 02:55										-20		
01/12/2016 03:00										-23		
01/12/2016 03:05										-25		
01/12/2016 03:10										-22		
01/12/2016 03:15										-16		
01/12/2016 03:20										-15		
01/12/2016 03:25										-18		
01/12/2016 03:30										-22		
01/12/2016 03:35										-21		
01/12/2016 03:40										-19		
01/12/2016 03:45										-35		
01/12/2016 03:50										-17		
01/12/2016 03:55										-20		
01/12/2016 04:00										-20		
01/12/2016 04:05										-25		
01/12/2016 04:10										-39		
01/12/2016 04:15										-38		
01/12/2016 04:20										-35		
01/12/2016 04:25										-39		
01/12/2016 04:30										-22		
01/12/2016 04:35										-30		
01/12/2016 04:40										-18		
01/12/2016 04:45										-19		
01/12/2016 04:50										-19		
01/12/2016 04:55										-28		