FAULT AT TORRENS ISLAND SWITCHYARD AND LOSS OF MULTIPLE GENERATING UNITS ON 3 MARCH 2017

REVIEWABLE OPERATING INCIDENT REPORT FOR THE NATIONAL ELECTRICITY MARKET

Published: **10 March 2017**

AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

INCIDENT CLASSIFICATIONS

Classification	Detail
Time and date of incident	1503 hrs on 3 March 2017
Region of incident	South Australia
Affected regions	South Australia
Event type	Transmission equipment
Generation impact	610 MW of generation was lost as a result of this incident
Customer load impact	No customer load was lost as a result of this incident
Associated reports	Nil

ABBREVIATIONS

Abbreviation	Term
Hz	hertz
kV	kilovolt
MW	megawatt
MW.s	megawatt seconds
ms	millisecond
NER	National Electricity Rules
NEM	National Electricity Market
pu	per unit
SESS	South East Substation
TIPS	Torrens Island Power Station
UFLS	under frequency load shedding

IMPORTANT NOTICE

Purpose

AEMO has prepared this 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 preliminary data by Registered Participants as to the performance of some equipment leading up to, during, and after this event in accordance with clause 4.8.15 of the Rules. In addition, AEMO has collated preliminary information from its own systems. If a material change to the information in this report is identified by AEMO, it will issue an updated report.

While AEMO has made every effort to ensure the quality of the information in this report, its investigations are incomplete and the findings expressed in it may change as further information becomes available and further analysis is conducted. 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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1. OVERVIEW

This report relates to a reviewable operating incident[1] that occurred in South Australia on 3 March 2017. The reasons for reviewing this event are that a non-credible contingency event occurred and the power system in South Australia was not in a secure operating state for 40 minutes.

At 1503 hrs (AEST) on 3 March 2017, a series of faults at ElectraNet's Torrens Island 275 kilovolt (kV) switchyard resulted in the loss of approximately 610 megawatts (MW) of generation in South Australia (SA) across five generating units.

Although AEMO did not instruct load shedding, and there was no operation of the under frequency load shedding (UFLS) scheme in SA, there was a 400 MW drop in demand in SA as a result of this incident.

As this is a reviewable operating incident, AEMO is required to assess power system security over the course of the 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.

AEMO's conclusions related to the incident are:

- This non-credible contingency was initiated by the explosive failure of a capacitor voltage transformer in the Torrens Island 275 kV switchyard.
- The loss of generation at Pelican Point Power Station was unexpected, and was caused by an unexplained protection operation within ElectraNet's switchyard at Pelican Point. This protection has been removed from service, pending further investigation.
- The loss of the TIPS B2 generating unit was unexpected, and was caused by the failure of the boiler air heater drive. The cause of this failure is still under investigation by AGL.
- The power system in SA was not in a secure operating state for 40 minutes. AEMO took all reasonable actions to restore the power system to a secure operating state.

AEMO further concludes:

- There are close similarities between this event and the SA black system event on 28 September 2016 in that there was a large sudden reduction of generation in SA that resulted in the power flow across the Heywood Interconnector exceeding normal operating limits. Voltage levels at South East substation (SESS) were not as low as on 28 September 2016 – if they had been lower, the Loss of Synchronism (LoS) protection that disconnected the Heywood Interconnector in that event would have operated again, resulting in another black system event.
- All wind farms in SA successfully rode through a series of three transmission faults in short succession on 3 March, indicating the changes made to their protection system since 28 September 2016 have been successful. AEMO has not identified any sustained reduction in output from the wind farms as a consequence of the faults on the transmission system.

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 ElectraNet, AGL, and Engie, and from AEMO's energy and market systems.

Australian Eastern Standard Time (AEST) is used in this report. Local time in SA in March is AEST plus 30 minutes.

[1] Refer to clause 4.8.15 of the NER.

2. PRE-EVENT CONDITIONS

Immediately prior to this event, the demand in SA was 1,993 MW and was supplied by a combination of 987 MW of thermal generation, 457 MW of wind generation and 549 MW of import from Victoria (495 MW via Heywood and 54 MW on Murraylink).[2] The on-line inertia in SA was 8,590 MW.s.

There were no transmission outages affecting supply to SA.

The power system in SA was in a secure operating state prior to this event.

3. INITIATING FAULT

Starting at 15:03:46 hrs, a series of three faults occurred at the Torrens Island switchyard. These faults resulted in the loss of five generating units in SA. Table 1 details these faults and the associated loss of generation. The total loss of generation for this event was 610 MW, however 410 MW was lost within 1.5 seconds of the initial fault. The remaining 200 MW was lost over a period of between one to five minutes after the initial fault.

Table 1 Fault sequence

Time	Event / comments
15:03:46.262	**Fault 1** – A capacitor voltage transformer (CVT) in the Torrens Island switchyard associated with TIPS B4 generator failed explosively. This caused damage to the generator disconnector associated with TIPS B4, resulting in the trip of TIPS B4 generating unit from ~130 MW..
15:03:46.364	Pelican Point Power Station GT 11 tripped from ~150 MW due to operation of directional over-current protection external to the power station. The steam turbine at Pelican Point starts to run back from ~70 MW. As only one gas turbine (GT) was on line at Pelican Point at the time, the loss of this GT results in the automatic run-back and trip of the steam turbine.
15:03:46.920	**Fault 2** – 275 kV West busbar in the Torrens Island switchyard tripped. Likely cause is due to debris/smoke from the explosion of the voltage transformer.
15:03:47:812	**Fault 3** – TIPS B3 tripped from ~130MW. Likely cause is due to debris/smoke from the explosion of the CVT causing a flashover of TIPS B3 High level bus support insulators.
15:05	TIPS B2 starts to runback from ~130 MW due to loss of the boiler air heater drive.
15:05:15:031	Pelican Point steam turbine tripped as a consequence of the earlier trip of GT 11.
15:07:34.020	TIPS B2 tripped.

Refer to Appendix A for a diagram of the Torrens Island switchyard, and Appendix B for a full sequence of events.

4. POST EVENT ANALYSIS

4.1 Failure of capacitor voltage transformer

The following is based on information provided by ElectraNet.

At approximately 1503 hrs on Friday 3 March, a capacitor voltage transformer (CVT) associated with the TIPS B4 generating unit experienced a catastrophic failure. This resulted in three separate faults in the vicinity of the generating unit disconnectors on the TIPS B3 and B4 generating unit step up transformers, and subsequent collateral damage to high voltage plant in Torrens Island switchyard in the B3 and B4 bays.

The cause of the CVT failure is suspected to be the internal failure of the primary capacitor voltage divider. The resulting cloud of combustion products heavily polluted the ‘U’ phase west bus support insulator,

[2] Based on the results from the dispatch interval ending 1505 hrs.

resulting in a flashover and west bus earth fault. The combustion products also polluted the TIPS B3 high level conductor support insulators, resulting in a flashover of 'U' phase on Unit 3 and subsequent earth fault.

The failed CVT was a single phase unit, which was tested 38 days before the failure. The regular maintenance plan included a monthly visual inspection and yearly secondary voltage check. There were no current or outstanding defects on the unit.

While three-phase CVTs are monitored using a voltage comparison method across each phase, single phase units cannot be monitored in this way because there are no other 'like' units to compare the voltages against.

The catastrophic failure of this type of equipment is rare. In general, instrument transformers including CVTs have consistently shown a slow incremental deterioration indicating potential failure for well over 12 months from the start of the deterioration. ElectraNet has not previously observed explosive failures of CVTs.

CVTs are replaced when they indicate a significant primary capacitor deterioration (usually within 12 months of initial detection). De-energisation or exclusion zones are applied as interim controls, immediately following detection of deterioration.

There are currently twelve CVTs from the same manufacturer remaining in service, which are monitored via online relays and four-yearly routine secondary voltage checks.

ElectraNet already has online monitoring in place for these CVTs, and if an alarm is received the CVT will be de-energised. ElectraNet has also implemented an accelerated replacement program for these CVTs. Until replacement can occur, an exclusion zone has been put in place surrounding each unit.

4.2 Trip of generating units

4.2.1 Torrens Island Power Station

The following is based on information provided by AGL.

The explosive failure of the TIPS B4 generating unit synchronising CVT (owned by ElectraNet) caused damage to the generator isolators for TIPS B3 and B4 generating units, resulting in the trip of these generating units. The trip of these generating units was an expected outcome for this type of damage.

The cause of the TIPS B2 generating unit was the TIPS B2 boiler air heater tripping during the fault sequence. The air heater has a 415 V drive, with a backup compressed air drive (intended only for maintenance and emergency rotation of the air heater). This arrangement is the same on all four TIPS B units. Loss of the air heater drive causes an automatic unit trip following a 60-second delay (intended to potentially enable operators to respond to restore air heater drive). When the TIPS B2 air heater drive tripped, the unit trip followed shortly after, as the operators were unable to re-establish the drive in sufficient time. The cause of trip of the air heater drive has yet to be determined.

4.2.2 Pelican Point Power Station

The following is based on information provided by Engie and ElectraNet.

Prior to this event, generation at Pelican Point consisted of one gas turbine (GT 11) generating ~150 MW, and the steam turbine generating ~70 MW.

GT 11 tripped approximately 100 millseconds (ms) after the first fault at the Torrens Island switchyard. This was not an expected outcome for a fault in the Torrens Island switchyard. After the trip of GT 11, the steam turbine automatically tripped due to loss of the heat source from the gas turbine.

Analysis by Engie has shown that GT 11 correctly tripped in response to a trip signal from the protection equipment in the Pelican Point switchyard owned by ElectraNet. Analysis by ElectraNet has shown that the directional overcurrent protection associated with the GT 11 operated unexpectedly and sent a trip signal to the gas turbine. This protection has since been disabled pending further investigation.

4.3 Heywood Interconnector flow

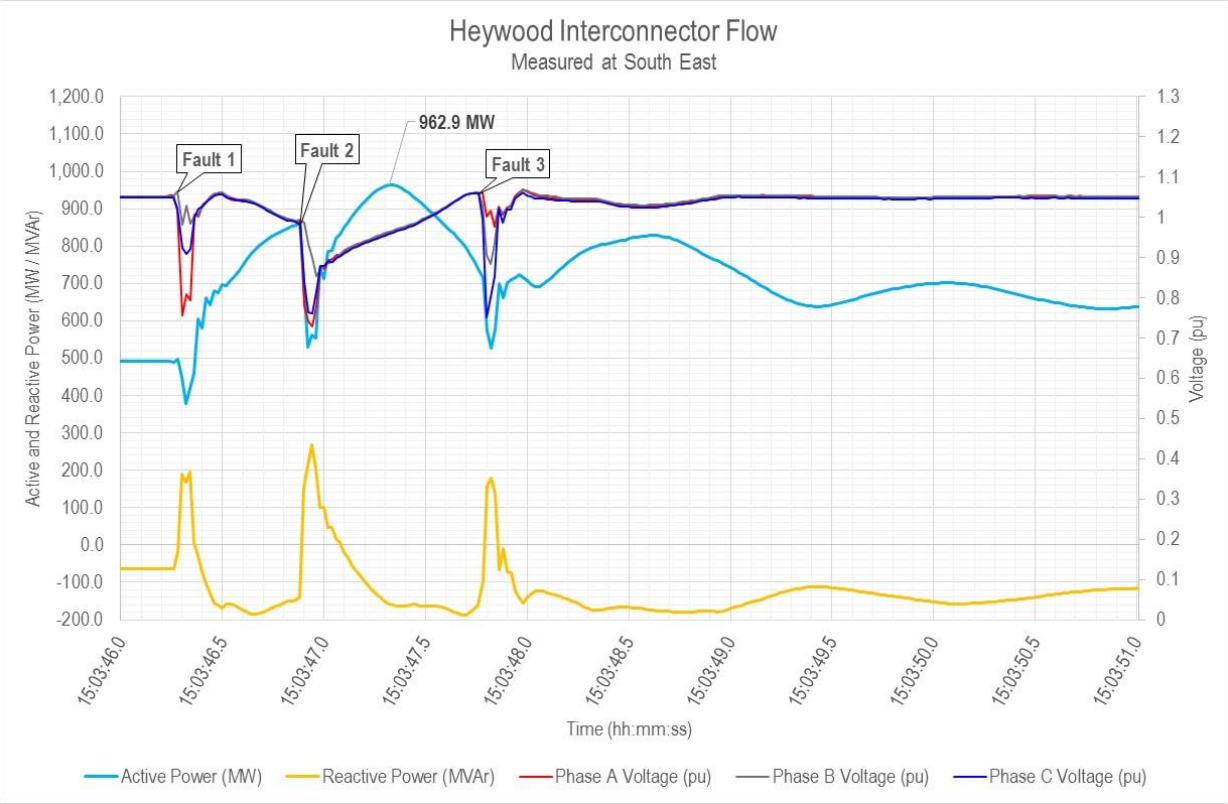
The power flow on the Heywood Interconnector just prior to this incident was 495 MW. Figure 1 shows active power (MW) and reactive power (MVAr) and voltages on the Heywood Interconnector, as measured at the SESS in SA.

The faults at the Torrens Island switchyard resulted in the near simultaneous disconnection of 410 MW of generation. This resulted in the power flow on the Heywood Interconnector peaking at 963 MW approximately 380 ms after the second fault, before levelling off at around 600 MW approximately three seconds later.

This rapid reduction in the Heywood Interconnector power flow was a result of demand reduction of ~250MW in SA as a result of the voltage disturbance. Voltage levels in the Torrens Island area, which is close to the major load centre of Adelaide, fell to approximately 0.1 pu, as shown in Figure 2.

AEMO did not instruct load shedding, and SA Power Networks have confirmed there was no operation of the UFLS scheme.[3] Figure 3 shows the demand reduction in SA immediately after the faults.

Figure 1 Heywood Interconnector



[3] The UFLS was not expected to operate as the frequency remained above 49 Hz.

Figure 2 Voltages at Torrens Island Power Station

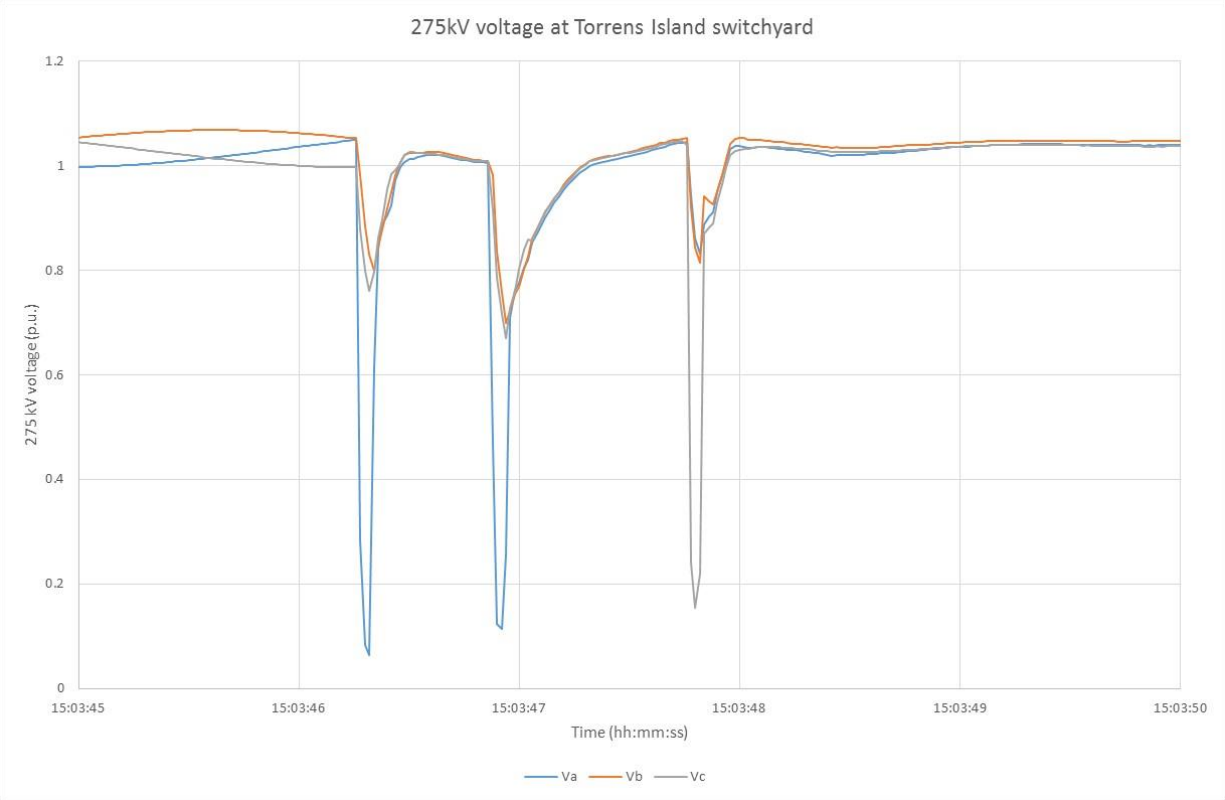
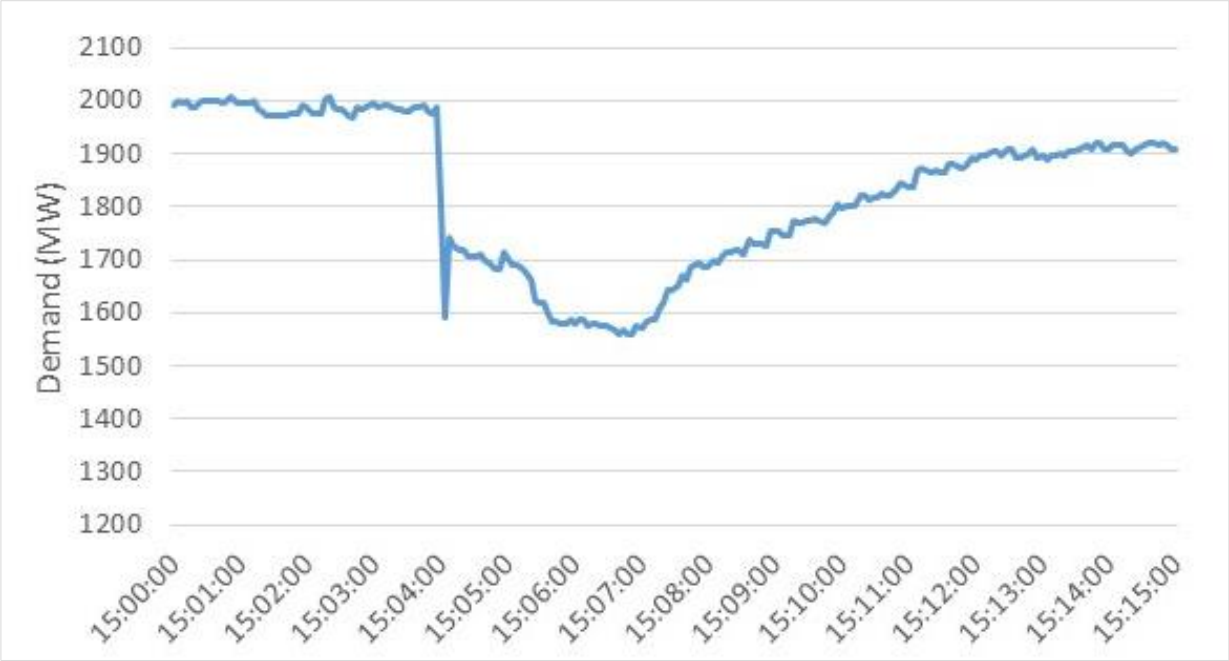


Figure 3 Demand in SA

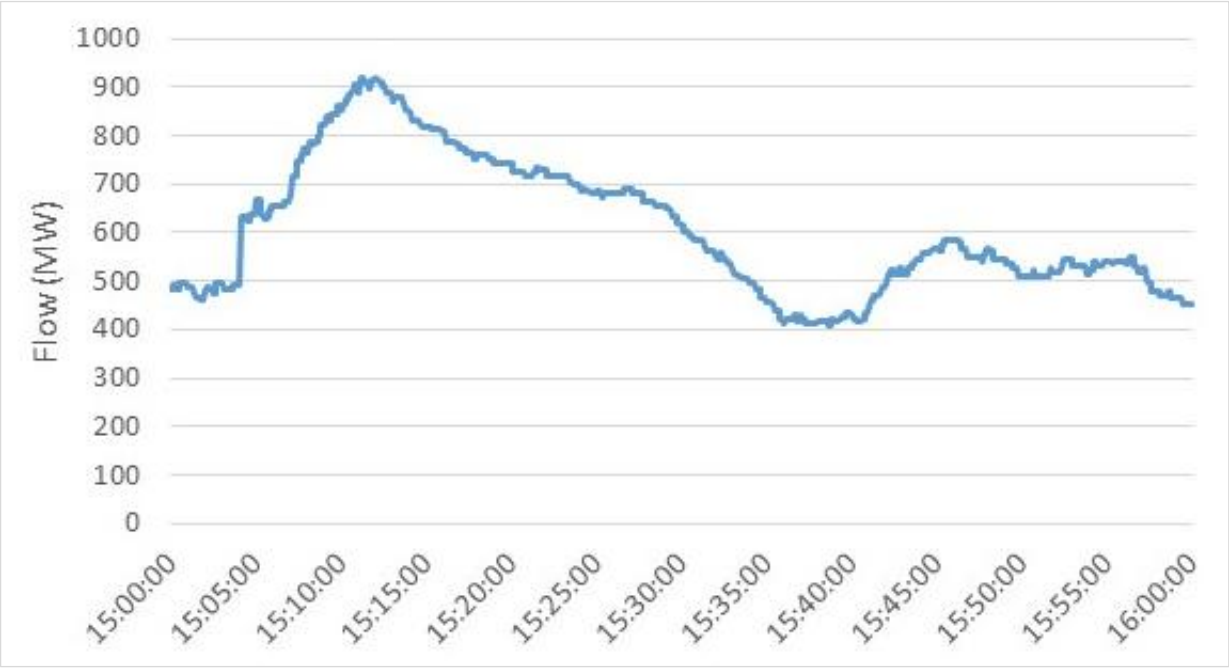


As noted above, there was a reduction in SA demand coincident with the faults at the Torrens Island switchyard. The initial reduction was ~400 MW, which rapidly reduced to around 250 MW. Although further analysis is required, AEMO believes, supported by information provided by ElectraNet, that this 150 MW change was a consequence of rooftop PV systems shutting off in response to the voltage disturbance,

producing a reduction in generation of 150 MW and consequently an increase in demand. As the rooftop PV systems recovered and automatically re-connected, their output increased and reduced the demand.

Although the power flow on the Heywood Interconnector initially recovered to around 600 MW, the loss of a further 200 MW of generation (as the TIPS B2 generating unit and the Pelican Point steam turbine ran back and tripped), combined with increasing demand in SA as load that initially reduced reconnected, resulted in a further increase in the Heywood Interconnector power flow to approximately 918 MW, as shown in Figure 4.

Figure 4 Heywood interconnector flow



As a result of the increased power flow across the interconnector, and the reduction in on-line generation in SA, AEMO's dispatch process issued start signals to a number of generating units in SA. These generating units synchronised from 1520 hrs. The power flow on the Heywood Interconnector was reduced to within normal limits by 1535 hrs.

4.4 Performance of wind farms

As set out above, during this event there were three transmission faults within a short period. Wind farms have reported operation of their low voltage ride-through protection as would be expected for these faults, and AEMO has not identified any sustained reduction in output from the wind farms as a result of this event. All wind farms in SA performed as expected during this event.

In contrast, as AEMO noted in its third report into the black system event, on 28 September 2016 there was a sustained reduction in output from a number of wind farms in response to a series of transmission system faults within a short timeframe. This resulted in the disconnection of the Heywood Interconnector and the black system event. Since that event, a number of windfarms have revised their protection settings.

4.5 Frequency

The frequency in the mainland parts of the network fell to a minimum of 49.77 Hz and recovered to within the normal frequency operating band (above 49.85 Hz) within five minutes. The frequency in Tasmania fell to a minimum of 49.78 Hz and recovered to within the normal frequency operating band (above 49.85 Hz) within five minutes.

The frequency standard in the mainland and Tasmania for a multiple contingency event allows the frequency to fall to a minimum of 47 Hz and return to the normal frequency operating band within 10 minutes. The frequency standard was met for this event.

5. POWER SYSTEM SECURITY

AEMO is responsible for power system security in the National Electricity Market (NEM). This means AEMO is required to operate the power system in a secure operating state and take all reasonable actions to return the power system to a secure state following a contingency event.[4] This section assesses how AEMO managed power system security over the course of this incident.

The power system in SA was in a secure operating state immediately prior to this event. Immediately after the event, AEMO's actions were concentrated on reducing the flow across the Heywood Interconnector.

At 1514 hrs, AEMO invoked non-conformance constraints on the TIPS B2, B3, and B4 generating units. Similarly, at 1517 hrs, non-conformance constraints were invoked on the Pelican Point Power Station. This enabled the market systems to recognise that these generating units were not available, and to dispatch other available generating units.[5]

Table 2 shows the constraint equations that violated during this event. A violating constraint equation is an indication that the power system may not have been in a secure operating state. All constraint violations had cleared by 1530 hrs.

Table 2 Violating constraints

Dispatch interval	Constraint equation	Violation (mw)	Constraint description
15:20:00	S>>NIL_TBTU_TBCG_1	5.00625	Out=NIL, avoid O/L Tailem Bend-Cherry Gardens 275kV line on trip of Tailem Bend-Tungkillo 275kV line,
15:25:00	S>>NIL_TBTU_TBCG_1	27.08564	
15:30:00	S>>NIL_TBTU_TBCG_1	30.31537	
15:20:00	V^SML_NSWRB_2	24.52505	Out = NSW Murraylink runback scheme, avoid voltage collapse for loss of Darlington Pt to Buronga (X5) 220kV line
15:25:00	V^SML_NSWRB_2	13.30893	
15:15:00	V_S_NIL_ROCOF	196.05135	Out = NIL, limit VIC to SA Heywood interconnection flow to prevent Rate of Change of Frequency exceeding 3 Hz/sec in SA immediately following loss of Heywood interconnector.
15:20:00	V_S_NIL_ROCOF	203.15998	
15:25:00	V_S_NIL_ROCOF	136.67999	

AEMO must ensure sufficient system strength in SA to ensure the power system in SA is in a secure operating state. To manage this, AEMO has a requirement that a minimum number of large synchronous generating units (or equivalent) are in service in SA.

This requirement was met immediately prior to this event, but was not met immediately after the event, due to the number of synchronous generating units that tripped. The requirement was met by 1543 hrs after additional synchronous generating units were dispatched.

The power system in SA was not in a secure operating state from 1503 hrs to 1543 hrs, a period of 40 minutes.

5.1 Reclassification

AEMO, in accordance with clause 4.2.3A of the NER, assessed whether or not to reclassify the event as a credible contingency event.[6]

As the cause of the contingency was identified and the faulty equipment isolated, AEMO was satisfied that the non-credible contingency event on the transmission network was unlikely to reoccur. At that stage, AEMO was not aware of the reason that TIPS B2 and Pelican Point GT 11 tripped.

[4] Refer to clause 4.2.4 of the NER.

[5] Normally when a generating unit trips AEMO expects the relevant trader to re-bid the unit as unavailable. This may take up to 15 minutes. By using the non-conformance process, AEMO was able to send start signals to other generating units sooner than would have otherwise happened. This was done in accordance with published procedures. Refer to SO_OP 3705 Dispatch.

[6] AEMO is required to assess whether or not to reclassify a non-credible contingency event as a credible contingency – NER clause 4.2.3A (c) – and to report how re-classification criteria were applied – NER clause 4.8.15 (ca). AEMO has to determine if the condition that caused the non-credible contingency event has been resolved.

AEMO considered whether to reclassify the loss of these units as a single credible contingency. As the Pelican Point GT 11 had not returned to service, and the trip of a single generating unit such as TIPS B2 is always credible, AEMO did not reclassify this non-credible contingency as a credible contingency.

At 0300 hrs on 7 March 2017, Pelican Point GT was returned to service. As AEMO had not been advised of the reason for the trip of either TIPS B2 or Pelican Point GT 11, AEMO decided to reclassify the simultaneous trip of Pelican Point GT 11 and the largest on-line generating unit at Torrens Island as a credible contingency.

On 8 March 2017, AEMO received advice from ElectraNet that, coincident with the fault at the Torrens Island switchyard, directional overcurrent protection had operated to trip GT 11. This protection has since been disabled by ElectraNet. Engie has confirmed that GT 11 tripped as a result of a trip signal received from ElectraNet's protection equipment, and no trip signal was generated by their protection equipment. On the basis of this information, AEMO was satisfied that the cause of the trip of GT 11 at Pelican Point had been identified and was unlikely to re-occur. AEMO cancelled the reclassification at 0915 hrs on 8 March 2017.

On March 9 2017, AEMO received advice from AGL that there was potential for TIPS B2 generating unit to trip for a fault close to the generating unit.

Based on this information, at 1512 hrs on 9 March 2017, AEMO reclassified the loss of TIPS B2 generating unit plus any of the other TIPS B generating units to be a credible contingency. Constraint set S-TIPSB2_N-2 was invoked.

6. SIMILARITIES TO BLACK SYSTEM EVENT ON 28 SEPTEMBER 2016

On 28 September 2016, SA suffered a black system event after a sudden loss of approximately 460 MW generation resulted in an increase in power flow across the Heywood Interconnector from ~500 MW to ~900 MW. This increase in power flow, coupled with low voltages at the SESS, resulted in the operation of the LoS protection at SESS,tripping the Heywood Interconnector.

Very similar conditions existed during this event, however the Heywood Interconnector did not trip.

Prior to the 3 March event, the power flow on the Heywood Interconnector was ~500 MW and (as noted in Section 3) there was a sudden loss of 410 MW of generation resulting in the flow on the Heywood Interconnector increasing to over 900 MW.

Figure 5 shows the impedance trajectory at SESS against the LoS protection relay settings for the black system event on 28 September 2016.[7] It shows that the impedance crossed both the inner and outer relay blinders, resulting in operation of the protection and tripping of the Heywood Interconnector.

[7] For more details, see AEMO's third report on the black system event available on the AEMO website

Figure 5 Loss of synchronism relay on 28 September 2016

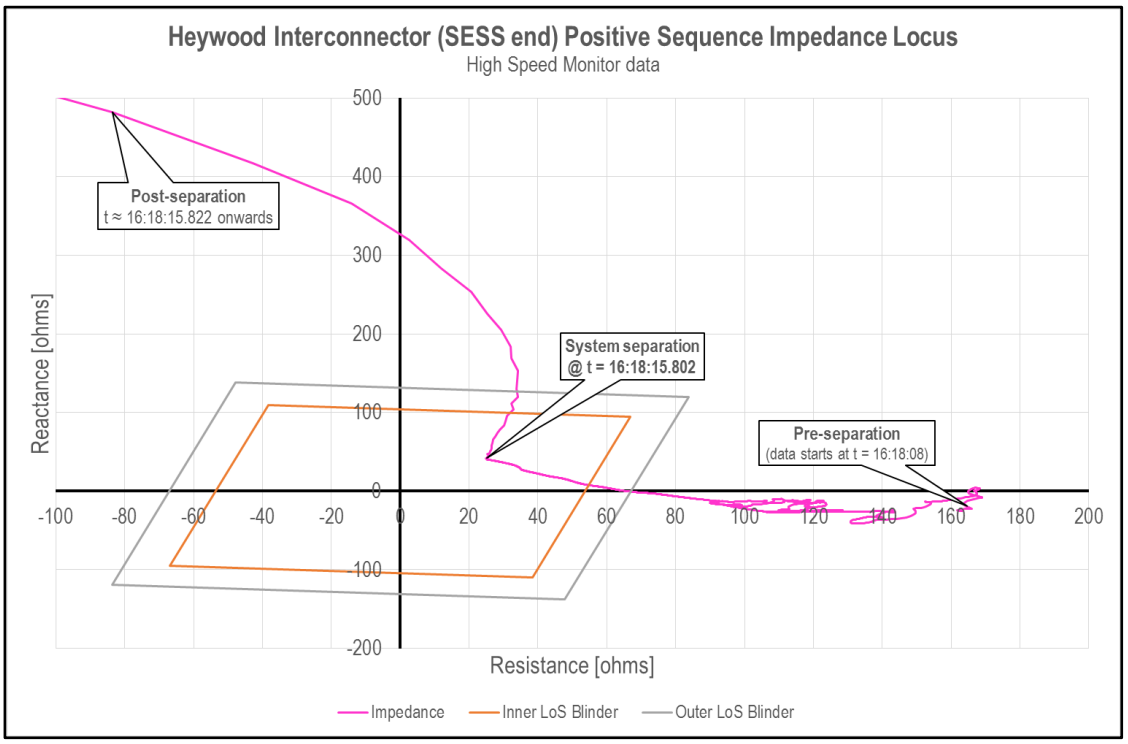


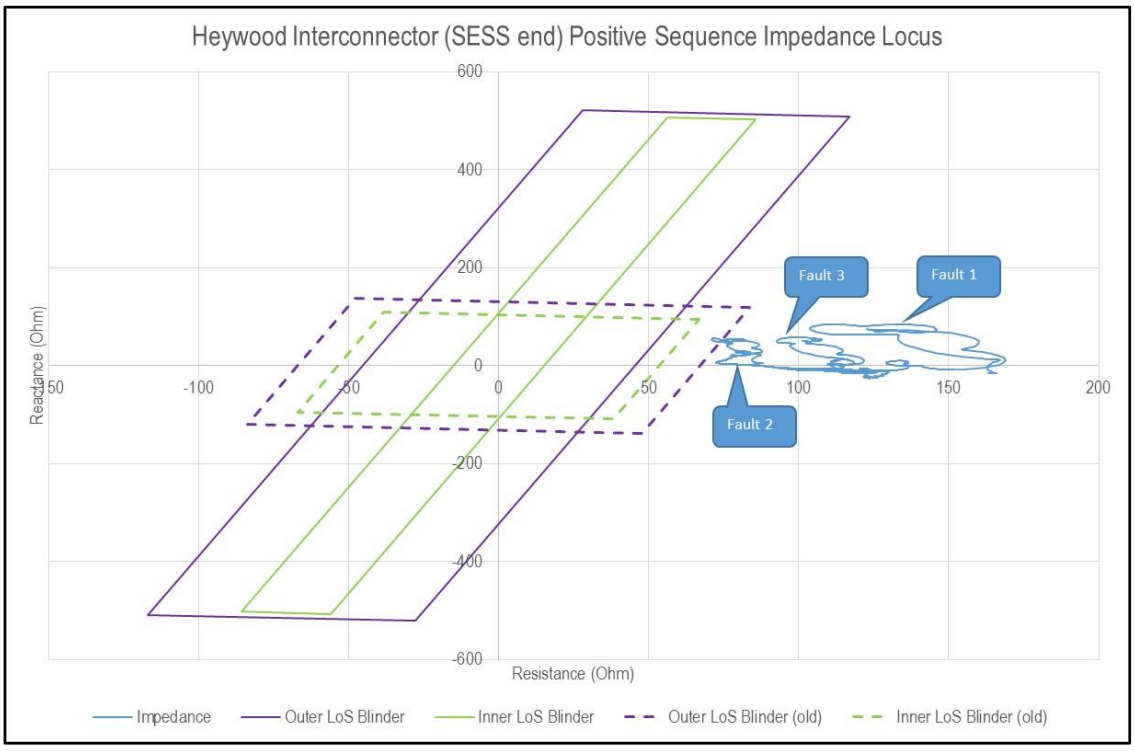
Figure 6 shows the impedance trajectory at SESS against the LoS protection relay settings during the event on 3 March 2017.

The LoS relay characteristics were recently changed as part of the planned works associated with the upgrade of the Heywood Interconnector. The new settings are shown by solid lines, with the old settings in dashed lines.

As Figure 6 shows, the impedance trajectory did not cross either the outer or inner relay blinders for this event. While the impedance did cross the old outer blinder setting, it did not cross the inner blinder, so the LoS protection would not have operated even if the old settings had still been in place.

Figure 6 also shows that, if the impedance trajectory for the 3 March 2017 event had been similar to that on 28 September 2016, then, despite the revised relay settings, the LoS protection would have operated, resulting in the loss of the Heywood Interconnector.

Figure 6 Loss of synchronism relay on 3 March 2017



While further analysis is required, AEMO believes the difference in impedance trajectory is related to the voltage levels at SESS:

- On 28 September 2016, coincident with the increased flow on the Heywood Interconnector, the voltage levels at SESS fell below 0.3 pu, as shown in Figure 7.
- On 3 March 2017, the voltage levels at SESS fell to only approximately 0.75 pu, as shown in Figure 8. Part of the reason for the improved voltage response at SESS on 3 March is the load reduction that occurred as a result of the voltage disturbance caused by the fault.

Figure 7 SESS voltages on 28 September 2016

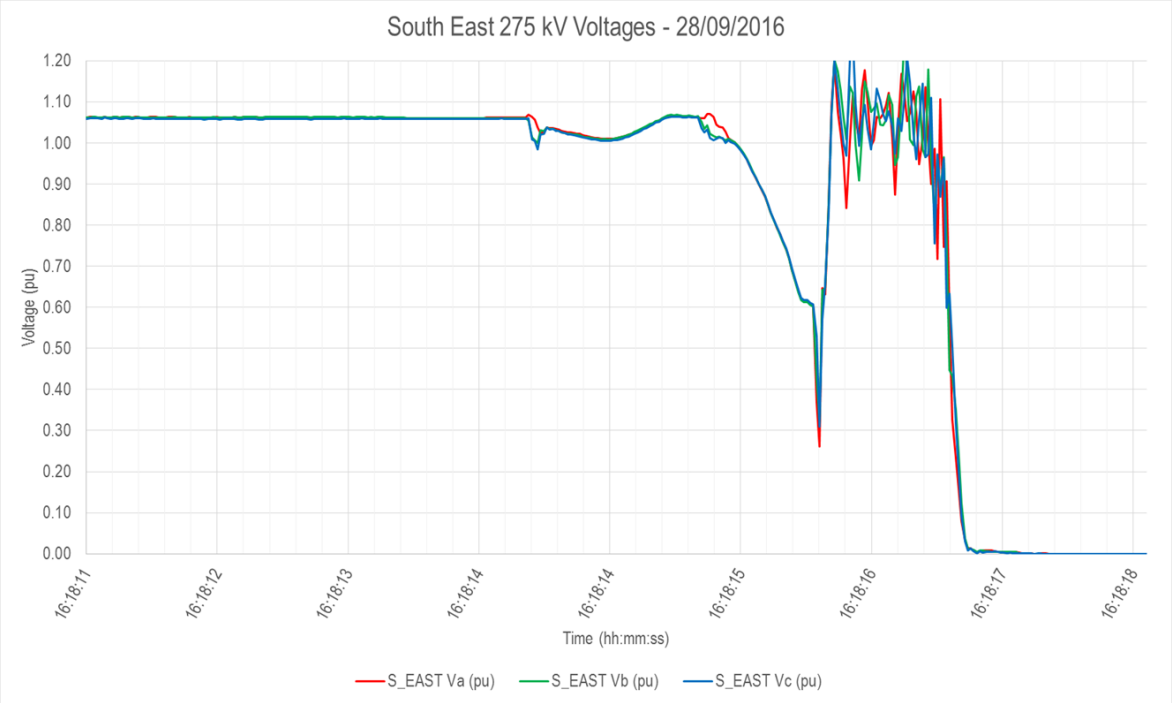
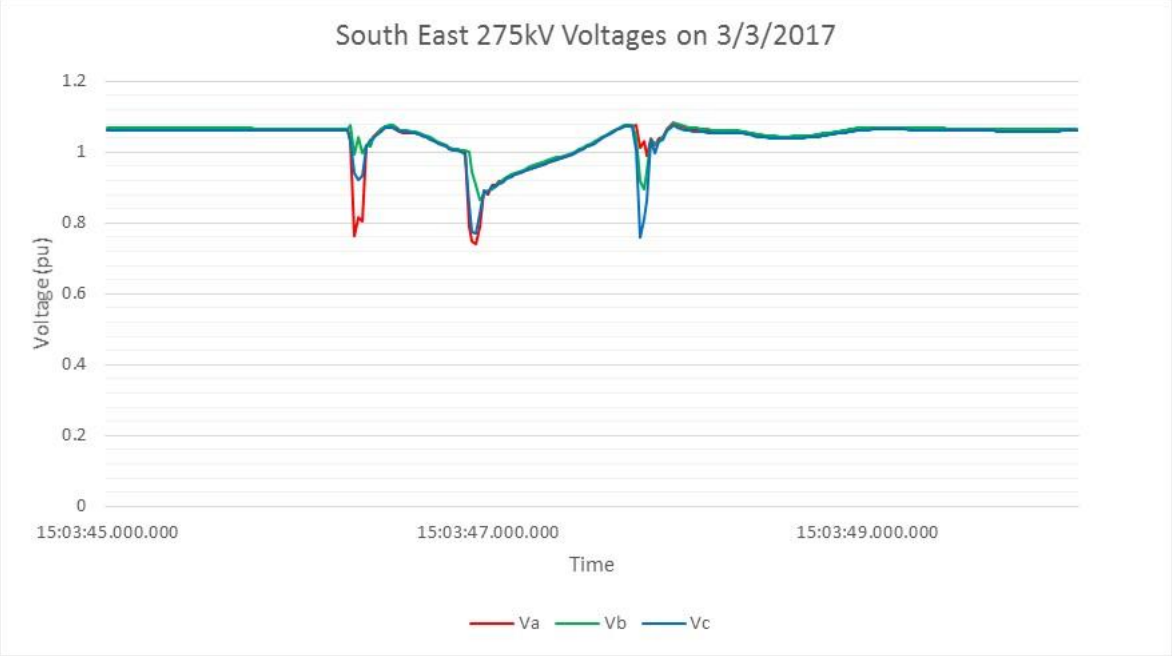


Figure 8 SESS voltages on 3 March 2017



AEMO could not have reasonably foreseen this event, as the near-simultaneous tripping of multiple generating units across separate power stations is an extremely rare event.

Based on the above, AEMO believes this event came very close to tripping the Heywood Interconnector. This would have resulted in a black system in SA, because the resulting rate of change of frequency (RoCoF) would have been approximately 8.7 Hz/s, and it would have been beyond the capability of the UFLS scheme in SA to shed sufficient load in time to prevent a black system. This relatively high RoCoF can be attributed to the proportionally low amount of conventional generation that remained on line after the event and the subsequently low inertia that would have occurred as a result.

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[8] over the course of this incident.

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

- The occurrence of a major power system contingency.[9]
  - AEMO issued Market Notice 57817 at 1605 hrs (one hour after the event) to advise participants of the trip of multiple generating units (a non-credible contingency) in SA.
- Reserve conditions.
  - AEMO issued Market Notice 57818 at 1615 hrs, to advise participants of an actual Lack of Reserve (LOR) 2 condition in SA.
  - AEMO issued Market Notice 57819 at 1706 hrs, with updated information in relation to the actual LOR 2 in SA.
  - AEMO issued Market Notice 57820 at 1752 hrs, cancelling the actual LOR 2 in SA and advising of an actual LOR 1 in SA.
  - AEMO issued Market Notice 57821 at 1836 hrs, cancelling the actual LOR 1 in SA.
- Reclassification of contingency events.
  - AEMO issued Market Notice 57878 at 0301hrs on 7 March 2017, to advise the reclassification of the simultaneous trip of Pelican Point GT 11 and the largest on-line generating unit at Torrens Island as a credible contingency.
  - AEMO issued Market Notice 57879 at 1132 hrs on 7 March 2017, with updates to the reclassification. Constraint information added.
  - AEMO issued Market Notice 57888 at 1541 hrs on 7 March 2017, with updates to the reclassification. Revised constraint information.
  - AEMO issued Market Notice 57901 at 0915 hrs on 8 March 2017, cancelling the reclassification.
  - AEMO issued Market Notice 57935 at 1512 Hrs on 9 March 2017, to advise of the reclassification of TIPS B 2 generating unit plus any of the other TIPS B generating units as a credible contingency

Over the course of this incident, AEMO issued appropriate, timely, and sufficiently detailed market information.

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:

- This non-credible contingency was initiated by the explosive failure of a capacitor voltage transformer in the Torrens Island 275 kV switchyard.
- The loss of generation at Pelican Point Power Station was unexpected, and was caused by an unexplained protection operation within ElectraNet's switchyard at Pelican Point. This protection has been removed from service, pending further investigation.
- The loss of the TIPS B2 generating unit was unexpected, and was caused by the failure of the boiler air heater drive. The cause of this failure is still under investigation by AGL.

[8] AEMO generally informs the market about operating incidents as they progress by issuing Market Notices.
[9] NER clause 4.8.3 and section 23 of the Power System Security Guidelines (SO_OP 3715).

- The power system in SA was not in a secure operating state for 40 minutes. AEMO took all reasonable actions to restore the power system to a secure operating state.

AEMO further concludes:

- There are close similarities between this event and the SA black system event on 28 September 2016 in that there was a large sudden reduction of generation in SA that resulted in the power flow across the Heywood interconnector exceeding normal operating limits. Voltage levels at SESS were not as low as on 28 September 2016 – if they had been lower, the LoS protection that disconnected the Heywood Interconnector in that event would have operated again, resulting in another black system event.
- All wind farms in SA successfully rode through a series of three transmission faults in short succession on 3 March, indicating the changes made to their protection system since 28 September 2016 have been successful. AEMO has not identified any sustained reduction in output from the wind farms as a consequence of the faults on the transmission system.

9. RECOMMENDATIONS

AEMO is continuing to pursue recommendations made after the black system event in SA, related to the development of control schemes to rapidly disconnect load or generation to in SA to prevent a separation event, or to ensure a stable island in SA if separation does occur.

AEMO will develop better modelling of load and rooftop PV response to severe voltage disturbances, to fully understand the implications for power system security.

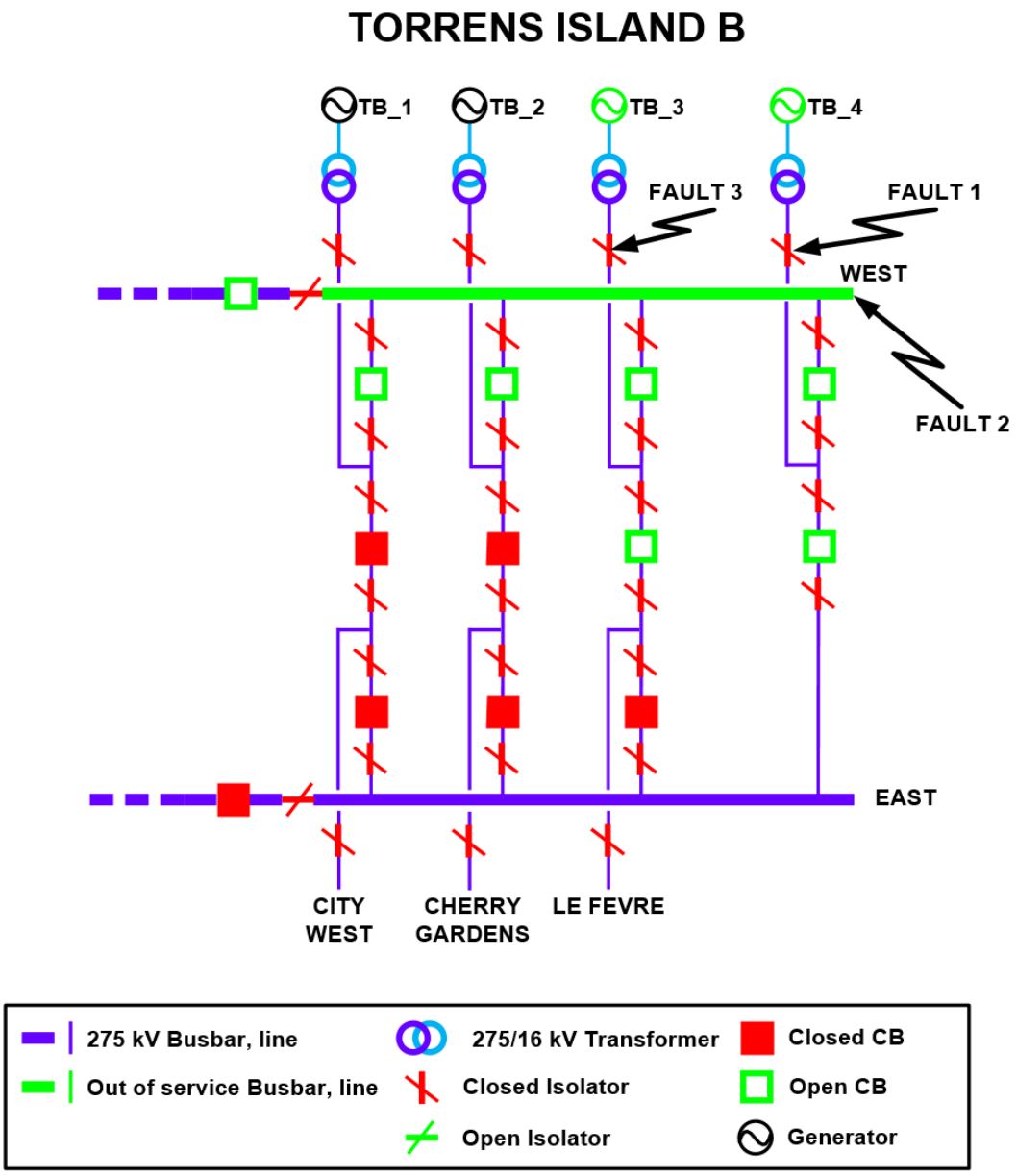
AEMO will work with Transmission Network Service Providers (TNSPs) to promote information sharing on asset failures.

10. PENDING ACTIONS

AEMO will continue to analyse this event as more information becomes available. If this analysis identifies any material change to the information in this report, AEMO will issue an updated report.

APPENDIX A. NETWORK DIAGRAM

This diagram shows the status of the switchgear at the Torrens Island switchyard immediately after the third fault.



APPENDIX B. SEQUENCE OF EVENTS

Figure 9 Sequence of events

Time	Event
15:03:46.262	CVT associated with TIPS B4 generator transformer failed. 'U' Phase fault. TIPS B4 tripped from ~130 MW.
15:03:46.364	Pelican Point GT 11 tripped from ~150 MW. ST 18 starts to run down from ~70 MW.
15:03:46.920	275 kV West Bus tripped.
15:03:47.812	TIPS B3 tripped from ~130 MW.
15:05:00.000	TIPS B2 starts to run down from ~130 MW.
15:05:15.031	Pelican Point ST 18 tripped.
15:07:34.020	TIPS B2 tripped.
15:10:00.000	Hallett, Dry Creek 2 and Quarantine 5 generating units synchronising.
15:10:00.000	Constraint V_S_NIL_ROCOF violating.
15:11:10.000	Heywood Interconnector flow peaks at 918MW. Limit = 476 MW.
15:14:00.000	Accelerated non-conformance on TIPS B2, B3 & B4. MN 57813, 57814, 57815.
15:15:00.000	Constraints S>>NIL_TBTU_TBCG_1 and V^SML_NSWRB_2 violating.
15:15:00.000	Angaston and Snuggery generating units synchronising.
15:17:00.000	Accelerated non-conformance on Pelican Point. MN 57816.
15:20:00.000	Dry Creek 2 and 3 generating units synchronising.
15:20:00.000	Murraylink interconnector flow exceeding secure limits.
15:25:00.000	Constraints V_S_NIL_ROCOF and V^SML_NSWRB_2 cease violating.
15:25:00.000	Mintaro, Port Lincoln 1 and Port Lincoln 3 generating units synchronising.
15:30:00.000	Constraint S>>NIL_TBTU_TBCG_1 ceases violating.
15:35:00.000	Heywood and Murraylink interconnector flow now at or below limit.
15:56:00.000	AGL advised AEMO that North Brown Hill WF limited to 14 MW due to DVAR issue. Constraint applied.
15:58:00.000	Engie advised AEMO that Pelican Point does not have 66 kV supply, which is delaying a restart. AEMO advised they would be issuing Engie with a direction to start GT 12 to provide reserve.
16:01:00.000	AGL advised AEMO that TIPS B3 and B4 unavailable for next few days. TIPS B2 may return to service but not confirmed. TIPS A3 expected on line 3-4 hours.
16:05:00.000	MN 57817, advice of non-credible contingency.
16:15:00.000	LOR 2 in SA from 1503 hrs to 1700 hrs. MN 57818. Deficit = 90 MW.
16:29:00.000	Engie advised AEMO that Pelican Point GT 11 expected on line in 10 minutes.
16:48:00.000	Engie advised AEMO that Pelican Point GT 11 failed to start. Vibration monitoring problem. Preparing GT 12 which is expected to sync in 1.5 hours.
17:06:00.000	Update to LOR 2. MN 57819. LOR 2 from 1503 hrs to 1800 hrs. Deficit = 40 MW.
17:34:00.000	ElectraNet advised AEMO that the CVT on TIPS B4 has failed resulting in damage to 275 kV West bus and isolator associated with TIPS B3.
17:47:00.000	Pelican Point GT 12 on line.
17:52:00.000	LOR 2 cancelled. LOR 1 exists until 1830 hrs. MN 57820.
18:36:00.000	LOR 1 cancelled, MN 57821,
18:49:00.000	Update to non-credible contingency event. MN 57823,
19:59:00.000	TIPS B2 returned to service.