POWER SYSTEM IN SOUTH AUSTRALIA AND VICTORIA NOT IN A SECURE OPERATING STATE ON 30 NOVEMBER AND 1 DECEMBER 2016

REVIEWABLE OPERATING INCIDENT REPORT UNDER THE NATIONAL ELECTRICITY RULES

Published: **14 June 2017**

AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

INCIDENT CLASSIFICATIONS

Classification	Detail
Time and date of incident	1050 hrs on 30 November 2016 and 1000 hrs on 1 December 2016
Region of incident	Victoria
Affected regions	Victoria and South Australia
Event type	Power system not in a secure operating state
Generation Impact	No loss of generation
Customer Load Impact	No loss of customer load
Associated reports	• Power system insecure following trip of Heywood M1 transformer on 1 October 2013 • Insecure power system operation on 4 October 2011 • Load shedding in SA - Final Report

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 made every effort to ensure the quality of the information in this report but cannot guarantee its accuracy or completeness. 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:

- make no representation or warranty, express or implied, as to the currency, accuracy, reliability or completeness of the information in this report; and
- are not liable (whether by reason of negligence or otherwise) for any statements or representations in this report, or any omissions from it, or for any use or reliance on the information in it.

Copyright

CONTENTS

1. OVERVIEW

This report relates to reviewable operating incidents[1] that occurred on 30 November and 1 December 2016 in the Victoria (Vic.) region. During these incidents, the power system in Vic. and South Australia (SA) was not in a secure operating state for up to 50 minutes and up to 45 minutes respectively due to the combination of planned outages and the operation of Mortlake power station. There was no loss of generation or customer load as a result of these incidents.

As 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.[2]

AEMO has concluded that:

- Both incidents were caused by constraint action in response to operation of generating units at Mortlake power station.
- The power system was not in a secure operating state for greater than 30 minutes on both occasions. The actions taken by AEMO to restore the power system to a secure operating state were appropriate and timely.
- After the incident on 30 November, AEMO identified the potential for interaction between Mortlake generation and constraint equations associated with transmission outages between Mortlake, Tarrone and Heywood, but AEMO had not yet implemented a constraint before this re-occurred on 1 December.
- In response to these incidents and previous similar incidents, AEMO has removed the voltage unbalance constraint equations for outages between Moorabool and Heywood. The voltage unbalance constraints have been replaced by a zero MW constraint on Mortlake generation.

This report is prepared in accordance with clause 4.8.15(c) of the National Electricity Rules (NER). It is based on information from AEMO's energy and market management systems.

Australian Eastern Standard Time (AEST) is used in this report. In November/December local time in Vic. is AEST plus one hour and in SA AEST minus 30 minutes.

A separate reviewable operating incident that occurred at 0116 hrs on 1 December 2017 is covered in a report published on 28 February 2017[3].

2. PRE-EVENT CONDITIONS

There were a number of planned or forced outages immediately before these incidents:

On 30 November, the following equipment was out of service as part of planned work:

- Heywood No.2 2 500kV busbar. This outage meant there was only a single connection from Vic. to SA via the Heywood interconnector.
- Heywood–Alcoa Portland No. 2 500 kV transmission line. This outage resulted in load to Alcoa Portland (APD) being supplied via a single connection.
- The combination of these outages resulted in the de-loading of the Mortlake – Heywood – APD 500kV transmission line. This line was then de-energised by AEMO during the outage period to manage voltage limits.

To manage power system security during these outages, AEMO invoked the following constraint sets:

- V-HYMO – outage of Heywood to Mortlake 500kV line.
- V-HY_500BUS – outage of Heywood No.1 or No.2 500kV busbar.
- V-HYTX_M12 – outage of Heywood No.1 or No.2 500/275kV transformer.

[1] See NER clause 4.8.15.
[2] See NER clause 4.8.15(b).
[3] Reports available on the AEMO website at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Market-notices-and-events/Power-System-Operating-Incident-Reports?tagId=%7B43D1A742-C03A-40DC-AC4F-7C94F71D0DCD%7D

- S-X_BC_CP – both Black Range series capacitors by-passed.
- F-I_HYSE – FCAS requirements when SA at risk of separation for a single contingency.
- F-V-HYMO – FCAS requirements for outage of Heywood – Mortlake line.

On 1 December, the following equipment was out of service due to a previous fault.[4]

- Moorabool – Tarrone 500kV transmission line.
- Tarrone – Heywood – APD 500kV transmission line.

To manage power system security during these outages, AEMO invoked the following constraint sets:

- V-HYTR – outage of Heywood – Tarrone line.
- V-MLTR – outage of Moorabool – Tarrone line.
- F-V-HYTR – FCAS requirements for outage of Heywood – Tarrone line.
- F-V-MLTR – FCAS requirements for outage of Moorabool – Tarrone line.
- S-X_BC_CP – both Black Range series capacitors by-passed.

On both days Mortlake generating unit 11 was not available and Mortlake generating unit 12 was available but not being dispatched.

Refer to Appendix A for a diagram of the power system at the time of these incidents.

3. INCIDENT

3.1 30 November

From 1045 hrs (Dispatch interval 10:50) on 30 November 2016, constraint equation F_S++HYSE_L6_1[5] violated for greater than six dispatch intervals as shown in Table 1[6]. This constraint equation sets the fast lower (L6) frequency control ancillary service (FCAS) requirement for the SA region to cover the potential loss of the Heywood interconnection. The constraint violation indicates insufficient L6 FCAS was available in SA and that the power system may not be in a secure operating state.

Table 1: Constraint violations

Dispatch Interval	Violation degree (MW)
10:50	-51.7
10:55	-49.2
11:00	-48.2
11:05	-53.1
11:10	-47.6
11:15	-45.3
11:20	-41.9
11:25	-44.2
11:30	-27.2
11:35	-10.5

[4] Refer to incident report Load Shedding in SA - Final Report
[5] Part of constraint set F-I_HYSE – FCAS.
[6] Refer to Appendix B for a full list of violating constraints

At the same time as the constraint started to violate, the target and actual flow on the Heywood interconnector changed from ~250MW import into SA to ~150MW export from SA (a change of ~400 MW) as shown in Figure 1, and generation at Mortlake increased from zero to ~90 MW as shown in Figure 2.

Figure1: Flow on Heywood interconnector

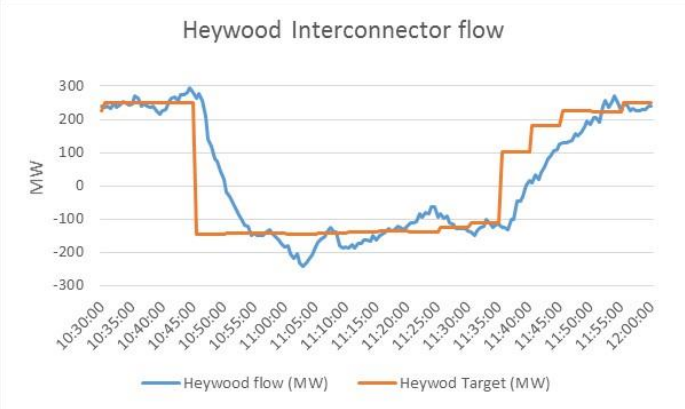
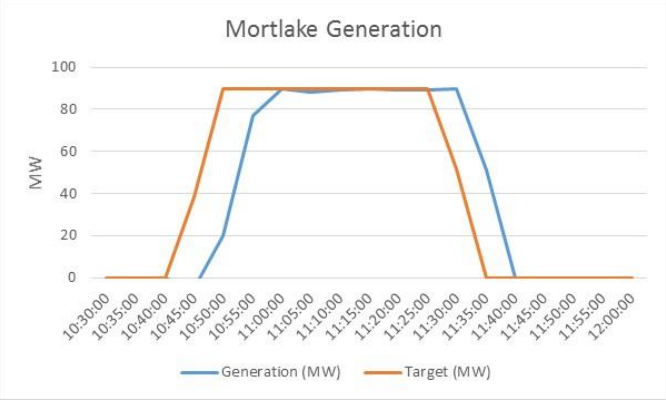


Figure 2: Mortlake generation on 30 November



Constraint violations ceased and the power system returned to a secure operating state at 1135 hrs on 30 November 2016.

3.2 1 December

From 0955 hrs (dispatch interval 10:00) on 1 December, a number of constraint equations violated for greater than six dispatch intervals as shown in Table 2. The constraint violations indicate that the power system may not be in a secure operating state.

Table 2: Constraint violations

Dispatch Interval	Violation Degree (MW)				
	F_S++HYSE_L60[A]	F_S++HYSE_L6_1[B]	SV_250_DYN[C]	V_HYML1_3[D]	V_HYML1_4[E]
10:00	0	0	0	190.1	147.3
10:05	-215.9	-123.3	158.2	183.7	18.3
10:10	-284.7	-378.1	204.1	306.2	113.7
10:15	-385.5	-444.2	246.8	303.8	86.2
10:20	-323.6	-525.3	275.0	230.9	11.4

Dispatch Interval	Violation Degree (MW)				
	F_S++HYSE_L60[A]	F_S++HYSE_L6_1[B]	SV_250_DYN[C]	V_HYML1_3[D]	V_HYML1_4[E]
10:25	-301.0	-501.3	251.9	209.3	3.4
10:30	-49.4	-473.4	25.0	189.2	116.9
10:35	-34.8	-189.5	25.0	117.6	45.3
10:40	-34.9	-171.8	25.0	103.1	30.8

[A] – Slow lower (L60) FCAS requirement for SA
[B] – Fast lower (L6) FCAS requirement for SA
[C] – Dynamic limit on Heywood interconnector
[D] – Manage voltage unbalance at APD 500kV busbar with one Mortlake unit in service. Mortlake limit.
[E] – Manage voltage unbalance at APD 500kV busbar with one Mortlake unit in service. Mortlake + Heywood limit.

Over approximately 25 minutes from when the constraints started to violate, the target and actual flow on the Heywood interconnector changed from ~250MW import into SA to ~500 MW export from SA (a change of 750MW) as shown in Figure 3, and generation at Mortlake increased from zero to ~90 MW as shown in Figure 4.

Figure 3: Flow on Heywood interconnector

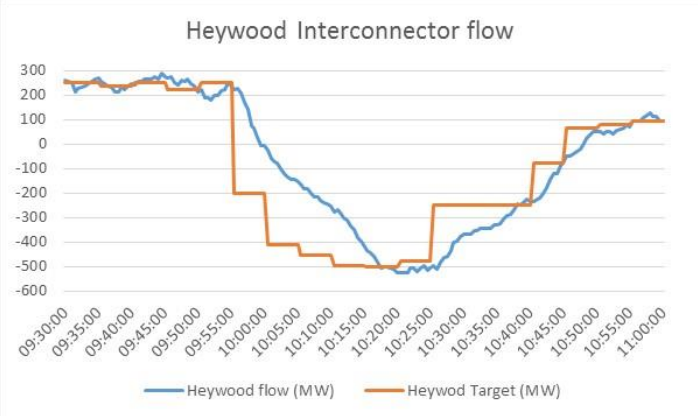
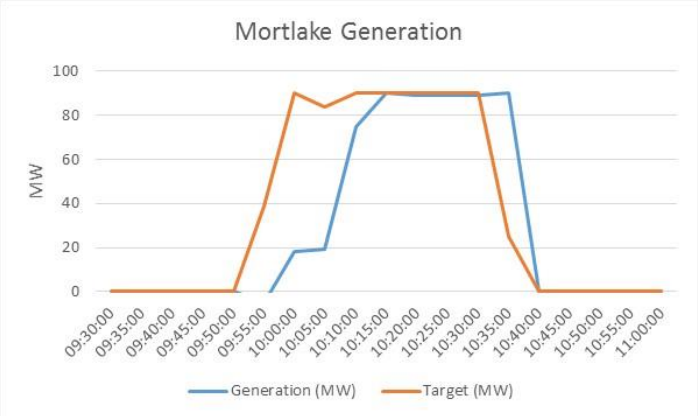


Figure 4: Mortlake generation on 1 December



Constraint violations ceased and the power system returned to a secure operating state at 1040 hrs on 1 December 2016.

4. ANALYSIS

4.1 Voltage unbalance

Constraint sets V-HYMO invoked for the 30 November outage, and V-HYTR and V-MLTR invoked for the 1 December outage contain constraint equations to manage potential voltage unbalance issues at

the Alcoa Portland Smelter (APD) 500kV busbar. The measure of voltage unbalance is the amount of negative sequence voltage at any particular connection point and must be less than 0.5% of nominal voltage[7]. Although voltage unbalance issues were identified based on modelling by AEMO, sufficient measurements of voltage unbalance at APD were not available. Consequently AEMO took a conservative approach and applied limits to the power system under certain network outage conditions to ensure voltage unbalance remained within the limits defined in the NER.

The voltage unbalance levels at APD are influenced by a combination of:

- Voltage unbalance increases with Mortlake generation on line.
- Voltage unbalance increases as load at APD increases.
- Voltage unbalance increases as the flow on the transmission lines between Moorabool and Heywood increases.

These factors can produce additive or counteractive effects on negative sequence voltage at APD, depending on the direction of power flow in the transmission lines between Moorabool and Heywood.

The constraint equations invoked to manage voltage unbalance issues determine the allowable flow on the Heywood interconnector based on the number of Mortlake generating units on line and the load at APD.

4.2 30 November

Prior to dispatch interval (DI) 1040 hrs Mortlake generation was off line and flow on the Heywood interconnector towards SA was 250 MW limited by constraint equation VS_250_DYN. Voltage unbalance constraints were not binding and therefore did not affect dispatch outcomes.

At DI 1040 hrs, Mortlake unit 12 received a dispatch signal to synchronise. At DI 1050 hrs, the generating unit was on line with a dispatch target of 90MW. At the same time, constraint equation V_HYMO2_1[8] started binding and setting a limit for flow on the Heywood interconnector to SA of -147 MW, that is, a flow of 147 MW from SA to Vic. Refer to Figure 1.

With the flow on the Heywood interconnector from SA to Vic., contingency lower FCAS was required to be enabled in SA to prevent excessive frequency rise in SA if the single connection from Vic. to SA via the Heywood interconnection was lost. Constraint equation F_S++HYSE_L6_1 was violating from DI 10:50 hrs due to a shortage of fast lower (L6) FCAS available in SA.

The shortage of L6 FCAS indicates the power system in SA was likely not in a secure operating state.

4.3 1 December

Similar to the incident on 30 November, before DI 0950 hrs, Mortlake generation was off-line and flow on the Heywood interconnector towards SA was 250 MW, limited by constraint equation VS_250_DYN. Voltage unbalance constraints were not binding and therefore not affecting dispatch outcomes.

At DI 0950 hrs, Mortlake unit 12 received a dispatch signal to synchronise. At DI 1000 hrs, the generating unit was on line with a dispatch target of 90 MW. At the same time, constraint equation V_HYML1_4[9] started binding (and violating) and setting a limit for flow on the Heywood interconnector to SA of -450 MW, that is a flow of 450 MW from SA to Vic.[10]. The actual target flow on the Heywood interconnector was -200 MW due to ramp rate limitations on generation in SA. That is generating units in SA could not increase generation within the dispatch interval to meet the required flow. The target flow across the Heywood interconnector increased to -500 MW by DI 1020 hrs. Refer to Figure 3. For the network configuration at the time, the maximum allowable flow of the Heywood interconnector was 250 MW from SA to Vic.

With the flow on the Heywood interconnector from SA to Vic., contingency lower FCAS was required to be enabled in SA to prevent excessive frequency rise in SA if the single connection from Victoria to SA via the Heywood interconnection was lost. Constraint equations F_S++HYSE_L6_1 and

[7] Refer to NER S5.1a.7
[8] Out = Heywood to Mortlake No. 2 500 kV line, limit voltage unbalance at the APD 500 kV bus, one Mortlake unit in service.
[9] Out = Heywood to Tarrone, or Tarrone to Moorabool No. 1 500 kV line, limit voltage unbalance at the APD 500 kV bus, one Mortlake unit in service
[10] A worked example of constraint equation V_HYML1_4 is provided in Appendix C

F_S++HYSE_L60 were violating from DI 10:05 hrs due to a shortage of fast lower (L6) and slow lower (L60) FCAS available in SA.

The high transfer from SA to Vic. and the shortage of L6 and L60 FCAS in SA indicates the power system in SA was not in a secure operating state.

4.4 Operation of Mortlake

Mortlake generation consists of two open cycle gas fired generating units with a registered capacity of 283 MW each. The generating units are registered as fast start generating units, that is, they have the capability of starting and reaching minimum output within 30 minutes. As part of a dispatch offer or dispatch bid for a fast start generating unit, a generator may supply a dispatch inflexibility profile[11].

A dispatch inflexibility profile must contain the following parameters:

- T1 time - time in minutes from when AEMO issues a dispatch instruction to start, and when the generating unit will synchronise.
- T2 time - time in minutes from when the generating unit synchronises until it can reach minimum output.
- Min load - the minimum output the generating unit must be dispatched to.
- T3 time - time in minutes the generating unit must remain at or above minimum load.
- T4 time - time in minutes the generating unit requires to reduce from its minimum load to zero output.

AEMO is required to dispatch generating units in accordance with the dispatch inflexibility profile.

On both 30 November and 1 December 2016, Mortlake unit 12 was bid with the following inflexibility profile:

- T1 time = 7 minutes.
- T2 time = 7 minutes.
- Min load = 90 MW.
- T3 time = 38 minutes.
- T4 time = 7 minutes.

Based on this profile, once AEMO's dispatch engine has issued a dispatch instruction to start the generating unit, it cannot issue another instruction to reduce the output below 90 MW for at least 52 minutes (T1 + T2 + T3 = 52 minutes) unless the generating unit is re-bid as unavailable by the Generator.

On 30 November at 1033 hrs, Origin Energy[12] submitted a rebid for Mortlake unit 12 at a price sufficiently low to ensure the unit received a dispatch target in the next dispatch interval. On 1 December, a similar rebid was submitted at 0941 hrs.

Based on the energy re-bid, AEMO issued a dispatch target to Mortlake unit 12 on both occasions. However, due to the inflexibility profile, the dispatch engine could not initially reduce the output below 90 MW despite the constraint violations. The inflexibility profile has a constraint violation penalty (CVP)[13] of 1130 compared to 360 for power system security constraints and 8 for fast lower FCAS constraints. This means that power system security and FCAS constraints will violate before an inflexibility profile is violated.

[11] NER 3.8.19(d) & 3.8.19(e).Additional information is available on the AEMO website at: https://www.aemo.com.au/-/media/Files/PDF/Fast_Start_Unit_Inflexibility_Profile_Model_October_2014.ashx

[12] Origin Energy is the operator of Mortlake power station

[13] Information on CVPs is available on the AEMO website at http://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Congestion-Information/2016/Schedule-of-Constraint-Violation-Penalty-Factors-v20.pdf

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 to the extent practicable and take all reasonable actions to return the power system to a secure state following a contingency event in accordance with the NER.[14]

This section assesses how AEMO managed power system security over the course of this incident.

5.1 30 November

As noted in Section 4.2, Origin Energy submitted a re-bid which resulted in Mortlake unit 12 receiving a dispatch target in DI 1040 hrs. From DI 1050 hrs, constraint equation F_S++HYSE_L6_1 started to violate and AEMO considered what options were available to restore the power system to a secure operating state:

1. Direct plant in SA to provide additional L6 FCAS –
    - No further L6 FCAS was available as all on-line generating units were being dispatched at their registered L6 FCAS capability.
2. Recall outage of the APD-HYTS line and the HYTS busbar –
    - The recall time for the APD-HYTS line was two hours and for the HYTS No.2 500kV busbar the recall was eight hours.
3. Direct Mortlake to shut-down –
    - This was considered ineffective, as after discussion with Origin Energy, the Mortlake generating unit would still need to continue to operate in accordance with its inflexibility profile due to the technical limitations of the generating unit. After the inflexibility profile had been completed, the generating unit would be dispatched off under normal network constraint action. This was expected to occur from DI ending 1130 hrs.

Origin Energy submitted a rebid for Mortlake generating unit 12 at 1106 hrs that resulted in the unit not being dispatched after 1130 hrs. The generating unit had shut-down by 1135 hrs.

The power system was returned to a secure operating state at 1135 hrs on 30 November 2016. The power system was not in a secure operating state for 50 minutes.

5.2 1 December

Although L6 and L60 FCAS requirements were not being met, AEMO determined that the more urgent issue was the high flow from SA to Vic. on the Heywood interconnector. For the network configuration at the time, the maximum allowable flow of the Heywood interconnector was 250 MW from SA to Vic. As shown in Figure 3, the actual flow was up to ~500 MW.

AEMO considered the quickest way to resolve the issue was by shutting down the Mortlake generating unit. However as noted in Section 5.1, once on line Mortlake generating units must comply with their inflexibility profile similar to events on 30 November. Further discussions with Origin Energy determined the process could be sped up by having the unit come to zero MW as quickly as possible after the expiry of the minimum on time (T3 time) and then remain synchronised but at zero MW output until the inflexibility profile was complete. When Mortlake reached zero MW, AEMO would then model the generator circuit breaker as open so the voltage unbalance constraints would see the unit as off-line. This action was confirmed appropriate by AEMO's congestion modelling team.

At 1030 hrs, AEMO issued a direction to Origin Energy to reduce generation at Mortlake power station to zero MW as soon as possible.

For DI 1035 hrs, the Mortlake generating unit received a dispatch target down to 25 MW as the time required at minimum load (T3 time) had expired. The unit reached zero MW by 1034 hrs and AEMO

[14] Refer to AEMO's functions in section 49 of the National Electricity Law and the power system security principles in clause 4.2.6 of the NER

modelled the generator circuit breaker as open at the same time, with all constraint violations ceasing by DI 1045 hrs.

The direction was cancelled at 1545 hrs after the MLTS-TRTS-HYTS-APD line had been returned to service.

The power system was returned to a secure operating state at 1040 hrs on 1 December 2016. The power system was not in a secure operating state for 45 minutes.

5.3 AEMO response

As a result of the incident on 30 November, AEMO identified the potential for interaction between Mortlake generation and constraint equations associated with transmission outages between Mortlake, Tarrone and Heywood,.

Although the power system conditions changed overnight due to the fault on the Moorabool-Tarrone 500kV line, AEMO was aware that any generation at Mortlake during this outage would likely result in a similar outcome to that which occurred on 30 November. However AEMO did not constrain Mortlake generation to prevent this before 1 December.

5.4 Subsequent actions

Since these incidents and given the similar incidents in 2013 and 2011[15]., it has become apparent that the National Electricity Network Dispatch Engine (NEMDE) may produce unfeasible market results with the voltage unbalance constraint equations invoked. As a result, the voltage unbalance constraints have been removed and replaced by constraining Mortlake generation to zero MW during future outages involving the transmission lines between Moorabool and Heywood.[16]

6. 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[17] over the course of this incident.

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

- Issue a Market Notice advising that AEMO has issued a direction or clause 4.8.9 instruction.[18]
- AEMO issued Market Notice 56067 at 1545 hrs on 1 December 2016 to advise that a direction had been issued to a participant in the Vic. region.

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

7. 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:

- Both incidents were caused by constraint action in response to operation of generating units at Mortlake power station.

[15] Reports available on the AEMO website at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Market-notices-and-events/Power-System-Operating-Incident-Reports?tagId=%7B43D1A742-C03A-40DC-AC4F-7C94F71D0DCD%7D

[16] Refer to limit advice published on the AEMO website at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/Congestion-information/Limits-advice.

[17] AEMO generally informs the market about operating incidents as they progress by issuing Market Notices.

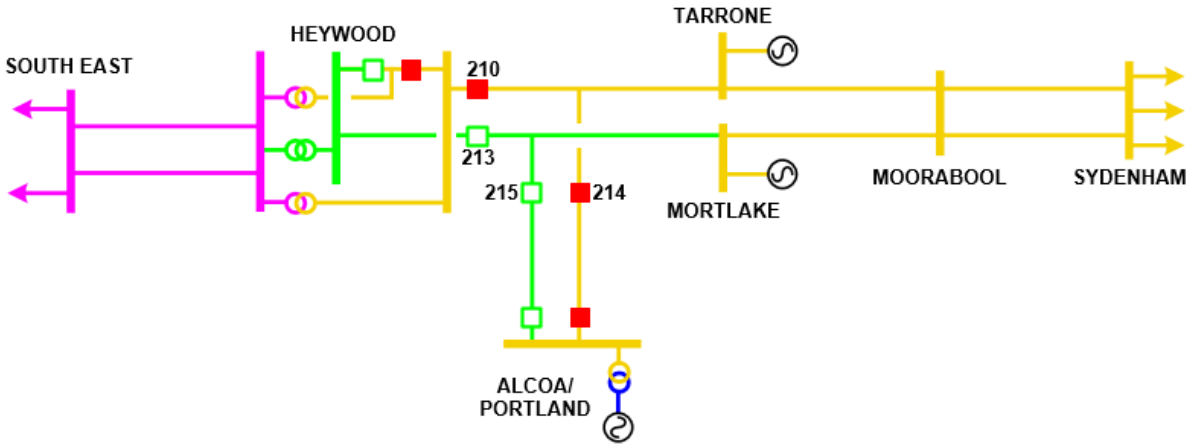
[18] Section 5 of the Intervention, Direction and Clause 4.8.9 Instructions procedure (SO_OP 3707).

- The power system was not in a secure operating state for greater than 30 minutes on both occasions. The actions taken by AEMO to restore the power system to a secure operating state were appropriate and timely.
- After the incident on 30 November, AEMO identified the potential for interaction between Mortlake generation and constraint equations associated with transmission outages between Mortlake, Tarrone and Heywood, but AEMO had not yet implemented a constraint before this re-occurred on 1 December.
- In response to these incidents and previous similar incidents, AEMO has removed the voltage unbalance constraint equations for outages in between Moorabool and Heywood. The voltage unbalance constraints have been replaced by a zero MW constraint on Mortlake generation.

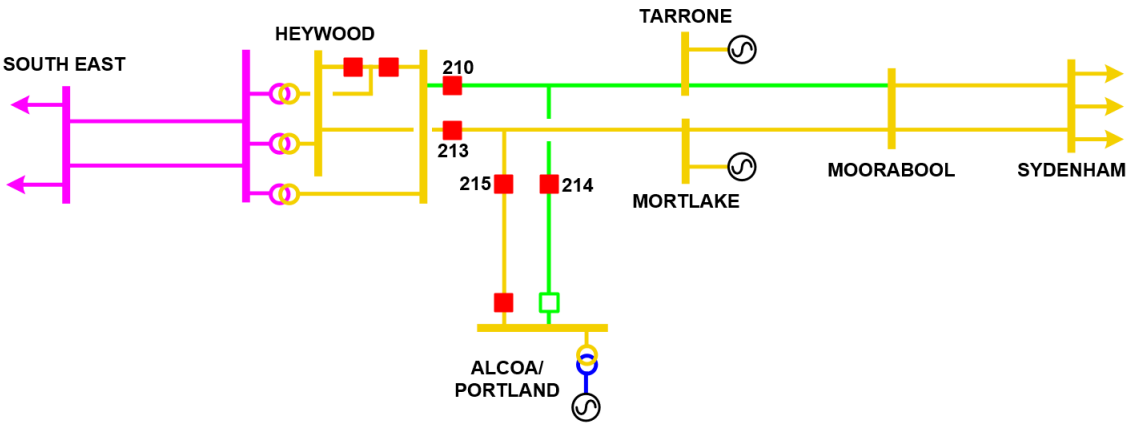
APPENDIX A. – POWER SYSTEM DIAGRAM

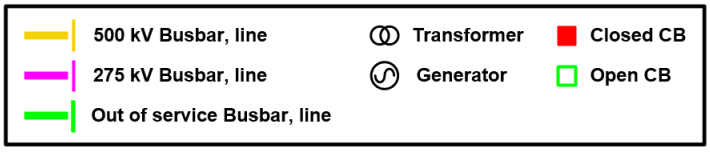
The power system immediately prior to the incidents

30 November 2016



1 December 2016





APPENDIX B. – CONSTRAINT VIOLATIONS

SETTLEMENTDATE	CONSTRAINTID	VIOLATIONDEGREE
30/11/2016 10:50	F_S++HYSE_L6_1	-51.68741
30/11/2016 10:50	F_S+RREG_0035	-33.65465
30/11/2016 10:55	F_S++HYSE_L6_1	-49.23578
30/11/2016 11:00	F_S++HYSE_L6_1	-48.23262
30/11/2016 11:05	F_S++HYSE_L6_1	-53.1076
30/11/2016 11:10	F_S++HYSE_L6_1	-47.62449
30/11/2016 11:15	F_S++HYSE_L6_1	-45.25028
30/11/2016 11:20	F_S++HYSE_L6_1	-41.92283
30/11/2016 11:25	F_S++HYSE_L6_1	-44.17748
30/11/2016 11:30	F_S++HYSE_L6_1	-27.23267
30/11/2016 11:35	F_S++HYSE_L6_1	-10.46221
01/12/2016 10:00	F_S++HYSE_L6_1	-123.33868
01/12/2016 10:00	F_S++HYSE_L6_2	-288.1501
01/12/2016 10:00	F_S+RREG_0035	-33
01/12/2016 10:00	V_HYML1_3	190.05
01/12/2016 10:00	V_HYML1_4	147.30883
01/12/2016 10:05	F_S++HYSE_L5	-63.57695
01/12/2016 10:05	F_S++HYSE_L60	-215.85325
01/12/2016 10:05	F_S++HYSE_L6_1	-378.13899
01/12/2016 10:05	F_S++HYSE_L6_2	-1406.03073
01/12/2016 10:05	F_S+RREG_0035	-33
01/12/2016 10:05	SV_250_DYN	158.19809
01/12/2016 10:05	S_V_ROCOF	81.11808
01/12/2016 10:05	V_HYML1_3	183.74999
01/12/2016 10:05	V_HYML1_4	18.32131
01/12/2016 10:10	F_S++HYSE_L5	-183.55863
01/12/2016 10:10	F_S++HYSE_L60	-284.69781
01/12/2016 10:10	F_S++HYSE_L6_1	-444.20216
01/12/2016 10:10	F_S++HYSE_L6_2	-1661.63766
01/12/2016 10:10	F_S+RREG_0035	-35
01/12/2016 10:10	SV_250_DYN	204.11913
01/12/2016 10:10	S_V_ROCOF	123.67913
01/12/2016 10:10	V_HYML1_3	306.15
01/12/2016 10:10	V_HYML1_4	113.67383
01/12/2016 10:15	F_S++HYSE_L5	-292.53256
01/12/2016 10:15	F_S++HYSE_L60	-385.46962
01/12/2016 10:15	F_S++HYSE_L6_1	-525.30534
01/12/2016 10:15	F_S++HYSE_L6_2	-1889.4953
01/12/2016 10:15	F_S+LREG_0035	-35
01/12/2016 10:15	F_S+RREG_0035	-35
01/12/2016 10:15	SV_250_DYN	246.7672

01/12/2016 10:15	S_V_ROCOF	143.16723
01/12/2016 10:15	V_HYML1_3	303.75
01/12/2016 10:15	V_HYML1_4	86.15412
01/12/2016 10:20	F_S++HYSE_L5	-221.27424
01/12/2016 10:20	F_S++HYSE_L60	-323.60844
01/12/2016 10:20	F_S++HYSE_L6_1	-501.32308
01/12/2016 10:20	F_S++HYSE_L6_2	-1810.59391
01/12/2016 10:20	SV_250_DYN	275
01/12/2016 10:20	S_V_ROCOF	94.39999
01/12/2016 10:20	V_HYML1_3	230.85001
01/12/2016 10:20	V_HYML1_4	11.35001
01/12/2016 10:25	F_S++HYSE_L5	-220.60463
01/12/2016 10:25	F_S++HYSE_L60	-300.9596
01/12/2016 10:25	F_S++HYSE_L6_1	-473.39875
01/12/2016 10:25	F_S++HYSE_L6_2	-1678.26309
01/12/2016 10:25	SV_250_DYN	251.89966
01/12/2016 10:25	S_V_ROCOF	64.17966
01/12/2016 10:25	V_HYML1_3	209.25
01/12/2016 10:25	V_HYML1_4	3.3561
01/12/2016 10:30	F_S++HYSE_L60	-49.38366
01/12/2016 10:30	F_S++HYSE_L6_1	-189.46339
01/12/2016 10:30	F_S++HYSE_L6_2	-447.99053
01/12/2016 10:30	SV_250_DYN	25
01/12/2016 10:30	V_HYML1_3	189.15
01/12/2016 10:30	V_HYML1_4	116.9
01/12/2016 10:35	F_S++HYSE_L60	-34.81731
01/12/2016 10:35	F_S++HYSE_L6_1	-171.81168
01/12/2016 10:35	F_S++HYSE_L6_2	-410.54713
01/12/2016 10:35	SV_250_DYN	25
01/12/2016 10:35	V_HYML1_3	117.55
01/12/2016 10:35	V_HYML1_4	45.3
01/12/2016 10:40	F_S++HYSE_L60	-34.87777
01/12/2016 10:40	F_S++HYSE_L6_1	-171.40248
01/12/2016 10:40	F_S++HYSE_L6_2	-401.45789
01/12/2016 10:40	SV_250_DYN	25
01/12/2016 10:40	V_HYML1_3	103.05
01/12/2016 10:40	V_HYML1_4	30.8

APPENDIX C. CONSTRAINT EQUATION V_HYML1_4

Constraint type: LHS<=RHS
Weight: 360

Constraint description: Out = Heywood to Tarrone, or Tarrone to Moorabool No. 1 500 kV line, limit voltage unbalance at the APD 500 kV bus, one Mortlake unit in service
Reason: Prevent excessive voltage unbalance at APD 500 kV bus

LHS=
Mortlake GT unit 1 (ENERGY)
+ Mortlake GT unit 2 (ENERGY)
+ 0.589 x MW flow west on the Vic-SA AC interconnector

RHS=
-363.75 {Constant}
- 0.75 x [MW load of APD]
+ *Generic Equation:* SWAMP_0_2_MOPS_DS

SWAMP_0_2_MOPS_DS

if
Absolute**(** Mortlake No.1 generator ON status
+ Mortlake No.2 generator ON status
- 1 {Offset}**) <= 0**
then
0
else
10000

For dispatch interval 1000 hrs on 1 December 2016

- MW load of APD = -251.6
- Mortlake GT 1 generation = 0
- Mortlake GT 1 status = off
- Mortlake GT 2 generation = 90
- Mortlake GT 2 status = On

Solving for flow on the Vic-SA interconnector

MW flow = (-363.75 – (0.75 * -251.6) – (90 + 0)) / 0.589
MW flow = - 450 MW.