

MULTIPLE CONTINGENCY EVENT FOLLOWING AN EARTHQUAKE IN VICTORIA ON 19 JUNE 2012

PREPARED BY: Systems Capability

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FINAL

Executive Summary

On 19 June 2012, an earthquake in Victoria resulted in the unexpected tripping of multiple generators in Victoria and South Australia amounting to the loss of approximately 1955 MW of generation and 400 MW of load across the NEM. Of the 400 MW of load, 200 MW consisted of major industrial loads in Tasmania lost due to under-frequency load shedding (UFLS).

The frequency in the Mainland fell to 49.2 Hz and in Tasmania to 47.9 Hz. The frequency operating standard was met in Mainland and Tasmania regions with the exception of the time to return to the Stabilisation band in the Mainland.

In addition to the generation tripping, the earthquake also caused the tripping of South Morang H1 and H2 330/220 kV transformers resulting in the offloading of the No.1 South Morang – Thomastown 220 kV transmission line. This non-credible contingency left the power system in a satisfactory but insecure state

Following the determination of appropriate control actions and the implementation of those actions by AEMO, the power system was returned to a secure operating state after 59 minutes. Under the circumstances, AEMO considers all reasonable steps were taken to return the power system to a secure operating state within 30 minutes.

Approximately 1700 MW (87%) of generation that had tripped was restored in approximately eight hours while the remaining generating units required further time for investigation by the asset owners. The major industrial loads that tripped through UFLS were given permission to return to service within approximately 25 minutes.

Based on AEMO's assessment of the event and information provided, AEMO correctly classified this event as a non-credible contingency event. While the electricity market information issued was appropriate, the publication time did not meet AEMO guidelines.

AEMO has determined that the power system responded adequately to the multiple contingency event and that actions undertaken during the event were appropriate.

The following recommendations have been made following the review:

1. AGL has advised that it will replace the governor control system on Torrens Island A units. This work is expected to be completed by 30 June 2013
2. AEMO will investigate the FCAS performance of enabled units by 31 December 2012
3. Powerlink will investigate with Queensland Rail on the transformer tripping and advise AEMO of any pertinent actions by 31 December 2012
4. AEMO will review the publication times of market notices set in the Power System Security Guidelines SO_OP3705 by 31 December 2012.

Disclaimer

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Abbreviations and Symbols

Abbreviation	Term
CB	Circuit Breaker
DI	Dispatch Interval
EMMS	Electricity Market Management System
EMS	Energy Management System
FOS	Frequency Operating Standard
FCAS	Frequency Control Ancillary Service
kV	Kilovolt
MW	Megawatt
MWh	Megawatt hour
NEM	National Electricity Market
NEMDE	National Electricity Market Dispatch Engine
NER	National Electricity Rules
NOS	Network Outage Schedule
PTR	Permission to Restore
PS	Power Station
R5	Raise 5 minute FCAS service
R6	Raise 6 second FCAS service

R60	Raise 60 second FCAS service
RTU	Remote Terminal Unit
RMS	Root Mean Square
TS	Terminal Station
μm	Micrometer
U/F	Under Frequency
UFLS	Under Frequency Load Shedding

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Executive Summary	2
Disclaimer	3
Abbreviations and Symbols	3
1 Introduction	7
2 Summary of Events	7
2.1 Initiating Event	8
2.2 Generation and Load Trips	8
2.3 Basslink Performance	9
2.4 Power System Security	9
3 AEMO Control Room Actions	11
3.1 Transmission Network Restoration	11
3.2 Constraints Invoked	11
3.3 Load Restoration	12
3.4 Market Information	12
4 Analysis of Generation Trips	13
4.1 Loy Yang A	13
4.2 Yallourn	13
4.3 Torrens Island	14
5 Analysis of Transmission Plant	15
5.1 South Morang H1 and H2 Transformers	15
5.2 No.5 Rowville – Yallourn 220 kV Transmission Line	17
6 Power System Performance (excluding frequency)	20
6.1 Power System Voltages	20
6.2 Power System Stability	20
6.3 Power System Thermal Limits	20
6.4 Analysis of Interconnector Flows	21
6.4.1 Victoria – New South Wales Interconnector	21
6.4.2 Victoria – South Australia Interconnector	22
6.4.3 Basslink	23
7 Power System Frequency Assessment	24
7.1 Mainland Frequency	24
7.1.1 Mainland Frequency Analysis	24
7.1.2 Mainland Frequency Control Ancillary Service Response	25
7.2 Tasmania Frequency	26
7.2.1 Tasmania Frequency Analysis	26
7.2.2 Tasmania Frequency Control Ancillary Service Response	27
7.2.3 Tasmania UFLS	27

8	Electricity Market Outcomes.....	27
9	Conclusions.....	27
10	Recommendations	28
11	Appendix A - Sequence of Events.....	29
12	Appendix B – Electricity Market Notices.....	32

1 Introduction

At 2053 hrs on Tuesday 19 June 2012, an earthquake of magnitude 5.4 occurred in the Latrobe Valley region of Victoria resulting in approximately 1955 MW of generation loss from generators in Victoria and South Australia. There was an approximately 400MW load reduction across the NEM in response to the disturbance; 200 MW consisted of major industrial load in Tasmania lost due to under-frequency load-shedding while a further 200 MW was due to frequency relief, loss of auxiliary loads from tripped generating units and natural load reduction in response to the incident. AEMO commenced load restoration at 2113 hrs on 19 June 2012.

This report has been prepared under clause 4.8.15 (c) of the National Electricity Rules (NER) to 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.

This report is largely based upon information provided by market participants and network service providers. Data from AEMO's Energy Management System (EMS) and Electricity Market Management System (EMMS) has also been used in analysing the incident.

All references to time in this report are to National Electricity Market time (Australian Eastern Standard Time).

2 Summary of Events

On 19 June 2012, a magnitude 5.4 earthquake resulted in the disconnection of multiple generating units in the Victoria and South Australia region. The particular generating units affected were:

- Victoria:
 - Loy Yang A1;
 - Loy Yang A3;
 - Loy Yang A4; and
 - Yallourn Unit 4 (manually tripped).
- South Australia:
 - Torrens Island A4 (45 MW).

The system frequency on the Mainland consequently dropped to 49.2 Hz at 20:53:54 hrs.

The decrease in Mainland frequency prompted a response from the Basslink frequency controller to increase transfer from Tasmania to Victoria. This in turn caused the Tasmania frequency to drop to 47.95 Hz which triggered under frequency load shedding in Tasmania. As a result, 200 MW of load in Tasmania was tripped.

In terms of transmission elements, the disturbance caused the South Morang H1 and H2 330/220 kV transformers to trip on Buchholz protection at 20:54:10 hrs. As a consequence of the trip of these transformers, the No.1 South Morang – Thomastown 220 kV transmission line was also offloaded. As a result of these outages the power system remained in a satisfactory but insecure state.

An event unrelated to the earthquake occurred at 2118 hrs when the No.5 Rowville – Yallourn 220 kV transmission line tripped, consequently deloading the Rowville – Richmond 220kV Line.

The system was restored to a secure operating state at 2152 hrs.

2.1 Initiating Event

At 20:53:29 hrs a magnitude 5.4 earthquake occurred 10 km southwest of Moe, Victoria at a depth of 9.9 km underground. Figure 1¹ shows the location of the earthquake.

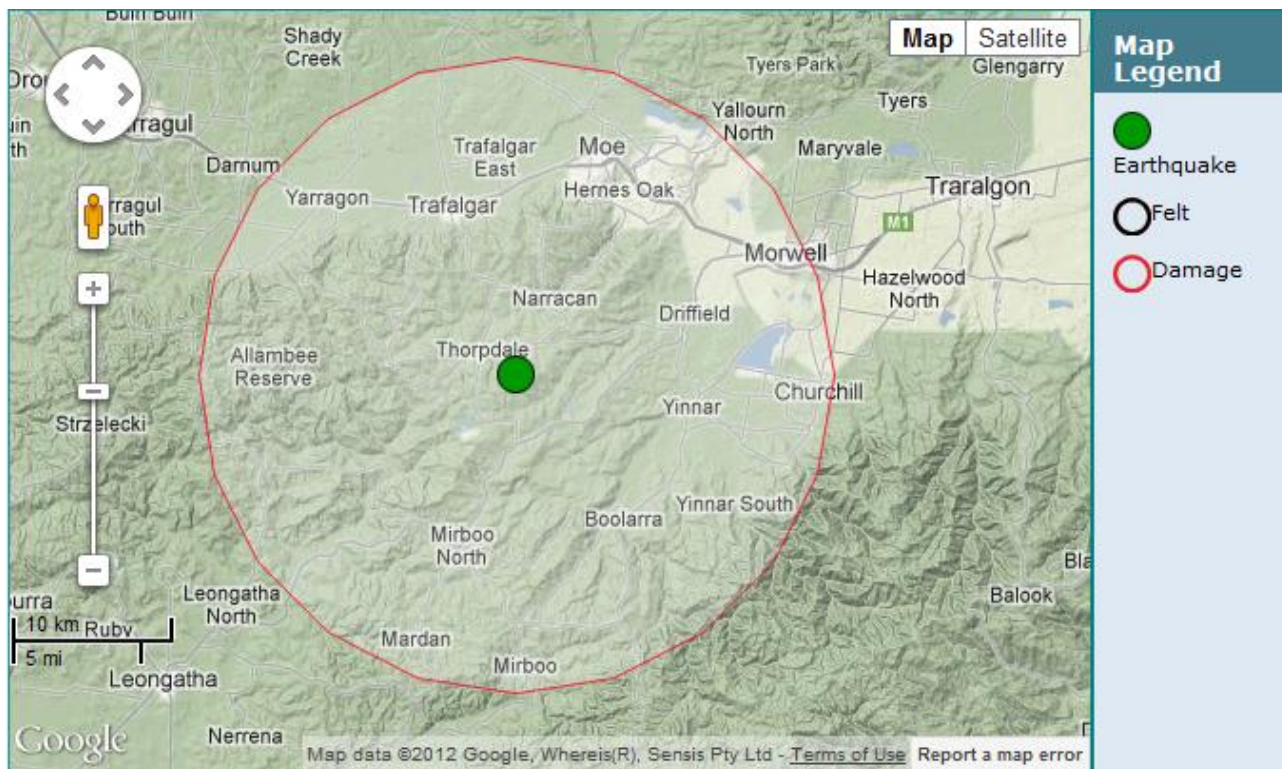


Figure 1 Location of earthquake

2.2 Generation and Load Trips

Table 1 below summarises the generating units and load that tripped during the earthquake:

Generating Unit	MW	Trip Time	Restoration Time	Load	MW	Trip Time	Restoration Time
Loy Yang A1	570	20:54 19/06	10:30 20/06	Major industrial load	200	20:53 19/06	21:13 19/06
Loy Yang A3	570	20:53 19/06	04:50 20/06				
Loy Yang A4	570	20:53 19/06	02:05 20/06				
Yallourn U4	200	20:53 19/06	01:02 21/09 ²				
Torrens Island A4	45	20:54 19/06	15:45 20/06				

Table 1 Generator and Load Trip Summary

While no under-frequency load shedding occurred in other regions an under-frequency relay did operate in the South Australia region but no load was connected to this relay at the time.

¹ <http://www.ga.gov.au/earthquakes/getQuakeShakeDamage.do?quakeId=3226344>

² Not immediately returned to service for further investigation

In Queensland there was an unexpected tripping of filter banks and a transformer at Raglan substation resulting in the disconnection of 2 MW of load at 2054 hrs. The transformer tripping was triggered by Queensland Rail's transformer protection system while the filter banks were set to trip at 49.5 Hz. Powerlink will investigate with Queensland Rail on the tripping and advise AEMO of any required actions.

Recommendations:

- Powerlink will investigate with Queensland Rail on the transformer and filter banks tripping and advise AEMO of any pertinent actions

Figure 2 below shows the NEM demand before and after the earthquake occurred.

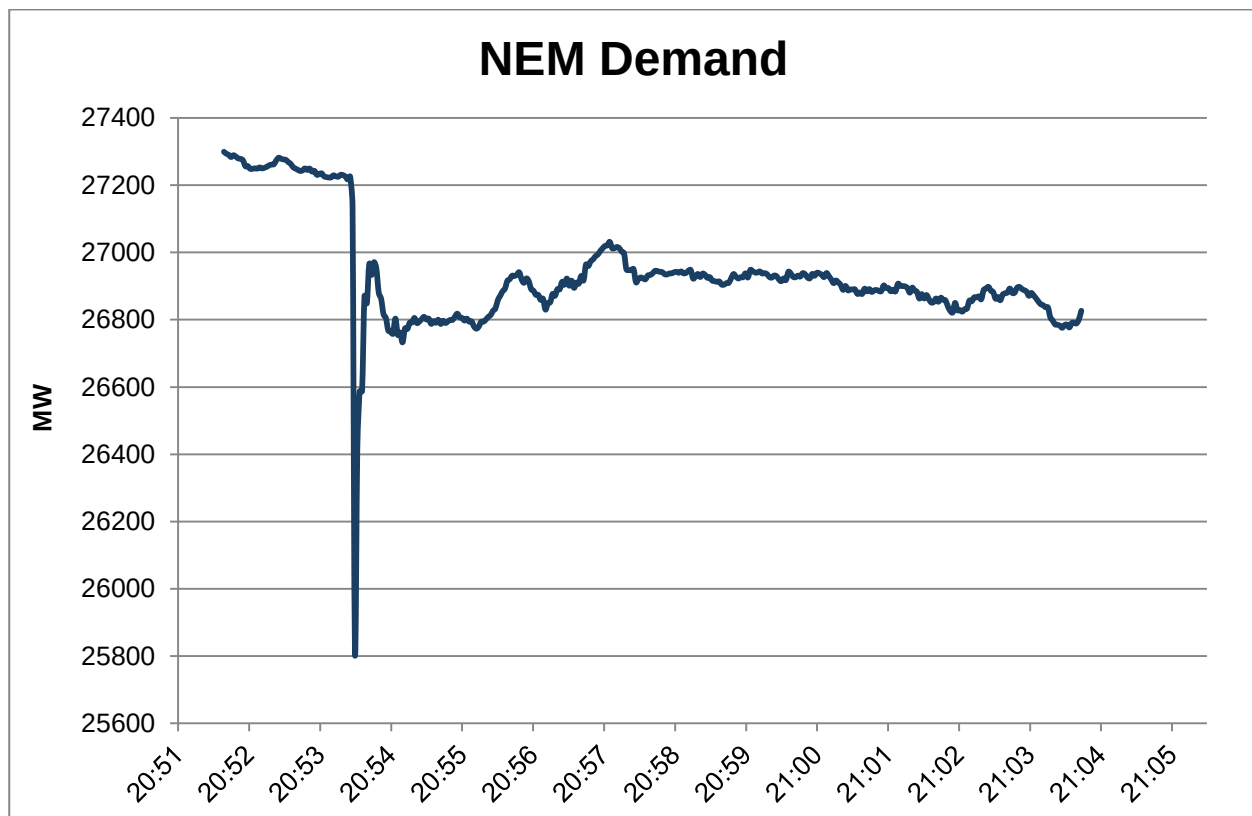


Figure 2 NEM demand profile during the incident

2.3 Basslink Performance

Basslink reacted to the frequency change as designed by increasing export flow from Tasmania to Victoria in an attempt to limit the frequency excursion.

2.4 Power System Security

Voltages in the power system stayed within the limits set by the respective TNSPs.

The loss of the South Morang H1 and H2 transformers at 2054 hrs resulted in the power system being in a satisfactory but insecure state for the further loss of the South Morang F2 transformer.

The trip of the South Morang F2 transformer would have resulted in an unstable voltage situation in Victoria leading to the potential of voltage collapse. The voltage stability issue was resolved at 2123 hrs through:

- a combination of the reduction of New South Wales – Victoria power flow;
- increase in Victoria generation output;

- optimisation of reactive power; and
- the natural reduction of Victoria demand.

The discretionary constraint set, I-NV_0000, applied at 2130 hrs further alleviated the voltage stability issue by limiting the flow through the New South Wales – Victoria interconnector.

Once the voltage stability issue was resolved, the potential overloading of the Dederang 330/220 kV transformers remained for the post contingent loss of the South Morang F2 transformer.

AEMO invoked the CA_SPS_3EF2F2EF_01 constraint set at 2150 hrs to return the power system to a secure operating state. This constraint prevents overload of the Dederang H1 transformer for the further loss of the South Morang F2 500/330 kV transformer. The power flow through the Dederang H1 transformer returned to secure levels at 2152 hrs.

The total time the power system was in an insecure operating state was 58 minutes.

The unplanned outage of the No.5 Rowville – Yallourn 220 kV line at 2118 hrs did not exacerbate the potential overloading of the Dederang transformers. Constraint set V-ROYP5_R was invoked at 2125 hrs to manage this outage.

3 AEMO Control Room Actions

The 2053 hrs earthquake event resulted in multiple contingency events in multiple regions across the NEM. AEMO's initial actions were to ensure that the power system was in a satisfactory state and to identify any immediate actions required. In the first 10 minutes following the event, the AEMO energy management system produced 1700 event logs and 366 alarms. The power system remained in a satisfactory operating state.

AEMO's real time contingency analysis application alerts AEMO to the most critical credible contingency events on the power system and the magnitude of potential overloads. There were a large number of critical contingencies which required analysis in order to determine the appropriate course of action. Obtaining a reliable powerflow solution and analysis of these contingencies is necessary in order to determine the appropriate course of action to return the power system to a secure operating state.

It has since been determined that the tripping event of the No. 5 Rowville – Yallourn 220 kV transmission line was unrelated to the earthquake, however assessing this event also added to AEMO's response time.

3.1 Transmission Network Restoration

AEMO liaised with SP AusNet to restore the transmission network in accordance with Table 2 below.

Plant	Outage Period	Duration
South Morang H1 transformer	20:54 19/06/2012 – 00:05 20/06/2012	3 hrs 11 mins
South Morang H2 transformer	20:54 19/06/2012 – 00:34 20/06/2012	3 hrs 40 mins
No.1 South Morang – Thomastown transmission line	20:54 19/06/2012 – 21:34 19/06/2012	40 mins
No.4 Rowville – Richmond transmission line	21:18 19/06/2012 – 21:51 19/06/2012	33 mins
No.5 Rowville – Yallourn transmission line	21:18 19/06/2012 – 00:51 20/06/2012	3 hrs 33 mins

Table 2 Network Outages

The South Morang H1 and H2 transformers took more than three hours to restore due to the time required by SP AusNet to inspect the equipment thoroughly to ensure there was no damage and to ensure protection relays were operating correctly. Based on advice from SP AusNet the No. 5 Rowville – Yallourn 220 kV transmission line required a line patrol to establish that it was clear to be restored.

3.2 Constraints Invoked

The AEMO control room invokes constraint equations to represent the physical restriction or configuration of the power system. By correctly modelling the power system, this allows the NEM dispatch engine to issue dispatch targets optimally while keeping the system in a secure state. AEMO has a library of constraint sets for pre-determined likely power system conditions and configurations. However, constraint sets did not exist to represent the situation following the earthquake.

Based on manual powerflow analysis a discretionary constraint set, I-NV_0000, was applied at 2130 hrs to limit the power flow through the interconnector from New South Wales to Victoria to manage the voltage stability issues.

The Constraint Automation tool³ could not be used at this time because a contingency analysis solution could not be found for the voltage instability caused by the contingency of the South Morang F2 transformer.

Once the voltage stability issue was resolved and the contingency analysis tool could solve, the Constraint Automation tool was used to generate the constraint set, CA_SPS_3EF2F2EF_01, applied at 2150 hrs to manage the potential for overloading the Dederang 330/220 kV transformers for the contingent loss of the South Morang F2 transformer.

The discretionary constraint set, I-NV_0000, was revoked at 2200 hrs.

The constraint sets were invoked as detailed in Table 3.

Constraint Set	Constraint Period	Description
NC-V_YWPS4 ⁴	21:20 19/06/2012 - 22:15 19/06/2012	Non-conformance Yallourn Unit 4
V-ROYP5_R	21:25 19/06/2012 - 01:05 20/06/2012	Out = Rowville to Yallourn No. 5 220 kV line, radial mode
V-SMTT1	21:30 19/06/2012 - 21:40 19/06/2012	Out = South Morang to Thomastown No. 1 220 kV line
I-NV_0000	21:30 19/06/2012 - 22:00 19/06/2012	Discretionary NSW to Vic transfer upper limit of 0 MW
V-SMTS_HTX_R ⁵	21:30 19/06/2012 - 00:45 20/06/2012	Out = South Morang H1 or H2 330/220 kV transformer
CA_SPS_3EF2F2EF_01	21:50 19/06/2012 - 00:25 20/06/2012	Constraint Automation, Avoid overload of Dederang H1 transformer for loss of South Morang F2 transformer.

Table 3 Invoked Outage Constraint Sets

3.3 Load Restoration

Load that was interrupted by the UFLS was given permission to be restored in accordance with the times of Table 4 below.

Load	Times	MW	Permission To Restore	Outage Time
Major industrial loads in Tasmania	20:54 – 21:17	200	21:13 hrs	23 mins

Table 4 Major Load Outage Duration

3.4 Market Information

Under the terms of NER clause 4.8.3 AEMO must promptly advise the market of any circumstance that may affect supply to participants. Following a significant event, the AEMO [Power System](#)

³ Constraint Automation Tool - <http://aemo.com.au/Electricity/Market-Operations/Congestion-Information-Resource/Constraint-Automation-Closing-the-Loop-Discussion-Paper>

⁴ This is an automatically generated and invoked constraint

⁵ A constraint set for an outage of both South Morang H1 and H2 transformers did not exist because it is not normally a credible contingency

[Security Guidelines SO OP3715](#) requires AEMO to issue an initial notification within 5 minutes of confirming and verifying the event. AEMO met this requirement via the AEMO Emergency Messaging system at 2108 hrs, advising the market of the event. Refer to Appendix B for details.

AEMO procedures also require that this initial message must be followed by a more detailed market notice within 15 minutes. While Market Notice No. 39034 was published at 2118 hrs, it contained no further details. Market Notices 39036 and 39037 were published at 2220hrs and 0054hrs respectively and provided details regarding the transmission network, generation lost and restoration of supply. Market Notice No. 39039 was published at 0549 hrs and provided full details of the non-credible event.

Refer to Appendix B – Market Notices for details of the market notices issued by AEMO.

AEMO Real Time Operations have advised that while there is a requirement to provide the market with information, resources at the time were being used to analyse the state of the power system, manage the load restoration process and restore power system security.

Recommendation:

- AEMO will review the feasibility of, and systems for, issuing a detailed market notice for a major event within the times specified in the Power System Security Guidelines

4 Analysis of Generation Trips

The earthquake resulted in the tripping of 5 major generating units for a total of 1955 MW. These units comprised of 3 units at Loy Yang A, Yallourn Unit 4 and Torrens Island A4.

4.1 Loy Yang A

The vibrations from the earthquake activated the turbine vibration protection on Units 1, 3 and 4. These units are monitored by the original Siemens vibration sensors designed to measure vibration amplitudes (um) on the bearing pedestals. The trip level on these sensors is 45 um.

The vibration equipment on Unit 2 had been replaced in 2011 as part of a governor upgrade and measures the vibration velocity (mm/s) of the bearing pedestals. The trip level is set to 10.5 mm/s RMS.

A maximum vibration amplitude of 450 um was measured on Unit 4 during the earthquake. The bearing pedestal displacement above the trip level setting led to the tripping of Unit 3 at 20:53:40 hrs. Unit 4 and Unit 1 tripped at 20:53:48 and 20:54:08 hrs respectively. The sensors on Unit 2 measured a vibration velocity level of 7.8 mm/s RMS which is below the trip setting.

All protection devices and controls operated as designed.

While the vibration protection initiates a turbine trip the generator circuit breaker is not opened until there is no driving force from the turbine, approximately 600ms later.

AGL have advised that the turbine supervisory equipment on Units 1, 3 and 4 are due for replacement to be consistent with Unit 2. Unit 1 has been completed and units 2 and 3 are due for completion in September 2013 and September 2014 respectively.

4.2 Yallourn

Yallourn Unit 4 came online at 1705 hrs on 19/06/2012 and was still in the process of completing its run-up when the earthquake occurred. Yallourn plant operators monitoring the run-up were not aware of the earthquake at the time and assumed that the vibrations were due to a plant malfunction.

The Yallourn units are set to alarm at vibration amplitude levels of 125 um and trip at 150 um. Yallourn operators noted that Unit 4 experienced larger vibration variations (137 um) compared to

Unit 2 (120 MW). As the vibrations on Unit 4 increased, the operator decided to manually trip the unit to avoid any potential plant damage to Unit 4 even though the vibrations had not reach tripping point. Unit 4 was generating approximately 200 MW when it was manually shut down without any issues at 20:53:48 hrs.

AEMO believes the operator acted appropriately under the circumstances.

4.3 Torrens Island

Prior to the earthquake, only Torrens Island Unit A4 was generating along with three Torrens Island B units. Following the network disturbances, Torrens Island Power Station Unit A4 tripped from 43 MW at 20:54:16 hrs. The unit tripped following the unit governor response to the significant frequency disturbance. The Torrens Island B units did not trip because the actuation system for the steam valves respond differently compared to Torrens Island A units due to different oil relay configuration and control system logic.

AGL advised AEMO on 20 June 2012 in accordance with NER Clause 4.15 that Torrens Island Unit A4 was not compliant with the Registered Performance Standard because it did not operate continuously during a power system frequency disturbance.

AGL conducted a review on the governor response and performance of all Torrens Island A units against the Performance Standard on 14 September 2012. As a result of the review, the control system on the governor will be redesigned and changes implemented on Torrens Island Unit A4 by 31 December 2012 before being implemented on the remaining Torrens Island A units by 30 June 2013.

Recommendation:

- AGL has advised that it will replace the governor control system on Torrens Island A units. This work is expected to be completed by 30 June 2013

5 Analysis of Transmission Plant

5.1 South Morang H1 and H2 Transformers

The status of the power system prior to the incident is shown in Figure 3. For clarity, only equipment relevant to this incident has been included in the diagram.

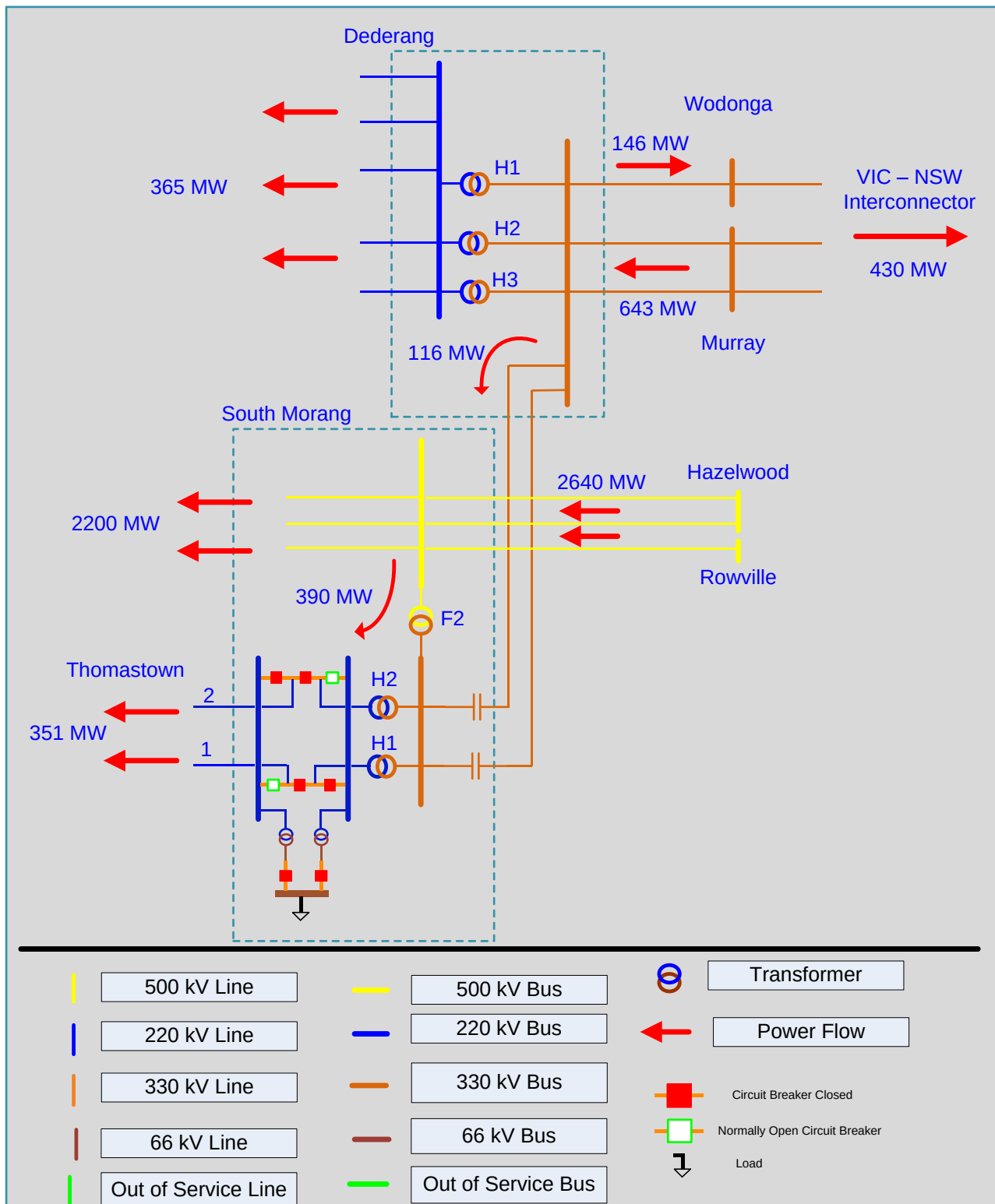


Figure 3 Pre event system conditions

The South Morang H1 and H2 transformers tripped at 2054 hrs on Buchholz relay operation. Due to the switching arrangement at the South Morang station, the No.1 South Morang – Thomastown 220 kV transmission line also de-loaded with the H1 transformer. Figure 4 shows the state of the network following the event.

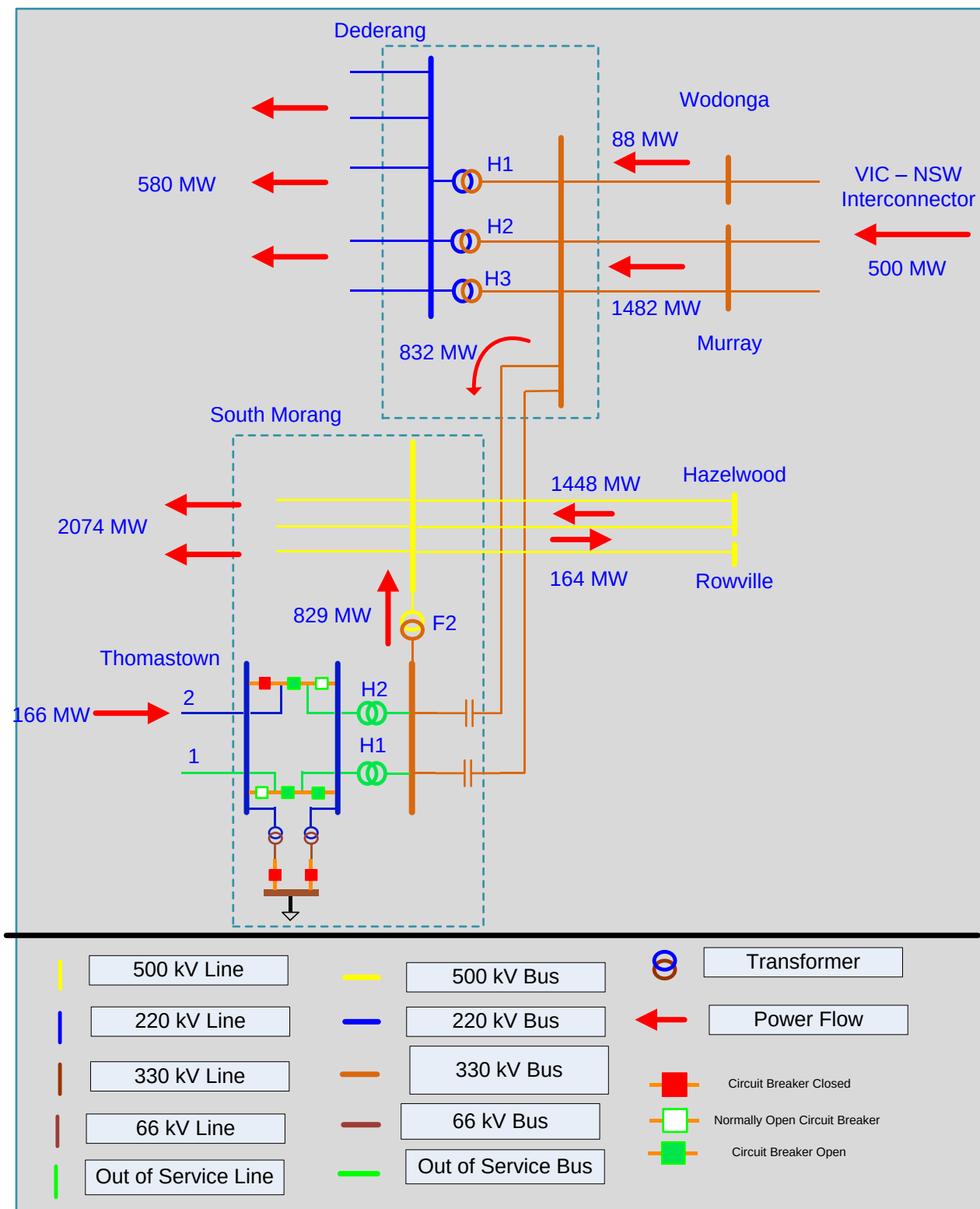


Figure 4 Post event system conditions

AEMO invoked the V-SMTS_HTX_R constraint set at 2130 hrs. This constraint set contained constraint equations designed for the outage of either South Morang H1 or H2 transformers. A constraint set for the outage of both South Morang H1 and H2 transformers did not exist because it is not normally considered a credible contingency event. Even though the V_SMTS_HTX_R

constraint set did not exactly match the current technical envelop it was considered a reasonable approach to restoring the power system to a secure state⁶. The V-SMTT1 constraint set was also invoked at 2130 hrs to address the off-loading of the No.1 South Morang – Thomastown 220 kV transmission line.

After further investigation, SP AusNet advised that the earth tremors triggered an oil surge within the transformers causing the Buchholz relay operation. SP AusNet has advised that the type of Buchholz relay used at South Morang is exclusive to the South Morang station. SP AusNet found no evidence of damage to the transformers or associated plant. In addition, inspection and checks carried out on the Buchholz relays found the Buchholz relays to be operating correctly.

The No.1 South Morang – Thomastown 220 kV transmission line was returned to service at 2134 hrs on 19/06/2012. Both South Morang transformers returned to service at 0034 hrs on 20/06/2012.

SP AusNet has advised that due to the low probability of earthquakes in the region and based on its cost/benefit analysis, there are no immediate plans to replace the Buchholz relays. However, the South Morang H1 and H2 transformers are expected to be replaced within the next 10 years subject to regulatory approval.

5.2 No.5 Rowville – Yallourn 220 kV Transmission Line

While on its own the trip of the No.5 Rowville – Yallourn 220 kV line is not a reviewable event and was not caused by the earthquake, this event has been included as it occurred within 30 minutes of the earthquake.

The status of the power system at Rowville station prior to the incident is show in Figure 5. For clarity, only equipment relevant to this incident has been included in the diagram.

⁶ As the contingency analysis tool was not solving at this stage the constraint automation tool could not be used. Refer also to section 3.2.

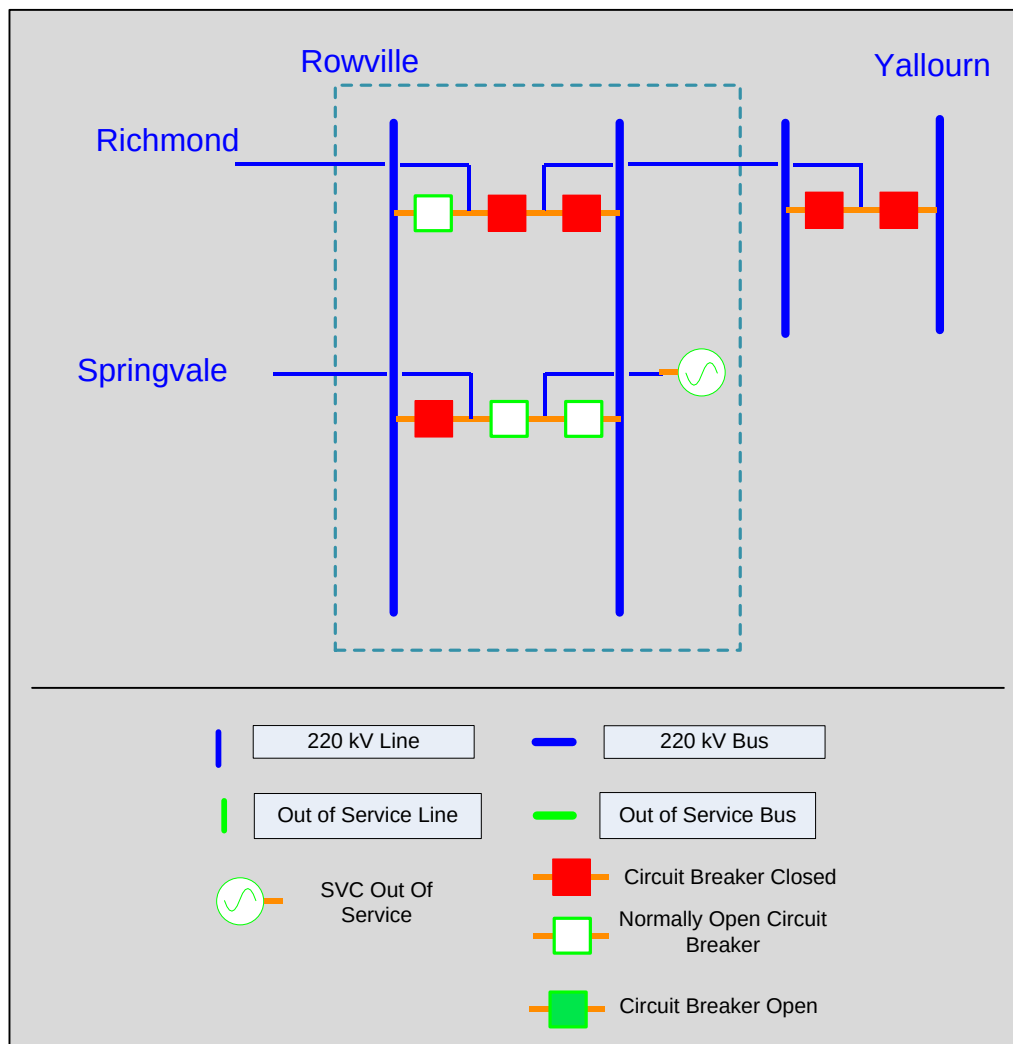


Figure 5 Pre-event system conditions

At 2118 hrs, approximately 25 minutes after the earthquake, the No.5 Rowville – Yallourn 220 kV transmission line tripped on X and Y protection at both ends of the transmission line. The line auto reclosed at the Rowville end as a result of the Single End Auto Reclose (SEAR) function at Rowville. Due to the switching configuration at Rowville terminal station, the No.4 Rowville - Richmond 220 kV transmission line was also unloaded. The state of the power system following the incident is shown in Figure 6.

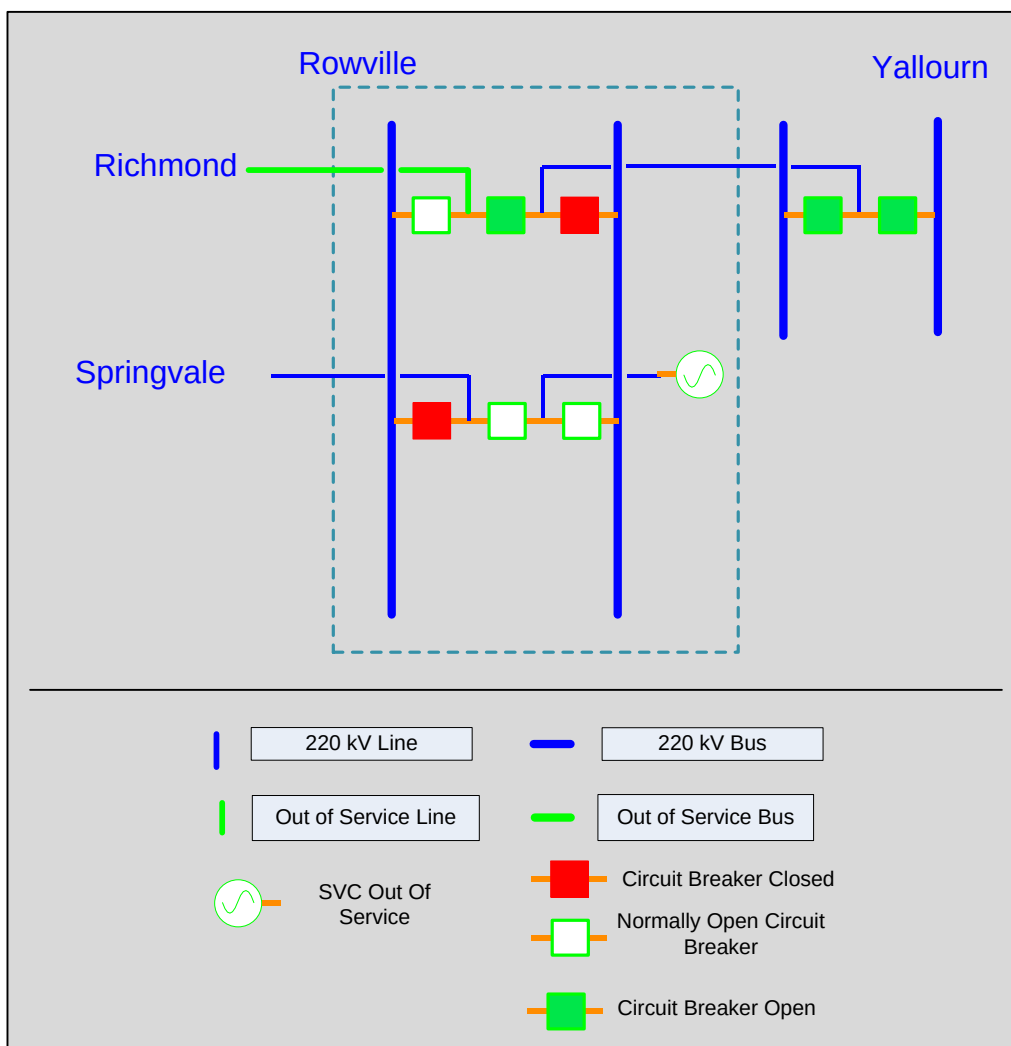


Figure 6 Post event system conditions

At 2125 hrs, the V-ROYP5_R constraint set was invoked by AEMO. The No.4 Rowville – Richmond 220 kV transmission line was restored at 2152 hrs by closing the CB at the Rowville end. The Yallourn end of the Rowville – Yallourn 220 kV transmission line was restored at 0051 hrs on 20/06/2012 after a line patrol was completed by SP AusNet staff and found no cause of a fault.

6 Power System Performance (excluding frequency)

6.1 Power System Voltages

AEMO's monitoring systems reported no voltage violation alarms during the event.

6.2 Power System Stability

AEMO's voltage stability monitoring tool indicated a voltage stability issue associated with the post contingent loss of the South Morang F2 transformer from 2058 hrs. Under the post-event system configuration in Victoria, there was insufficient reactive power in the Victoria region to support the high New South Wales – Victoria interconnector power flow for the post contingent loss of the South Morang F2 transformer.

This situation was prevalent from 2054 to 2123 hrs. The voltage stability issue was resolved through:

- a reduction of New South Wales – Victoria power flow;
- increase in Victoria generation output;
- optimisation of reactive power; and
- the natural reduction of Victoria demand.

6.3 Power System Thermal Limits

The contingent loss of the South Morang F2 transformer under the conditions illustrated in Figure 4 would have resulted in the majority of the Victoria – New South Wales import power flowing through the Dederang H1, H2 and H3 transformers, exceeding the rating of Dederang H1 transformer. The Dederang H2 and H3 transformers have a higher rating and post contingent flows would have been below this rating.

At 2150 hrs, the AEMO control room invoked the CA_SPS_3EF2F2EF_01 constraint set to limit the flow through the Dederang H1 transformer for the contingent loss of the South Morang F2 transformer. The power system was restored to a secure operating state at 2152 hrs.

From the discussion in Section 6.2 and 6.3, the power system was in an insecure state from 2053 hrs primarily because of the potential voltage instability followed by the transformer overload issue. The voltage stability issue was resolved at 2123 hrs while the transformer overload issue was resolved at 2152 hrs.

While the trip of the No.5 Rowville – Yallourn 220 kV transmission line at 2118 hrs did not exacerbate the contingent loss of the South Morang F2 transformer, it did add to the response time of the AEMO control room.

6.4 Analysis of Interconnector Flows

An analysis of the Victoria – New South Wales, Victoria – South Australia and Basslink interconnectors is presented below. While transfer limits were exceeded for short periods on these interconnectors, no constraint violations occurred.

The sudden loss of Victorian generating units caused a significant change in each of the interconnector flows, with a total change in interconnector flow of approximately 1600 MW.

The remaining NEM interconnectors did not exceed the respective transfer limits.

6.4.1 Victoria – New South Wales Interconnector

The graph in Figure 7 shows the Victoria – New South Wales response to the incident.

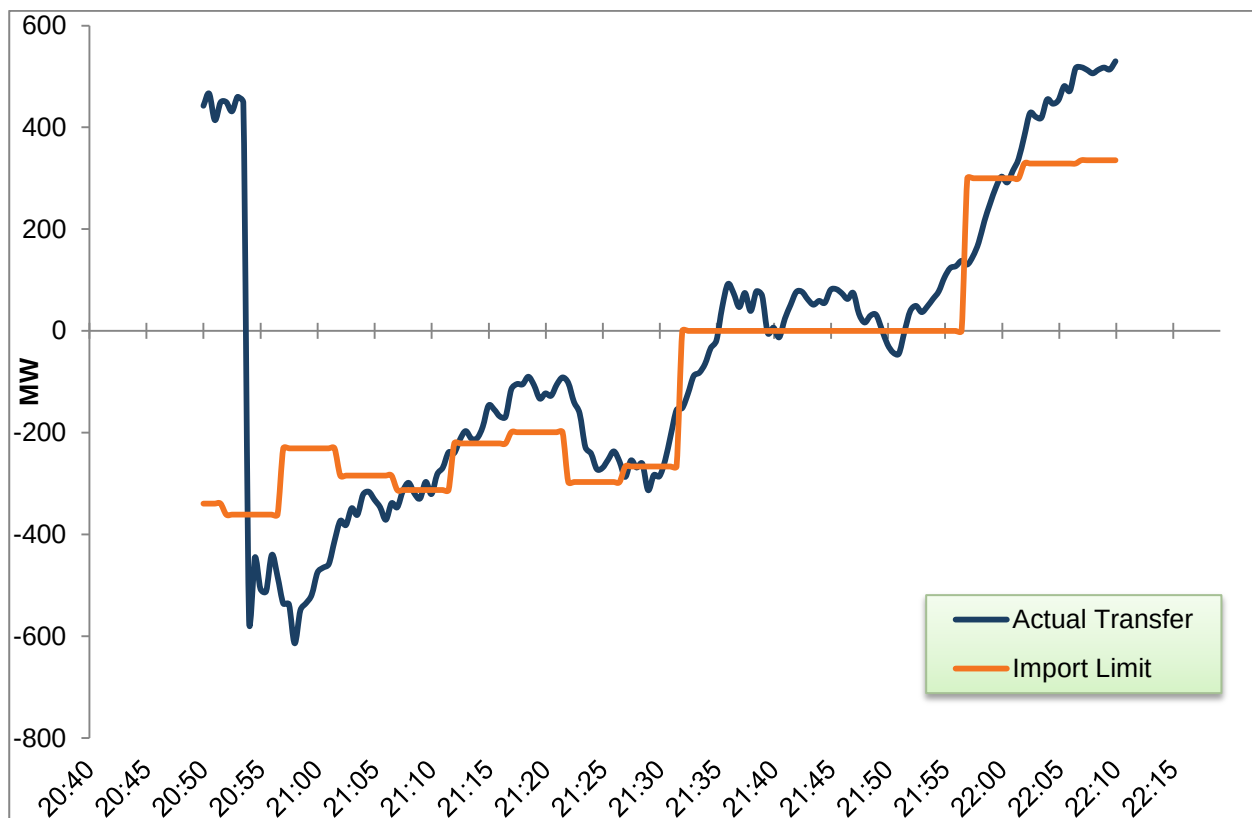


Figure 7 Victoria - New South Wales Interconnector Flows

Prior to the event, Victoria was transferring approximately 430 MW into New South Wales. Following the tripping of the generating units, the interconnector flow reversed with New South Wales transferring approximately 500 MW to Victoria, representing a change of approximately 930 MW. The limit at this time was set by voltage stability constraints for flow out of NSW. Given the revised technical envelope these limits were no longer applicable.

At 2130 hrs, the AEMO control room invoked a discretionary constraint, I-NV_0000, to limit the interconnector flow to restore power system security following the loss of the South Morang H1 and H2 transformers.

6.4.2 Victoria – South Australia Interconnector

The graph in Figure 8 shows the Victoria – South Australia response to the incident.

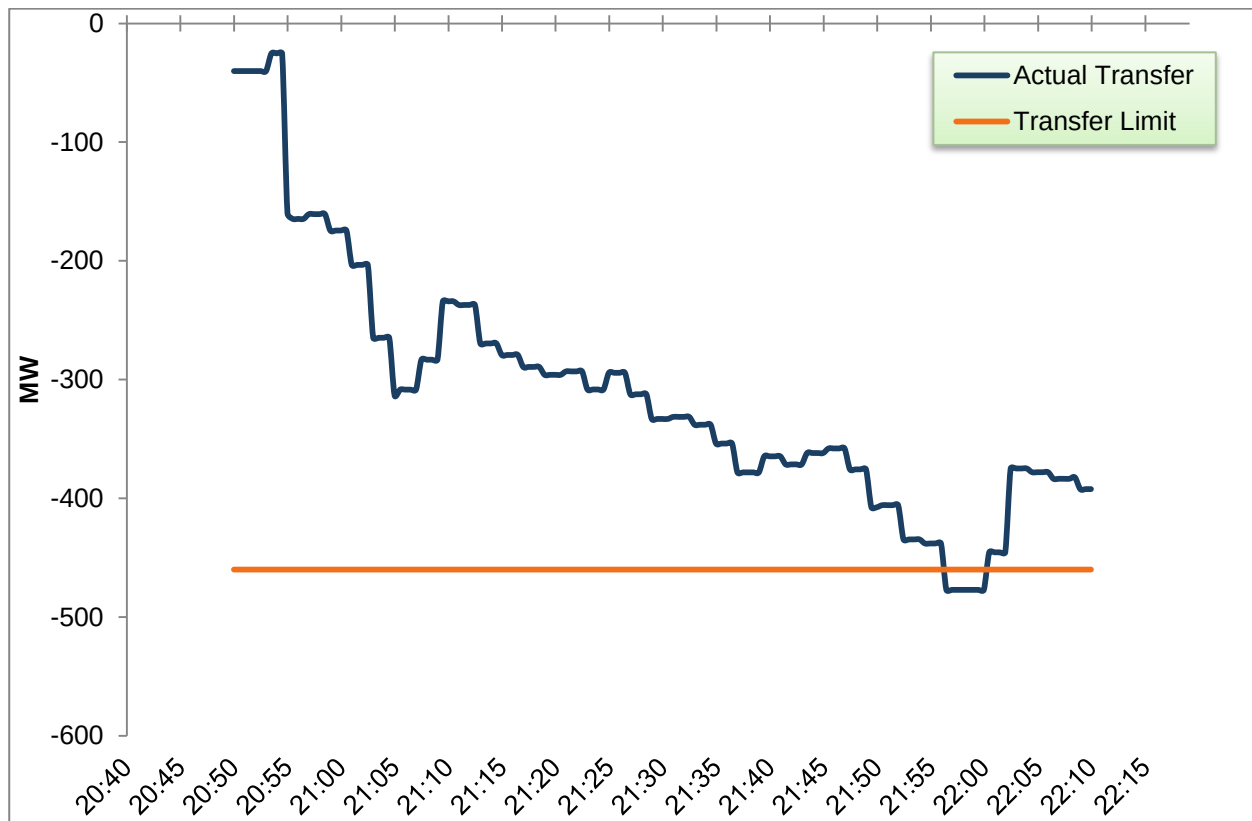


Figure 8 Victoria - South Australia Interconnector Flows

At the time of the event, South Australia was transferring approximately 15 MW to Victoria. The transfer increased to approximately 180 MW immediately following the event, representing a change of approximately 195 MW. The transfer eventually increased up to the transfer limit of 460 MW at 2155 hrs as the transfer from NSW was reduced. The transfer limit was set by the S>V_NIL_HYTX_HYTX thermal constraint equation to avoid overloading the remaining Heywood 275/500 kV transformer for the trip of the other Heywood 275/500 kV transformer.

6.4.3 Basslink

The graph in Figure 9 shows the Basslink response to the incident.

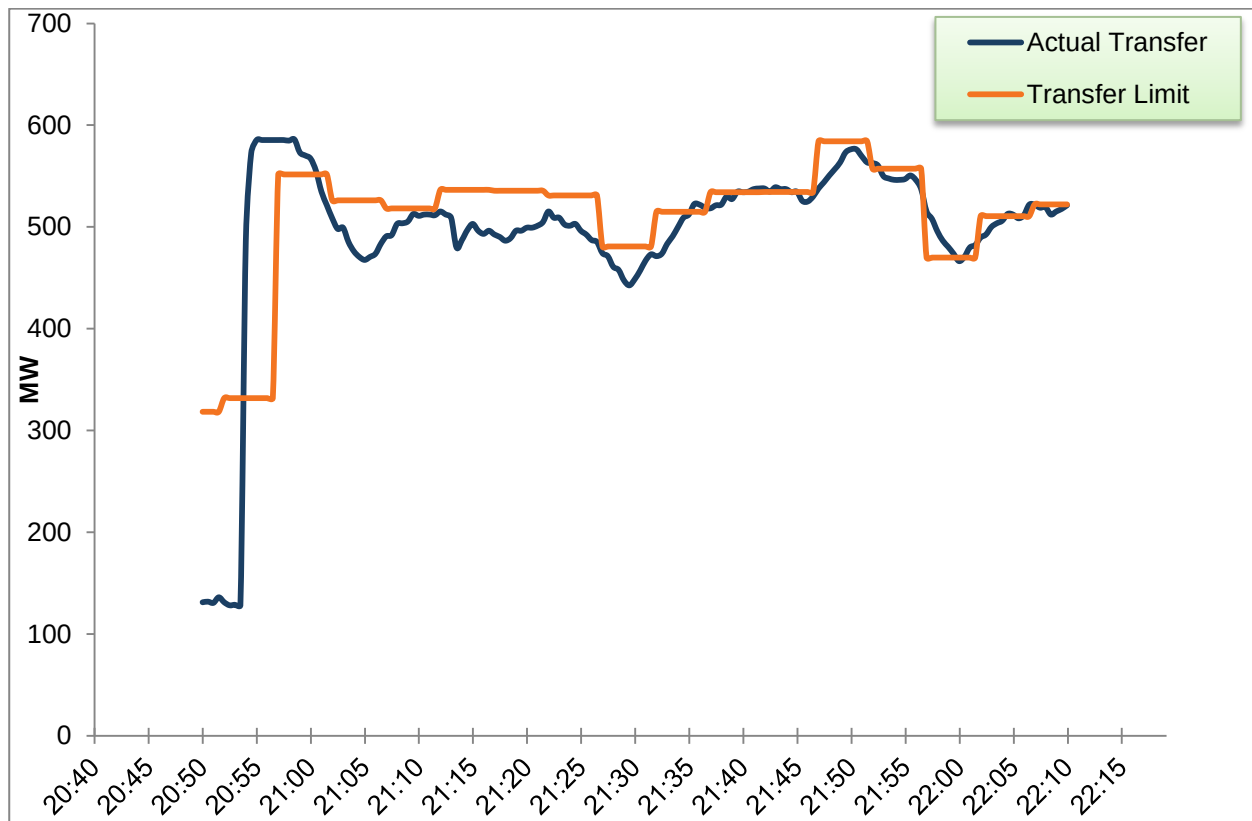


Figure 9 Basslink Flows

Prior to the event, Tasmania was transferring about 130 MW to Victoria. In response to the frequency excursion in Victoria, the interconnector increased power flow into Victoria close to its design limit at approximately 580 MW, representing a change of approximately 450 MW. The transfer exceeded the transfer limits set by FCAS requirements, for short durations due to the normal action of the Basslink frequency controller.

7 Power System Frequency Assessment

The multiple tripping of generation units within a five minute period categorises the event as a multiple contingency event as defined in the Frequency Operating Standards (FOS).

7.1 Mainland Frequency

The table below summarises the actual performance of frequency in the Mainland against the FOS.

Condition	Frequency Operating Standard	Actual System Performance
Recovery	49.85 to 50.15 Hz within 10 minutes	4.1 minutes to recover
Stabilisation	49.5 to 50.5 Hz within 2 minutes	2.4 minutes to stabilise
UFLS Threshold	49.0 Hz	Threshold not breached
Containment	47 to 52 Hz	Frequency band not breached

Table 5 Mainland FOS - interconnected system

7.1.1 Mainland Frequency Analysis

The graph in Figure 10 shows the Mainland frequency deviation during the incident.

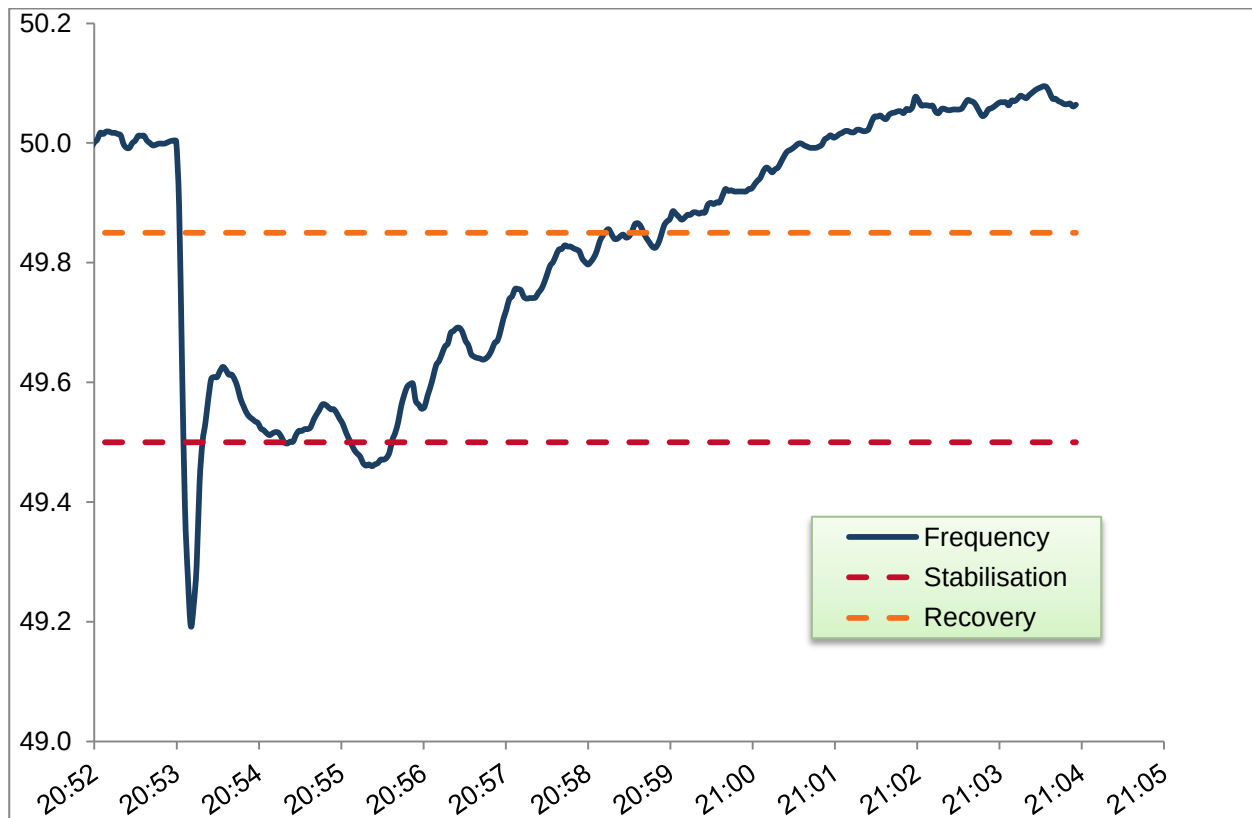


Figure 10 Mainland frequency on 19 June 2012

The power system frequency in the Mainland fell to a minimum of 49.2 Hz at 20:53:54 hrs. The power system responded to bring the system frequency back within the stabilisation lower limit in

approximately 14 seconds. However, the system frequency fell below the stabilisation lower limit again after 122 seconds which is in violation of the Mainland FOS.

The frequency returned and remained in the stabilisation band after 146 seconds and returned within the recovery band lower limit within 245 seconds. The recovery criteria of the Mainland FOS were met.

7.1.2 Mainland Frequency Control Ancillary Service Response

The figure below shows the Mainland FCAS services enabled and delivered during the incident.

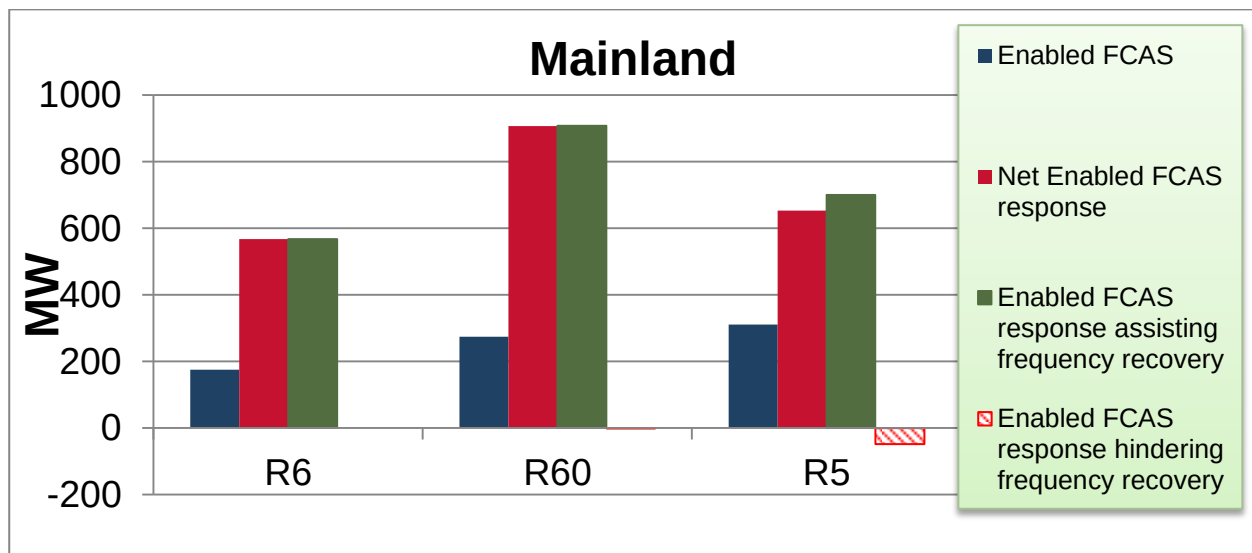


Figure 11 Mainland FCAS raise service enabled on 19 June 2012.

The amount of FCAS that is enabled is only sufficient to cover any single credible contingency event⁷. Approximately 175 MW of R6 was enabled but 568 MW was effectively delivered from the enabled units to assist in frequency recovery. For the R60 service, approximately 275 MW was enabled but 908 MW was delivered from the enabled units. With regards to the R5 service, 311 MW was enabled but 700 MW was delivered from the enabled units to help increase the frequency.

The significant response of units in the Mainland contributed to the stabilisation and recovery of the Mainland frequency.

⁷ With regard to raise services, normally the largest single generating unit connected at the time.

7.2 Tasmania Frequency

The table below summarises the actual performance of frequency in Tasmania against the FOS.

Condition	Frequency Operating Standard	Actual System Performance
Recovery	49.85 to 50.15 Hz within 10 minutes	5.7 minutes to recover
Stabilisation	48.0 to 52.0 Hz within 2 minutes	0.2 minutes to stabilise
UFLS Threshold	47.96 Hz	UFLS triggered
Containment	47.0 to 55.0 Hz	Frequency band not breached

Table 6 Tasmania FOS – interconnected system

7.2.1 Tasmania Frequency Analysis

The graph in Figure 11 shows the Tasmania frequency deviation during the incident.

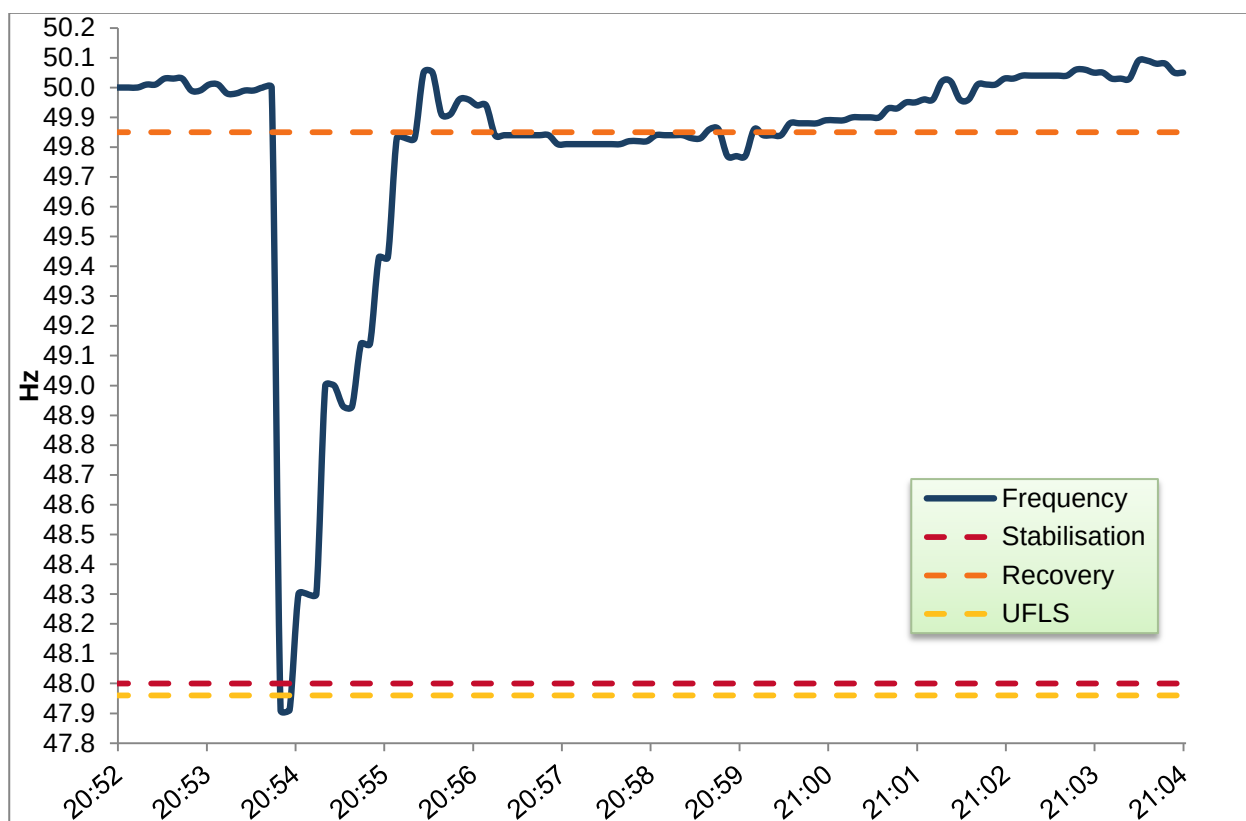


Figure 12 Tasmania frequency on 19 June 2012

The loss of approximately 1955 MW from the Mainland resulted in a drop in Mainland frequency. The Basslink frequency controller responded as expected to increase the export from Tasmania from approximately 130 MW to 580 MW into Victoria. This resulted in a frequency excursion in the Tasmanian frequency from 49.99 to 47.95 Hz.

The minimum frequency experienced at 20:53:47 hrs crossed the threshold for the Tasmania UFLS which is set to trigger at 47.96 Hz resulting in the shedding of 200 MW of major industrial

load. Frequency recovered to within the stabilisation band within 0.2 minutes and to within the recovery band within 5.7 minutes. The Tasmania region frequency operating standard was met for this event.

7.2.2 Tasmania Frequency Control Ancillary Service Response

The figure below shows the Tasmania FCAS services enabled and delivered during the incident.

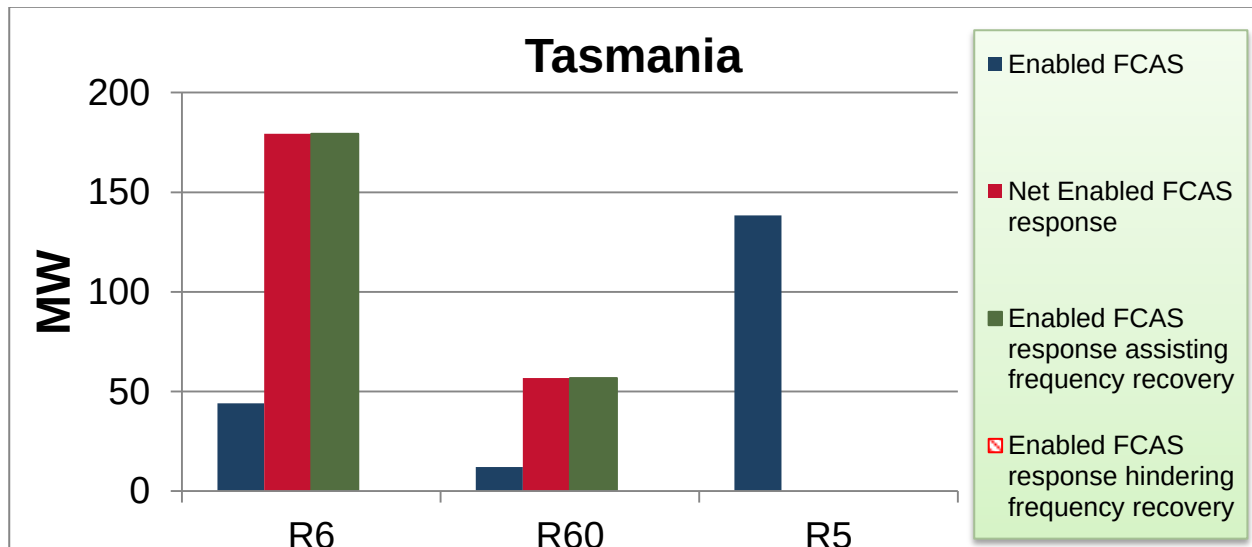


Figure 13 Tasmania FCAS raise service enabled on 19 June 2012

The amount of FCAS that is enabled is only sufficient to cover any single credible contingency event. Approximately 44 MW of R6 was enabled but 179 MW was effectively delivered to assist in frequency recovery. For the R60 service, approximately 12 MW was enabled but 57 MW was delivered. With regards to the R5 service, 138 MW was enabled but none was delivered.

Recommendation:

AEMO will further investigate this lack of R5 response as part of the review of FCAS delivery in a report to be published by 31 December 2012.

7.2.3 Tasmania UFLS

Under frequency trip signals were sent to major industrial loads at 20:53:47 hrs in accordance with the under frequency load shedding schedule. Approximately 200 MW of load was shed as a result. Of the load that was shed, 27 MW was an inadvertent trip due to an internal wiring fault of a harmonic filter associated with one of the loads.

Work was completed on 30 July 2012, to resolve the wiring fault and to upgrade the firmware in the capacitor circuit RTUs.

8 Electricity Market Outcomes

There was no material impact on the market due to the multiple contingency incident.

9 Conclusions

The Victoria earthquake that occurred on 19 June 2012 resulted in the loss of 1955 MW of generation and 400 MW of load (200 MW of load due to under-frequency load shedding). Both the H1 and H2 transformers at South Morang also tripped as a direct result of the earthquake.

Clearance to restore all load was given within 20 minutes of the event occurring.

The No. 5 Rowville – Yallourn 220kV line tripped approximately 25 minutes after the earthquake but this event was not directly associated with the earthquake.

Immediately after the loss of generation and the tripping of the transformers at South Morang the power system was in an insecure state. The power system was restored to a secure operating state 58 minutes after the initial event occurred. Although this is longer than the 30 minutes as determined by the NER to restore to a secure system, it is considered acceptable given the complexity of the event.

The frequency operating standard for the Tasmania region was met. The frequency operating standard for the mainland regions of the NEM was largely met except for a delay of 26 seconds in returning to the stabilisation band.

The total delivery of FCAS was in excess of the amounts dispatched resulting in a significant reduction in the impact of the loss of generation however AEMO will further investigate the lack of FCAS response from some generating units.

10 Recommendations

1. AGL has advised that it will replace the governor control system on Torrens Island A units. This work is expected to be completed by 30 June 2013
2. AEMO will investigate the FCAS performance of enabled units by 31 December 2012
3. Powerlink will investigate with Queensland Rail on the transformer tripping and advise AEMO of any pertinent actions by 31 December 2012
4. AEMO will review the feasibility of, and systems for, issuing a detailed market notice for a major event within the times specified in the Power System Security Guidelines by 31 December 2012.

11 Appendix A - Sequence of Events

Date	Time	Event	Comment
19/06/2012	20:53:29	Earthquake occurred in the Latrobe Valley	
	20:53:40	Loy Yang A3 trips	570 MW
	20:53:48	Loy Yang A4 trips	570 MW
	20:53:48	Yallourn U4 trips	200 MW
	20:53:57	TAS major industrial load trips	200 MW
	20:54:08	Loy Yang A1 trips	570 MW
	20:54:10	South Morang H1 and H2 330/220 kV transformer trips	Offloads No.1 South Morang – Thomastown 220 kV transmission line
	20:54:16	Torrens Island A4 trips	45 MW
	20:54	Raglan transformer trip	2 MW
	20:54	Internal AEMO emergency SMS message issued	
	20:55	AEMO's Contingency Analysis tool raises alarm for loss of South Morang F2 transformer	
	21:08	AEMO issues notification through the Emergency Messaging System	
	21:13	Permission to Restore – Rio Tinto load	
	21:17	Permission to Restore – Nyrstar load	
	21:18	Market Notice 39034 issued	
	21:18	No.5 Rowville – Yallourn 220 kV transmission line trips	Offloads No.4 Rowville – Richmond 220 kV transmission line
	21:20	NC-V_YWPS4 constraint set invoked	

	21:25	V-ROYP5_R constraint set invoked	
	21:30	V-SMTT1 constraint set invoked	
	21:34	No.1 South Morang – Thomastown transmission line on load	
	21:30	I-NV_0000 constraint set invoked	
	21:30	V-SMTS_HTX_R constraint set invoked	
	21:40	V-SMTT1 constraint set revoked	
	21:50	CA_SPS_3EF2F2EF_01 constraint set invoked	Power system security restored
	21:51	No.4 Rowville – Richmond transmission line on load	
	22:00	I-NV_0000 constraint set revoked	Replaced with CA_SPS_3EF2F2EF_01 constraint set
	22:20	Market Notice 39036 issued	
20/06/2012	00:05	South Morang H1 transformer on load	
	00:25	CA_SPS_3EF2F2EF_01 constraint set revoked	
	00:34	South Morang H2 transformer on load	
	00:34	Loy Yang A4 synchronised	
	00:36	Loy Yang A4 de-synchronised	
	00:45	V-SMTS_HTX_R constraint set revoked	
	00:51	No.5 Rowville – Yallourn transmission line returned to service	

00:54	Market Notice 39037 issued
04:55	Loy Yang A3 returned to service
05:49	Market Notice 39039 issued

12 Appendix B – Electricity Market Notices

Market Notice ID	Issue Date	Content
39034	21:18 19/06/2012	South Eastern Australia reported earthquake 2053hrs AEMO has become aware of a significant power system disturbance in South Eastern Australia, load, generation and transmission equipment have tripped.
39036	22:20 19/06/2012	In order to manage power system security in the Victorian network constraints have been placed on the NSW - Vic and Murray link interconnectors. CA_SPS_3EF2F2EF was invoked at 21:50hrs until further notice. At South Morang (Vic Region) both H1 and H2 330/220kV transformers remain offload. Across all regions all load has been cleared to be restored In Victoria approximately 2000MW of generation remains offline.
39037	00:54 20/06/2012	At South Morang (Vic Region) both H1 and H2 330/220kV transformers have been returned to service. In Victoria approximately 2000MW of generation remains offline, anticipating 1740MW to be progressively returned to service over the next 8 hrs. CA_SPS_3EF2F2EF was revoked at 0025hrs 20/6/12 V-SMTS_HTX_R was revoked at 0045hrs 20/6/12
39039	05:49 20/06/2012	Advice of a Non-credible contingency event - 19 June 2012 At 2053hrs 19/06/2012 in the NEM regions the following plant tripped from the system In Vic Generators LYA1, LYA3, LYA4, YW4 South Morang TS H1 trans South Morang TS H2 trans In South Aust TIPS A4 Approximately 400MW of Load lost, 200MW of which was under frequency loadshed in Tas