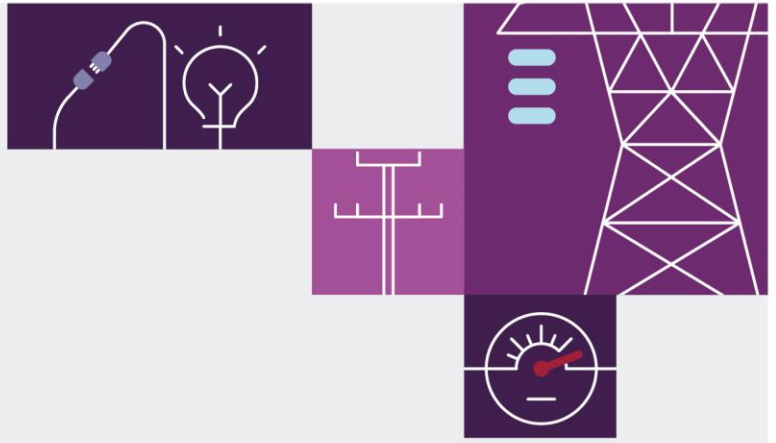


Preliminary Report – Trip of Moorabool – Sydenham 500 kV No. 1 and No. 2 lines on 13 February 2024

February 2024

A preliminary operating incident
report for the National Electricity
Market – information as at
15/2/2024





Important notice

Purpose

AEMO has prepared this preliminary report as part of its review of the reviewable operating incident that occurred on 13 February 2024 involving the trip of the Moorabool Terminal Station – Sydenham Terminal Station 500 kilovolt (kV) No. 1 and No. 2 lines, subsequent disconnection of generation and load, and load shedding, as a first step in reporting under clause 4.8.15(c) of the National Electricity Rules.

The observations in this report will be updated in AEMO's final operating incident report, where new information becomes available.

Disclaimer

AEMO has been provided with preliminary data by Registered Participants as to the status and response of some facilities before, during and after the event in accordance with clause 4.8.15 of the National Electricity Rules. In addition, AEMO has collated preliminary information from its own systems. Any analysis and conclusions expressed in this document are also of a preliminary nature.

While AEMO has made reasonable efforts to ensure the quality of the information in this report, its investigations are incomplete, and any 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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Abbreviations

Abbreviation	Term
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AEST	Australian Eastern Standard Time
APD	Alcoa Portland
BESS	battery energy storage system
BoM	Bureau of Meteorology
CA	contingency analysis
DPV	distributed photovoltaic [generation]
DWGM	Declared Wholesale Gas Market
FCAS	frequency control ancillary service/s
FOS	Frequency Operating Standard
GTS	Geelong Terminal Station
HSM	high speed monitoring
HWTS	Hazelwood Terminal Station
HYTS	Heywood Terminal Station
Hz	hertz
JLTS	Jeeralang Terminal Station
kV	kilovolt/s
Km	kilometre/s
km/h	kilometre/s per hour
KTS	Keilor Terminal Station
LOR	lack of reserve
LOR3	lack of reserve 3
LYA	Loy Yang A
LYPS	Loy Yang Power Station
MLTS	Moorabool Terminal Station
MN	Market Notice
MPC	market price cap
MW	megawatt/s
NEL	National Electricity Law
NEM	National Electricity Market
NER	National Electricity Rules
NOFB	normal operating frequency band
PMU	phasor measurement unit
PS	power station
p.u.	per unit
RERT	reliability and emergency reserve trader
ROTS	Rowville Terminal Station

Abbreviation	Term
RRP	regional reference price
SF	solar farm
SMTS	South Morang Terminal Station
SYTS	Sydenham Terminal Station
TI	trading interval
TJ	terajoule
TNSP	Transmission Network Service Provider
TTS	Thomastown Terminal Station
VNI	Victoria – New South Wales Interconnector
WOTS	Wodonga Terminal Station
WF	wind farm



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1 Overview

This preliminary report relates to a reviewable operating incident¹ that occurred on 13 February 2024 in Victoria. At 1308 hrs on 13 February 2024, the Moorabool (MLTS) – Sydenham (SYTS) No. 1 and 2 500 kilovolt (kV) lines tripped following failure of six 500 kV towers (three on each of the two 500 kV circuits). The simultaneous trip of these 500 kV lines and subsequent disconnection of all four Loy Yang A generating units, Dundonnell Wind Farm (WF) and Yaloak South WF had a significant impact on the Victorian power system. Initial review indicates Dundonnell WF tripped as designed due to operation of the South West 500 kV special control scheme. In total, approximately 2,690 megawatts (MW) of generation was lost, and 1,000 MW of load was shaken off² in Victoria following the disturbance.

Following the event, at 1420 hrs on 13 February 2024, AusNet³ was instructed to shed 300 MW of load to manage loading of in-service network elements. AEMO subsequently instructed load to be restored at 1450 hrs and 1510 hrs.

Later, at 1543 hrs on 13 February 2024, a further separate incident occurred involving trip of the Hazelwood Terminal Station (HWTS) – Jeeralang Terminal Station (JLTS) 220 kV No. 2 line and the offloading of the HWTS 500/220 kV No. 1, No. 2, No. 3 and No. 4 transformers. This incident will be subject to a separate review.

Separate to the transmission system event, storm activity across Victoria caused significant damage to the distribution networks on Tuesday 13 February 2024, impacting more than 500,000 residential and business customers.

Given the significance of this event, AEMO has prepared this preliminary report for the industry covering the period from the initial event at 1308 hrs until 1515 hrs on 13 February 2024. This preliminary report provides a summary of the known facts relating to the incident as known at the date of publication and does not attempt to provide any analysis or recommendations.

AEMO would like to thank all participants who assisted in the effective management of this event.

National Electricity Market (NEM) time (Australian Eastern Standard Time [AEST]) is used in this report.

¹ See National Electricity Rules (NER) 4.8.15(a)(1)(i), as the event relates to a non-credible contingency event; NER 4.8.15(a)(1)(v), as the event involved the issue of instructions for load shedding; and the Australian Energy Market Commission (AEMC) Reliability Panel Guidelines for Identifying Reviewable Operating Incidents.

² Load shake-off refers to generalised disconnection of load in response to unusual network conditions during a disturbance, such as a deep voltage dip or phase angle jump.

³ AusNet is the Victorian Declared Transmission System Network Operator.

2 Pre-event conditions

2.1 Generation and demand

A summary of the Victorian system conditions at 1305 hrs on 13 February 2024, just prior to the incident, is provided in Table 1. Table 2 provides a summary of Victorian generator dispatch at 1305 hrs on 13 February 2024.

Table 1 Victorian key system parameters at 1305 hrs on 13 February 2024

Quantity description	Value (MW)
Victorian operational demand	7,724
Victorian scheduled and semi-scheduled generation	7,633
Victorian distributed photovoltaic generation	2,293
Basslink flow into Victoria (George Town end)	132
Heywood interconnector flow into Victoria	156
Murraylink interconnector flow into South Australia	110
Victoria – New South Wales Interconnector (VNI) flow into New South Wales	97

Table 2 Victorian generation dispatch at 1305 hrs on 13 February 2024

Station name	Dispatched generation (MW)	Station name	Dispatched generation (MW)
Ararat WF	0.1	Loy Yang A Power Station (PS) Unit 2	529
Ballarat Battery Energy Storage System (BESS)	24.6	Loy Yang A PS Unit 3	559
Bald Hills WF	91.1	Loy Yang A PS Unit 4	543
Bannerton Solar Park	2.4	Macarthur WF	145
Berrybank WF	114.9	Bogong / Mackay PS	170.1
Berrybank 2 WF	77.6	Mortlake PS G11	254
Bulgana BESS	4.2	Mortlake South WF	57.9
Bulgana WF	157	Mt Gellibrand WF	81.8
Cherry Tree WF	54.3	Murray PS	752.9
Dundonnell 1 WF	130.4	Murra Warra WF	80.2
Dundonnell 2 WF	32.7	Murra Warra WF Stage 2	101.8
Dundonnell 3 WF	110.3	Numurkah SF	42.8
Gannawarra BESS	10.4	Oaklands Hill WF	52.4
Gannawarra Solar Farm (SF)	9.9	Phillip Island BESS	0.9
Glenrowan SF	75.7	Salt Creek WF	42.2
Glenrowan West SF	73.7	Stockyard Hill WF	0
Hazelwood BESS	-41.4	Victorian Big Battery	0.7
Jeeralang A PS Unit 1	36.3	Valley Power Unit 3	4.1
Jeeralang A PS Unit 2	44.5	Wemen SF	2.4

Station name	Dispatched generation (MW)	Station name	Dispatched generation (MW)
Jeeralang A PS Unit 3	43.2	Winton SF	69.7
Jeeralang A PS Unit 4	41.4	Yaloak South WF	22.2
Karadoc SF	83.5	Yatpool SF	70.5
Kiamal SF	106.2	Yendon WF	93.2
Loy Yang B PS Unit 1	565.4	Yallourn W PS Unit 3	372.1
Loy Yang B PS Unit 2	565	Yallourn W PS Unit 4	332.6
Loy Yang A PS Unit 1	559		

2.2 Weather

On 13 February 2024, the Bureau of Meteorology (BoM) issued assessments of low intensity heatwave conditions across Victoria and fire weather warnings ranging from extreme to catastrophic in parts of Victoria and South Australia, with hot and gusty northerly winds expected. Melbourne was forecast to reach close to 37°C ahead of a cool change, expected to move quickly through the region and arrive at Melbourne between 1600 hrs and 1700 hrs. Thunderstorms were expected from late morning over the north and central southern parts of the region, before extending into central and eastern Gippsland in the afternoon and evening.

At approximately 1200 hrs, a severe storm cell developed near Ballarat moving southeast that was associated with severe winds in the vicinity. Damaging winds greater than 90 kilometres per hour (km/h) were observed in the wider area and near destructive winds were recorded at Avalon Airport, approximately 20 kilometres (km) from MLTS, with the BoM reporting a peak wind gust of 122 km/h at 1319 hrs.

2.3 Temporary increase to frequency control ancillary services

Prior to the event, AEMO was managing a sustained low frequency event including the loss of approximately 500 MW of generation from Stockyard Hill WF that occurred at approximately 1135 hrs and had increased the minimum frequency control ancillary service (FCAS) regulation raise requirement. Constraint set F-MAIN_RREG_0450 was invoked between 1200 hrs and 1355 hrs on 13 February 2024 to ensure mainland regulation raise requirement was greater than 450 MW.

3 Event

3.1 Sequence of events

The sequence of events is outlined below in Table 3.

Table 3 Sequence of events

Market time (hhmm)	Event
1308	<ul style="list-style-type: none">• The MLTS – SYTS 500 kV No. 1 and No. 2 lines tripped.• Approximately 2,690 MW of generation was lost, including:<ul style="list-style-type: none">– All four Loy Yang A units over the following 2 minutes.– Dundonnell WF. Initial review indicates Dundonnell WF tripped as designed.– Yaloak South WF.• Approximately 1,000 MW of load was shaken off.
1322	<ul style="list-style-type: none">• AEMO issued Market Notice (MN) 114577 to advise of a significant power system event involving the trip of generation and transmission lines in Victoria.
1420	<ul style="list-style-type: none">• Actual lack of reserve 3 (LOR3)⁴ condition declared with AEMO instructing AusNet to shed 300 MW of load in the metropolitan area. MN 11604 advised that the maximum load to be interrupted was up to 450 MW.• Market price cap (MPC) was set in Victoria for Trading Intervals (TI) 1425 onwards.[^]
1450	<ul style="list-style-type: none">• AEMO instructed AusNet to commence load restoration, beginning with 150 MW of load in Keilor Terminal Station (KTS)/Thomastown Terminal Station (TTS)/Rowville Terminal Station (ROTS) metropolitan area.
1510	<ul style="list-style-type: none">• AEMO instructed AusNet to restore remaining load (150 MW) in the KTS/TTS/ROTS metropolitan area.
1515	<ul style="list-style-type: none">• Actual LOR3 cancelled.• MPC was removed in Victoria for TI 1515 onwards.

[^] In accordance with the requirements of National Electricity Rules (NER) 3.9.2(e)(1).

3.2 Power system response

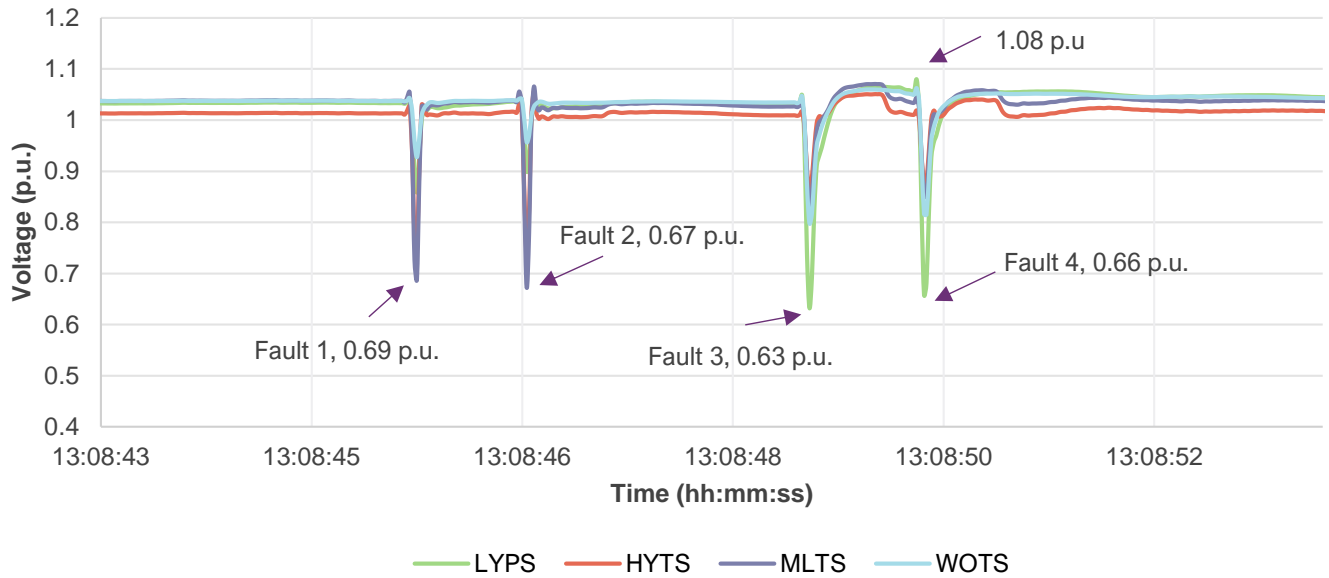
High speed monitoring (HSM) and phasor measurement unit (PMU) data is still in the process of being collated and analysed to confirm the exact sequence of events. In the final incident report, ordering of events could change from what is presented here.

AEMO’s initial review of the PMU data below indicates there were four faults in Victoria. As shown in Figure 1 below, the voltage depression during the fault was experienced throughout Victoria and was observed to be as low as 0.63 per unit (p.u.).

⁴ Refer to the LOR fact sheet for more details on LOR conditions at <https://aemo.com.au/learn/energy-explained/fact-sheets/lack-of-reserve-notices>.



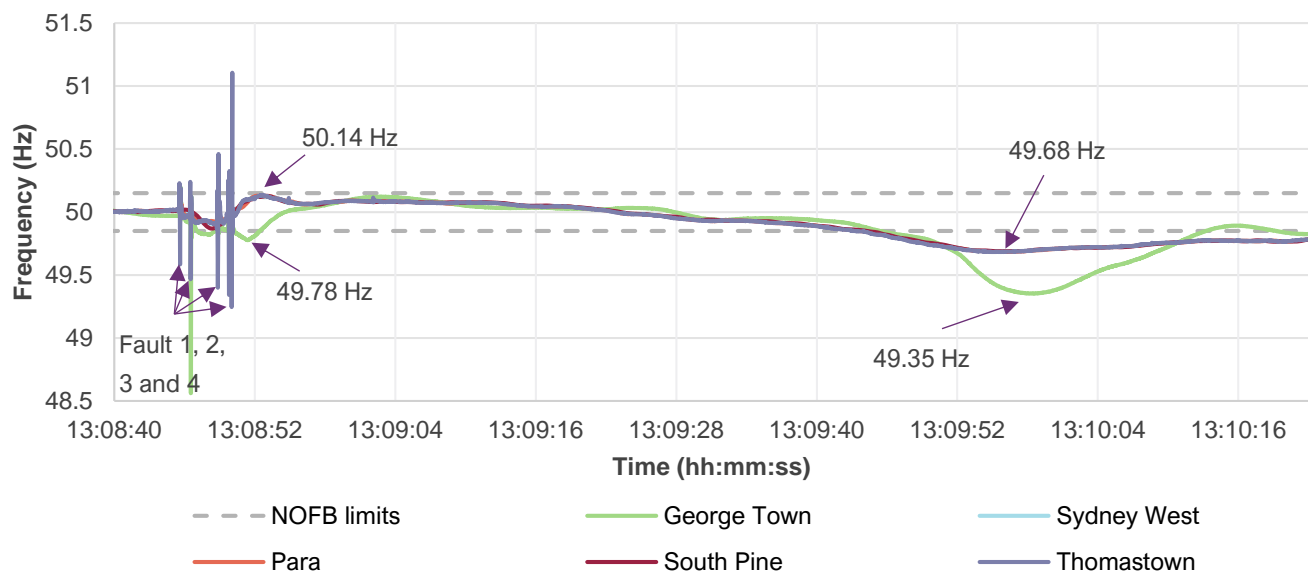
Figure 1 Positive sequence voltage throughout Victoria on 13 February 2024



WOTS: Wodonga Terminal Station. LYPS: Loy Yang Power Station. LYPS is connected to Loy Yang A Power Station, Loy Yang B Power Station, Valley Power and the Basslink interconnector.

As Figure 2 shows, frequency on the mainland (measurements shown for Para, South Pine, Sydney West and Thomastown) initially increased to 50.14 hertz (Hz) shortly after the faults, before decreasing to a minimum of 49.68 Hz, and stabilising at approximately 49.85 Hz. The effects of the event were also experienced in Tasmania via the Basslink interconnector, with Tasmania recording a minimum frequency of 49.35 Hz.

Figure 2 Frequency during the event on 13 February 2024

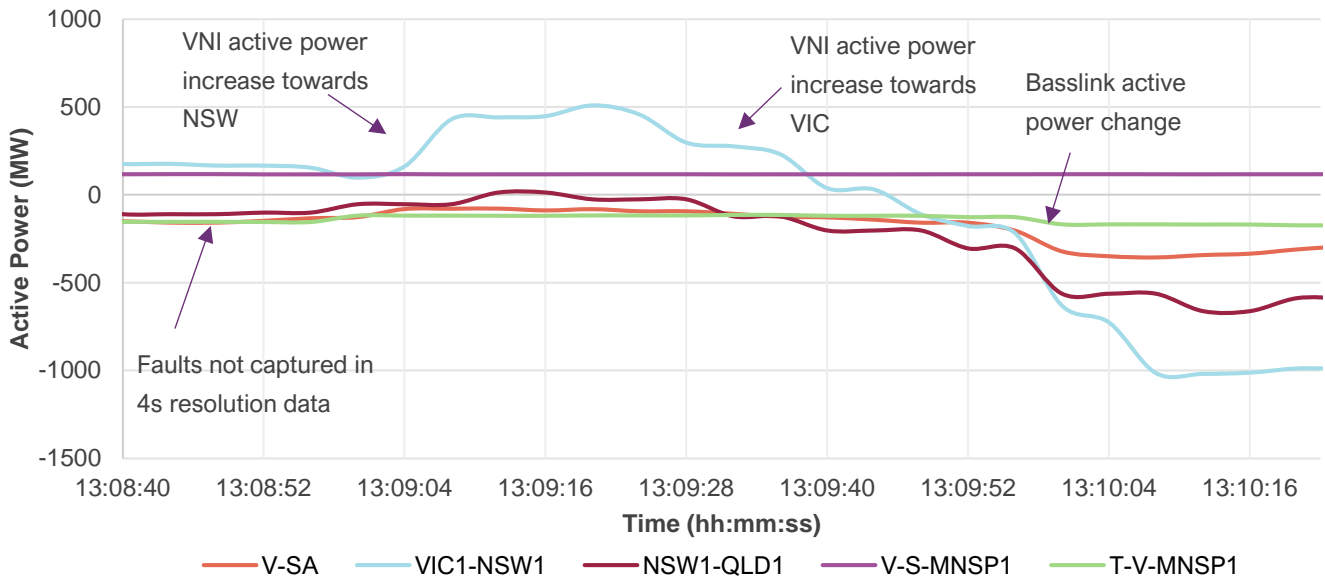


NOFB: normal operating frequency band.

The available data for interconnector flow is lower resolution and subsequently does not show the initial faults shown in the high speed data. The data shows that following the trip of load and generation in Victoria, the flow across the Victoria – New South Wales Interconnector (VNI) initially increased towards New South Wales and then

changed direction towards Victoria. Changes to Basslink flow are also observed, co-incident with the above changes in frequency at George Town in Tasmania.

Figure 3 Interconnector flow on 13 February 2024



3.3 Gas system operations

Soon after the event, AEMO published a revised 2.00 pm schedule for the Victorian Declared Wholesale Gas Market (DWGM) shortly before 1400 hrs on 13 February 2024 with a 55 terajoule (TJ) demand override to support additional gas generation demand in Victoria. AEMO continued to monitor gas generation demand.

3.4 Market impact

3.4.1 Central dispatch process operation

The central dispatch process in the NEM operates every five minutes and measures generation and interconnector flows at the start of each five-minute trading interval (TI). Although the initiating event occurred at 1308 hrs, the market impact manifested itself over several intervals:

- TI 1310 was measured at around 1305 hrs and did not include any impacts of the event.
- TI 1315 was measured at around 1310 hrs and an initial change in VNI flow was included, but the Loy Yang A unit trips had not been included.
- TI 1320 was measured at around 1315 hrs and included a large increase in flow into Victoria from New South Wales, as well as all of the Loy Yang A units being out of service. This was the first interval where there were violations of several constraints in Victoria and Tasmania (over-constrained dispatch), triggering automated constraint relaxation procedures.
- AGL submitted rebids for the four Loy Yang A units at 1315 hrs, which was after the start of the TI 1320 dispatch run, and these were used for TI 1325 and subsequent dispatch runs. The Loy Yang A units were

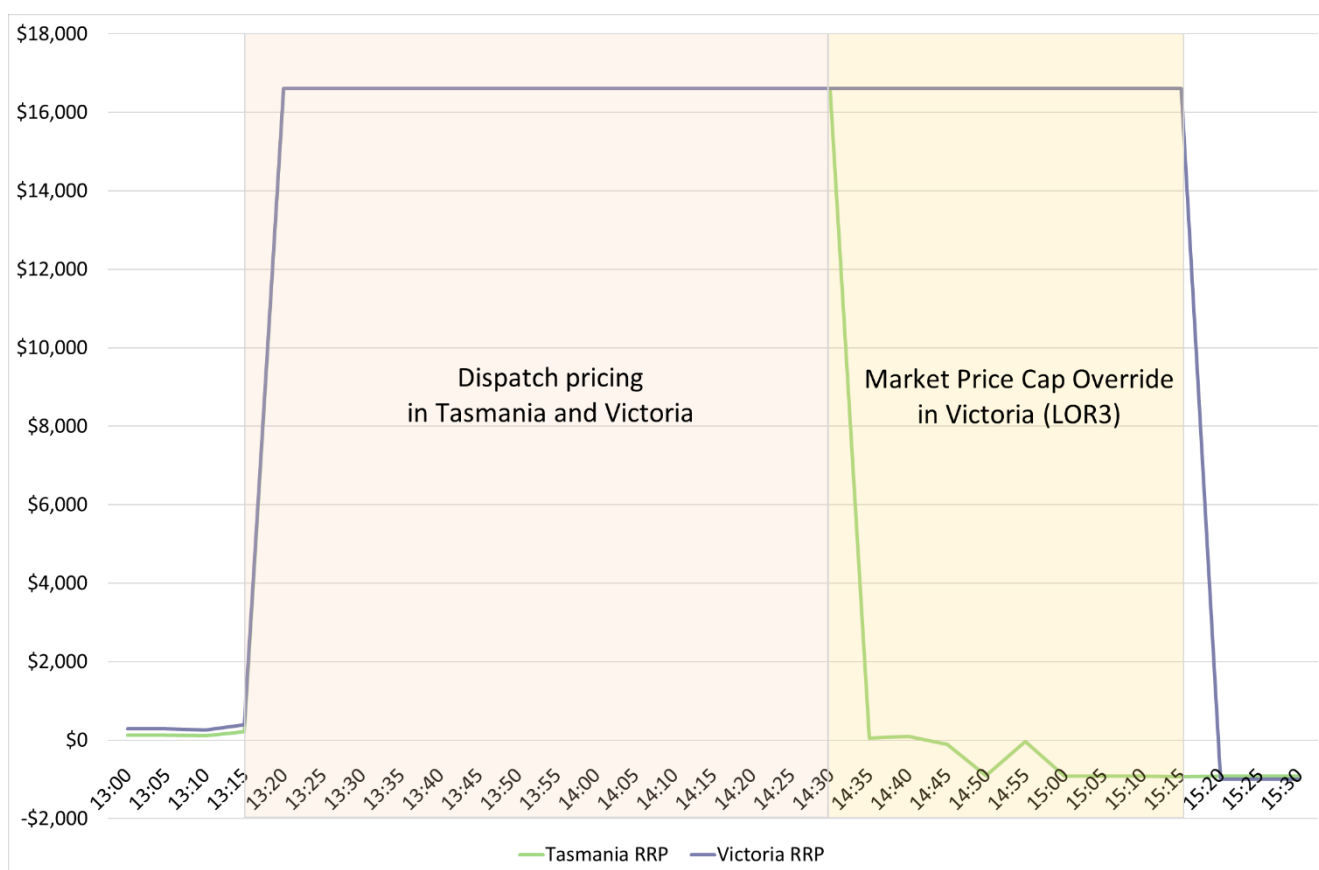
dispatched at their ramp rates from 0 MW to 90 MW across the four units in TI 1320 and then to 0 MW subsequently.

- From TI 1320 to TI 1430, over-constrained dispatch continued until load in Victoria reduced to the extent that constraints no longer violated.
- From TI 1435 to TI 1515, AEMO applied the manual MPC override (see Table 3) until the lack of reserve 3 (LOR3) condition in Victoria was cancelled.

3.4.2 Market prices in Tasmania and Victoria

The regional reference price (RRP) impacts for Tasmania and Victoria are shown in Figure 4. RRP in other regions were not materially affected by the incident. AEMO will report on FCAS price impacts in due course.


Figure 4 Price impacts during over-constrained dispatch and market price cap



3.4.3 Constraint relaxation⁵

National Electricity Rules (NER) 3.8.1(c) requires AEMO to establish a procedure to allow relaxation of power system constraints to resolve infeasible dispatch solutions. This is commonly referred to as over-constrained dispatch, and the procedure allows AEMO to resolve spot prices that are otherwise distorted by the process to prioritise violating constraints in dispatch.

⁵ Constraint Relaxation Procedure ME_PD_03, at <https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/market-operations/dispatch-information>.



The procedure operates by adjusting the limits in the violating constraints, but does not change the physical (MW) dispatch. In this incident, the automated process was able to resolve all but one of the trading intervals affected by over-constrained dispatch.

TI 1320 was manually resolved by AEMO on the day after the incident and the prices for that interval were subsequently revised⁶. The outcome of that review was minor changes to energy prices in New South Wales and Queensland, and reduction in regulation FCAS prices in Tasmania from the market price cap to \$9.88 (lower regulation) and \$150.68 (raise regulation).

The originally published market price caps in Tasmania and Victoria were not changed.

AEMO is undertaking a more detailed analysis of the over-constrained dispatch pricing outcomes in Tasmania and Victoria for this incident. The results of that analysis are not available at the time of publishing this preliminary report.

⁶ Refer Market Notices 114583 and 114718.



4 Reclassification

As the transmission elements involved in the non-credible contingency event remain out of service, AEMO has not reclassified this event. AEMO has also sought information from the generators that disconnected and at present is not aware of any prevailing conditions that would necessitate AEMO undertaking a process to consider reclassifications involving any of those assets.

AEMO will continue to seek information about this event and assess whether a recurrence is more likely to occur under any prevailing conditions. If during its full investigation AEMO becomes aware of a need for reclassification, AEMO will put in place the required reclassification(s), issue any necessary market notices, and report on them in the final incident report.

5 System security

Following the trip of the MLTS – SYTS 500 kV No. 1 and No. 2 lines at 1308 hrs on 13 February 2024, power flowed into the Keilor Terminal Station (KTS)/TTS/Rowville Terminal Station (ROTS) metropolitan area from south-western Victoria. Thermal limits on the 220 kV lines between Geelong Terminal Station (GTS) and MLTS were intermittently violating for dispatch intervals ending between 1315 hrs and 1420 hrs on 13 February 2024.

Following the trip of Victorian load and generation at approximately 1308 hrs, flow across VNI initially increased towards New South Wales and then changed direction to towards Victoria. The increased southbound power flow resulted in contingency analysis (CA) violations between 1315 hrs and 1425 hrs on 13 February 2024.

There was enough generation in the Victoria region to meet demand, however, due to constraints on the network, this generation was not able to supply the load. At 1420 hrs on 13 February 2024, an actual LOR3 condition was declared and AEMO issued a direction under section 116 of the National Electricity Law (NEL) (deemed a clause 4.8.9 instruction under NER 4.8.9(a1)(2)) to load shed 300 MW of load in the KTS/TTS/ROTS metropolitan area to maintain the system in a secure operating state.

AEMO issued another instruction at 1450 hrs on 13 February 2024 to commence restoration of 150 MW of the load, and a further instruction at 1510 hrs to restore the remaining 150 MW of load in the KTS/TTS/ROTS metropolitan area. At 1515 hrs on 13 February 2024, the actual LOR3 condition was cancelled.

6 Reserve and reliability market notices

As a result of this incident, actual and forecast lack of reserve (LOR) conditions in Victoria were declared. In response to these LOR conditions, AEMO notified the market of its intention to commence contract negotiations for its reliability and emergency reserve trader (RERT) functions. Details of the relevant market notices, capacity shortfalls and RERT notices issued on 13 February 2024 are outlined below. Although RERT was contracted, it was not pre-activated or activated.

Table 4 Reserve and reliability market notices

Time (hhmm)	Market Notice	Details	LOR time period	Capacity requirement	Capacity available
13 February 2024					
1352	114589	Forecast LOR2 in Victoria	1430 hrs 13/2/2024 to 1600 hrs 13/2/2024	384 MW	562 MW
1418	114602	Intention to commence RERT negotiation	Requests for tender for period – 1500 hrs to 1700 hrs	N/A	N/A
1419	114603	Intention to commence RERT negotiation	Duplicate notice	N/A	N/A
1427	114604	Actual LOR3 in Victoria	Customer load shedding of un-interruptible load is occurring in Victoria due to a shortfall in available capacity	Maximum load to be interrupted is up to 450 MW from 1420 hrs on 13/2/2024	
1519	114632	Cancellation of actual LOR3 in Victoria	Actual LOR3 condition in Victoria cancelled at 1515 hrs on 13/2/2024	N/A	N/A
1615	114644	Cancellation of actual LOR2 in Victoria	Actual LOR2 condition in Victoria cancelled at 1614 hrs on 13/2/2024	N/A	N/A

7 Operation of Victoria following the event

Following the trip of the MLTS – SYTS No. 1 and No. 2 500 kV lines, South Australia and the Alcoa Portland (APD) smelter remained connected to the NEM via the Heywood interconnector and via the MLTS A1 and A2 500/220 kV transformers. Under this arrangement, a credible contingency event – the loss of the MLTS A1 500/220 kV transformer – would have resulted in the synchronous separation of South Australia and the APD smelter from the NEM.

To manage power system security for credible contingency events, AEMO issued a direction to a participant to maintain power system security. This was similar to actions applied for the Victorian – South Australia separation event on 31 January 2020⁷ following collapse of six towers on the MLTS – Mortlake and MLTS – Haunted Gully 500 kV lines.

Following the event, Loy Yang A commenced restoration of generation, with unit 2 returning to service at 1606 hrs on 13 February 2024, unit 3 at 2132 hrs on 13 February 2024, unit 4 at 1522 hrs on 14 February 2024 and unit 1 at 0133 hrs on 15 February 2024.

AEMO continues to monitor operational demand in South Australia to manage system security, with potential for directions to ElectraNet to maintain minimum operational demand.

On 15 February 2024 AusNet reconfigured the SYTS 500 kV line switching bays at MLTS to provide additional 500 kV busbar tie facilities. This reconfiguration removed the risk that a credible contingency event would result in the synchronous separation of South Australia and the APD smelter from the NEM.

At the time of writing this report, AusNet is continuing to work on temporary line works to by-pass the line sections with the downed towers and re-establish a 500 kV connection between MLTS and SYTS. The anticipated return to service of the MLTS – SYTS 500 kV lines via emergency structures is 22 February 2024 for the first line and 27 February 2024 for the second line, however this is highly uncertain at this stage and subject to change.

⁷ See https://aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/power_system_incident_reports/2021/final-report-victoria-and-south-australia-separation-event.pdf?la=en.

8 Next steps

AEMO intends to undertake analysis relating to this event and prepare a final incident report⁸ in due course with the input and support of AusNet, AGL⁹, Tilt Renewables¹⁰, Pacific Blue¹¹ and other participants. AEMO has also requested high speed data and other relevant information from a range of participants, particularly in Victoria.

The investigation is expected to include, but not be limited to:

- Confirmation of the exact timing and sequence of events based on available high speed data.
- Confirmation of the cause of the tower failure, including any commonalities with recent tower failures in South Australia¹², Tasmania¹³, Victoria¹⁴ and Western Australia.
- Review of power system security.
- Where relevant, review of operation of any special protection schemes.
- Review of generator performance, including the cause of all generator trips.
- Evaluation of market impacts.
- Distributed photovoltaic (DPV) generation impact.
- Recommendations to improve power system resilience and address issues identified through the review.

⁸ As required by NER 4.8.15(c).

⁹ AGL is the owner of Loy Yang A Power Station.

¹⁰ Tilt Renewables is the owner of Dundonnell WF.

¹¹ Pacific Blue is the owner of Yaloak South WF.

¹² See https://aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/power_system_incident_reports/2022/trip-of-south-east-tailem-bend-275-kv-lines-november-2022.pdf?la=en.

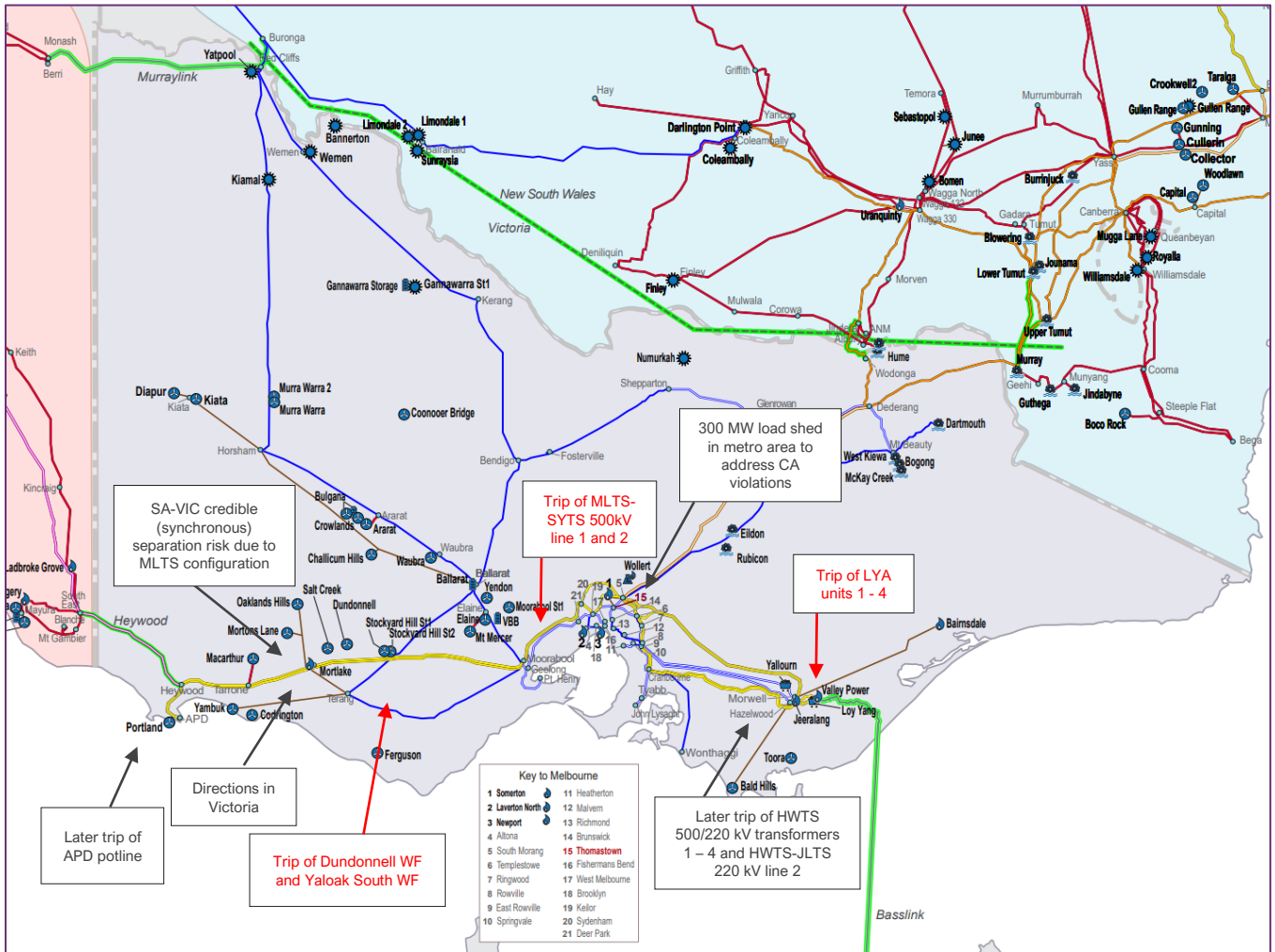
¹³ See https://aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/power_system_incident_reports/2022/trip-of-liapootah---palmerston---waddamana-no-1-and-no-2-220-kv-lines.pdf?la=en.

¹⁴ See https://aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/power_system_incident_reports/2021/final-report-victoria-and-south-australia-separation-event.pdf?la=en.

A1. System diagram

Figure 5 provides an illustration of the key events associated with the incident (red text) and additional information relevant to the ongoing operation and review of the event (black text).

Figure 5 Incident overview



LYA: Loy Yang A.