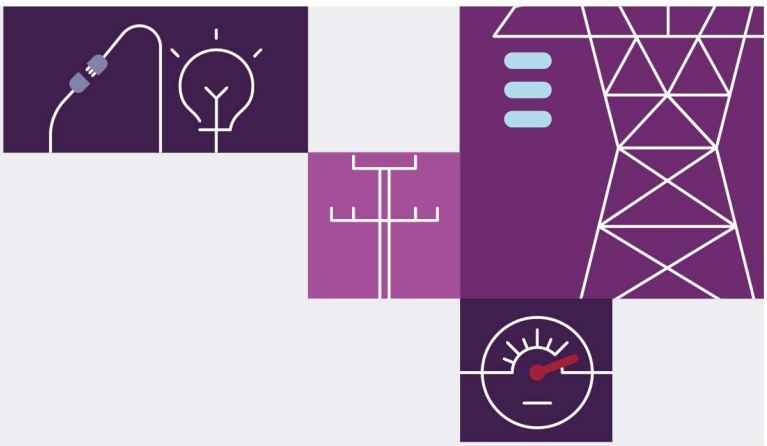
Trip of Liapootah – Palmerston – Waddamana No 1 and No 2 220 kV lines on 14 October 2022

June 2023

Reviewable Operating Incident Report under the National Electricity Rules



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. This report supersedes the preliminary operating incident report for this incident, published in October 2022.

Disclaimer

To inform its review and the findings expressed in this report, AEMO has been provided with data by registered participants as to the status or response of some facilities before, during and after the reviewable incident, and has also collated information from its own observations, records and systems. Any views expressed in this report are those of AEMO unless otherwise stated and may be based on information given to AEMO by other persons. AEMO has made reasonable efforts to ensure the quality of the information in this report but cannot guarantee its accuracy or completeness. Any views expressed in this report may be based on information given to AEMO by other persons.

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

AEMO acknowledges the Traditional Owners of country throughout Australia and recognises their continuing connection to land, waters and culture. We pay respect to Elders past and present.

Incident classifications

Classification	Detail
Time and date of Incident	0919 hrs 14 October 2022
Region of incident	Tasmania
Affected regions	Tasmania
Event type	Environmental – landslide
Generation impact	234 MW
Customer load impact	530 MW
Related reports	Preliminary Report – Trip of Liapootah- Palmerston lines[1]

Abbreviations

Abbreviation	Term
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AEST	Australian Eastern Standard Time
AIS	Anti-Islanding Scheme
AUFLS2	Adaptive Under Frequency Load Shedding scheme 2
AVR	Automatic Voltage Regulator
FCSPS	Frequency Control System Protection Scheme
GPS	Generator Performance Specification
HSM	High Speed Monitoring
HVDC	high voltage direct current
Hz	hertz
kV	Kilovolt/s
MN	Market Notice
MVAr	megavolt amperes reactive
MW	megawatt/s
NEM	National Electricity Market
NER	National Electricity Rules
PMU	Phasor Measurement Unit
pu	Per unit
RRP	Regional Reference Price
RoCoF	Rate of Change of Frequency
TAS	Tasmania
TNSP	Transmission Network Service Provider
UEL	Under-Excitation Limiter

[1] See https://aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/market_event_reports/2022/preliminary-report-trip-of-liapootah-palmerston-lines.pdf?la=en.

Contents

Tables

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1 Overview

This report has been prepared under clause 4.8.15(c) of the National Electricity Rules (NER) in relation to a reviewable operating incident that occurred on 14 October 2022 in Tasmania. It supersedes AEMO's preliminary report published on 28 October 2022. The incident involved non-credible contingency events impacting multiple transmission lines including the trip of a major double circuit 220 kilovolt (kV) line linking the North and South of Tasmania.

Prior to the incident, widespread daily rainfalls totalling 50 mm were observed in northern Tasmania, with localised 24-hour rainfall totals of more than 100 mm to 0900 hrs on 14 October 2022, making it Tasmania's wettest October day on record. Poatina observation station (approximately 10 km to the north-west of the impacted tower) recorded 125.8 mm of rainfall in the 48 hours to 0900 hrs on 14 October 2022. Severe weather warnings for intense rainfall and damaging winds were issued on 13 and 14 October 2022. At 0915 hrs on 14 October 2022, power transfer between North and South Tasmania was approximately 201 megawatts (MW) in the southerly direction.

At approximately 0919 hrs on 14 October 2022, the Liapootah – Palmerston – Waddamana No 1 and No 2 220 kV lines tripped. Post-incident investigation has concluded that this was caused by a landslide impacting the footings and structure of a strain tower on the double circuit line and within the Palmerston – Waddamana section.

The trip of the Liapootah – Palmerston – Waddamana No 1 and No 2 220 kV lines caused the following subsequent events:

- Trip of the Waddamana – Lindisfarne No 1 and No 2 220 kV Lines (at the Waddamana end only).
- Trip of Basslink high voltage direct current (HVDC) interconnector, which was importing 425 MW to Tasmania at the time.
- Trip of Musselroe Wind Farm and Lemonthyme Power Station and the disconnection of Cattle Hill Wind Farm at Waddamana substation due to the 220 kV circuit breaker configuration at Waddamana substation and the loss of the 220 kV lines (a total generation loss of 234 MW).
- Trip of approximately 530 MW of electrical load in Tasmania (480 MW of this being industrial load).

As a result of this incident, North and South Tasmania remained connected only via the remaining in-service Waddamana – Palmerston 110 kV line. With the 220 kV lines out of service, any subsequent trip of this 110 kV line would split Tasmania into two separate electrical islands.

To maintain system security with only one 110 kV line connecting North and South Tasmania, AEMO implemented a range of operational measures as described in Section 5.

AEMO's review has concluded that the power system remained secure, and the Frequency Operating Standard[2] was met in response to this incident and during the subsequent operation of Tasmania while temporary circuit repairs were ongoing.

As this was a reviewable operating incident, AEMO is required 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.

[2] At https://www.aemc.gov.au/sites/default/files/2020-01/Frequency%20operating%20standard%20-%20effective%201%20January%202020%20-%20TYPO%20corrected%2019DEC2019.PDF.

AEMO's conclusions, recommendations and actions arising from its reviews are summarised in Table 1.

Table 1 Summary of findings, conclusions, and recommendations

Findings	Recommendations
The trip of Liapootah – Palmerston – Waddamana No 1 and No 2 220 kV lines was caused by a landslide impacting the footings and structure of a double circuit strain tower supporting these lines.	TasNetworks initially disconnected the affected section of lines between Palmerston – Waddamana allowing the Liapootah – Waddamana section to be placed into service on 19 October 2022. The affected towers were permanently bypassed and the Liapootah – Palmerston – Waddamana lines were returned to service on 2 December 2022.
The trip of the Waddamana – Lindisfarne No 1 and No 2 220 kV lines at the Waddamana end only was as expected due to the circuit breaker switching arrangements at Waddamana substation and the trip of the Liapootah – Palmerston – Waddamana 220 kV lines.	-
The trip of Basslink while transferring 425 MW to Tasmania was due to low Tasmanian power system voltages at the time of the 220 kV line faults. These low voltages caused the Basslink converter to experience a period of extended commutation failure. In response to this, Basslink's loss of thyristor redundancy protection operated and tripped Basslink. Basslink tripped in line with expected performance.	Following the approval of TasNetworks on 15/12/2022 and AEMO on 19/12/2022, a change was implemented on 21/12/2022 that added a 100 millisecond (ms) inhibit of thyristor monitoring after commutation failure. This effectively removes the Basslink extended commutation failure trip mechanism and reduces the risk of a Basslink trip under similar conditions as resulted during this event.
Cattle Hill Wind Farm disconnected at Waddamana when generating 32 MW due the circuit breaker switching arrangements at Waddamana substation and the trip of the Liapootah – Palmerston – Waddamana 220 kV lines. The Liapootah – Waddamana - Palmerston 220 kV transmission lines provide a critical connection between northern and southern Tasmania. The two circuits also provide a connection for Cattle Hill Wind Farm. At Waddamana, each circuit is connected to one 220 kV busbar via isolators. As a result, a fault anywhere between Liapootah and Palmerston results in the loss of the complete circuit length, as well as a busbar at Waddamana.	AEMO recommends TasNetworks considers the installation of line circuit breakers and any associated works to enable the Liapootah – Waddamana and the Waddamana – Palmerston circuits to be sectionalised at Waddamana as part of its plans for Waddamana substation to improve security for the loss of any of the line sections.
Musselroe Wind Farm tripped when generating 148 MW. Musselroe Wind Farm initially reduced its active power output at the inception of the event. TasNetworks has confirmed that if significant voltage drops occur during network faults, the wind farm will enter its multiple fault ride-through mode, causing the active power to drop significantly to maintain connection without tripping. The wind farm finally tripped due to the operation of its Anti-Islanding Scheme triggered by the Slip Acceleration (rate of change of frequency (RoCoF)) input.	AEMO recommends TasNetworks and Musselroe Wind Farm review the inputs to the Anti-Islanding Scheme to minimise the risk the wind farm disconnects due to Slip Acceleration under similar network conditions.
The Lemonthyme Power Station tripped when generating 54 MW. Lemonthyme tripped on under-excitation protection due to operating with high reactive import and low terminal voltage immediately prior to the high bus voltage at Sheffield.	As a result of the trip of the 220 kV lines and the trip of Basslink and subsequent operation of the Frequency Control System Protection Scheme (FCSPS), the north part of Tasmania initially experienced low voltages and then high voltages during this incident. The existing Automatic Voltage Regulator (AVR) at Lemonthyme does not include the Under-Excitation Limiter (UEL) function. AEMO recommends Hydro Tasmania implements the UEL function during the AVR replacement planned by Hydro Tasmania during 2024. This function should minimise the risk of the power station tripping under similar fault conditions.
The Adaptive Under Frequency Load Shedding scheme 2 (AUFLS2) and the Frequency Control System Protection Scheme (FCSPS) operated as expected during this event.	The schemes operated in response to the drop in system frequency due to the 220 kV line faults and the trip of Basslink while importing 425 MW to Tasmania.
The trip of Basslink while transferring 0 MW at 0959 hrs on 14 October 2022 following restoration to service was due to high 220 kV bus voltages, more than 1.06 per unit (pu) (above 232 kV), at George Town substation inhibiting the alternating	Whilst the Basslink protection operated as designed under this condition, AEMO recommended Basslink modify its operating procedure for returning Basslink to service to highlight the risk that high bus voltages, >231 kV in Tasmania or >544 kV in Victoria, will inhibit

Findings	Recommendations
current (AC) filters from being available to switch into service. Under this scenario, Basslink was unable to operate and tripped.	the AC filters from being switched which, during the Basslink deblock sequence, will result in a trip of Basslink. AEMO was advised by Basslink on 9 June 2023 that it has updated its operating procedure.

This report is prepared in accordance with clause 4.8.15(c) of the NER. It is based on information provided by Participant(s) noted in Table 6 and available to AEMO.

2 The incident

2.1 Pre-event conditions

2.1.1 Generation dispatch and demand

A summary of Tasmanian operational conditions at 0915 hrs on 14 October 2022, just prior to the incident, is shown in Table 2.

Table 2 Tasmanian key system conditions at 0915 hrs, 14 October 2022

Quantity description	Value (MW)
Tasmanian operational demand	1,167
Tasmanian scheduled and semi scheduled generation	718
Tasmanian distributed photovoltaic (PV) generation	96
Basslink flow into Tasmania (George Town end)	446
North to South flow[A]	201

A. Cut-set flow from Palmerston to Waddamana and Liapootah on both 220 kV double circuit and 110 kV lines.

Table 3 provides a summary of Tasmanian generator dispatch at 0915 hrs on 14 October 2022.

Table 3 Tasmania generation dispatch at 0915 hrs, 14 October 2022

Station name	Dispatched generation (MW)	Station name	Dispatched generation (MW)
Bastyan	0	**Lake Echo**	0
Bell Bay	0	**Mackintosh**	0
Cethana	79	**Meadowbank**	35
Cattle Hill Wind Farm	24	**Musselroe Wind Farm**	145
Devils Gate	58	**Poatina**	0
Fisher	46	**Reece**	0
Gordon	21	**Tarraleah**	55
Granville Harbour Wind Farm	36	**Trevallyn**	99
John Butters	0	**Tribute**	0
Lemonthyme/Wilmot	54	**Tungatinah**	7
Catagunya/Liapootah/Wayatinah	58	**Tamar Valley CCGT / OCGT**	0
Bluff Point Wind Farm	22	**Studland Bay Wind Farm**	21

2.1.2 Prior outages

There were no planned transmission outages in Tasmania at the time of the event on 14 October 2022.

Due to water ingress at Poatina Power Station one day before the incident, on 13 October 2022, Poatina – Palmerston 220 kV lines were de-energised at Hydro Tasmania's request.

2.1.3 Weather conditions and operational forecasts in Tasmania on 14 October 2022

A cold front and associated rain-bearing cloud band over Tasmania brought widespread heavy rainfall to the region on 13 and 14 October 2022. The weather conditions relevant to this event can be summarised as follows:

- An overcast day on 14 October 2022, with mild temperatures and heavy rainfall. Operational demand in Tasmania was expected to peak at 1,326 MW at 0730 hrs, as per the day-ahead (1230 hrs) pre-dispatch forecast. Hobart recorded a minimum temperature of 11.0°C and a maximum temperature of 16.4°C.
- Widespread daily rainfalls totalling 50 mm were observed in northern Tasmania, with localised 24-hour rainfall totals of more than 100 mm to 0900 hrs on 14 October 2022, making it Tasmania's wettest October day on record. Poatina observation station (approximately 10 km to the north-west of the impacted tower) recorded 125.8 mm of rainfall in the 48 hours to 0900 hrs on 14 October 2022. Severe weather warnings for intense rainfall and damaging winds were issued on 13 and 14 October 2022.
- Major flood warnings were current at 0900 hrs on 14 October 2022 for Macquarie River, Meander River, Mersey River, Forth River, River Derwent, North Esk River and South Esk River.
- High wind generation was forecast (up to approximately 75% of regional capacity), with wind generation expected to ease to moderate levels for a period in the afternoon.

2.2 Event

At approximately 0919 hrs on 14 October 2022, the Liapootah – Waddamana – Palmerston No 1 and No 2 220 kV lines tripped. Post-event investigation concluded that this was caused by a landslide impacting the footings and structure of a strain tower supporting this double circuit transmission line (as shown in Figure 1).

Figure 1 Photograph of double circuit strain tower damaged by landslide

Image supplied by TasNetworks.

The trip of the Liapootah – Palmerston – Waddamana No 1 and No 2 220 kV lines led to the following subsequent events and conditions:

- The trip of both Waddamana – Lindisfarne 220 kV lines, at the Waddamana end only.
- The trip of Basslink HVDC interconnector, which was importing 425 MW to Tasmania at the time.
- The trip of 234 MW of generation in Tasmania:
  - Cattle Hill Wind Farm line disconnected at Waddamana as expected (32 MW).
  - Musselroe Wind Farm tripped (148 MW).
  - Lemonthyme Power Station tripped (54 MW).
- The loss of approximately 530 MW of load in Tasmania, 480 MW of which was industrial load tripped due to the operation of the tripped frequency control ancillary services (FCAS) "Adaptive Under Frequency Load Shedding Scheme 2" (AUFLS2) and Frequency Control System Protection Scheme (FCSPS) remedial action schemes. These schemes operated in response to the event, including the trip of Basslink and the loss of Tasmanian generation.

The Liapootah – Palmerston – Waddamana 220 kV Lines are two of the three lines that connect North and South Tasmania. Following the trip of the two 220 kV lines, North and South Tasmania remained connected only by the remaining in-service Waddamana – Palmerston 110 kV line. With the 220 kV lines out of service, any subsequent trip of this 110 kV line would split Tasmania into two separate electrical islands.

To maintain system security with only one 110 kV line connecting North and South Tasmania, AEMO implemented a range of operational measures as described in Section 5.

2.2.1 Sequence of events

Table 4 below the key events during the incident.

Table 4 Sequence of incident events

Event sequence (hh:mm:ss.000)	Description	Notes
14/10/2022 09:18:55.580	Trip of both Liapootah – Palmerston – Waddamana 220 kV lines	Caused by a landslide damaging a transmission line tower.
	De-loading of both Waddamana – Lindisfarne 220 kV lines	Lines opened at the Waddamana end only. This was due to the circuit breaker switching arrangements at Waddamana substation and the trip of the Liapootah – Palmerston – Waddamana 220 kV lines.
09:18:56.213	Cattle Hill Wind Farm line disconnected at Waddamana while generating 32 MW	Cattle Hill Wind Farm line was disconnected from the network as expected due to the circuit breaker configuration and the trip of the four 220 kV lines connecting Waddamana to the wider network.
09:18:56.445	Basslink tripped while transferring 425 MW to Tasmania	Caused by extended commutation failure.
09:18:56.461 to 09:18:56.920	Approximately 530 MW of load tripped (480 MW being industrial load)	Industrial load tripped due to the operation of FCSPS and AUFLS2. In addition, due to the voltage reduction associated with this event, there was an approximate 35 MW load drop off.
09:18:56.785	Musselroe Wind Farm tripped while generating 148 MW	Anti-Islanding Scheme operated from its Slip Difference function.

Event sequence (hh:mm:ss.000)	Description	Notes
09:19:01.420	Lemonthyme Power Station tripped while generating 54 MW	Lemonthyme tripped on under-excitation protection due to operating with high reactive import and low terminal voltage immediately prior to the high bus voltage at Sheffield substation.
0949 hrs	Basslink re-energised at George Town	-
0959 hrs	Basslink tripped while transferring 0 MW	Basslink was returned to service but tripped due to high voltage at George Town blocking the AC filters from switching into service. Under this scenario, Basslink was unable to operate and tripped.
1015 hrs	Basslink returned to service and constrained to 0 MW	TasNetworks adjusted the bus voltage at George Town substation allowing Basslink to reconnect. Constraint set I-VT_000 which limits Tasmanian import to 0 MW remained in place to maintain system security.
1044 hrs	All tripped industrial load restored	-
1200 hrs	Flow on Basslink managed via constraints	Victoria to Tasmania flow limited to 50 MW until 1240 hrs and 100 MW from 1240 to 1510 hrs.
1510 hrs	Basslink resumed normal operation	-
19/10/2022 2030 hrs	Liapootah – Waddamana No 1 and No 2 220 kV lines restored	Restored with the Palmerston Tee Waddamana sections isolated due to damaged towers approximately 10 km from Palmerston substation see Figure 3.
02/12/2022 1528 hrs	Liapootah – Palmerston – Waddamana No 1 and No 2 220 kV lines fully restored	Restored after reconnecting Palmerston Tee Waddamana sections of the lines once the damaged towers were by-passed.

2.3 Root cause of tower failure

As described in Section 2.1.3, weather conditions in Tasmania brought widespread heavy rainfall to the region on 13 and 14 October 2022.

The severe rainfall and resulting ground conditions caused a landslide which impacted the footings and structure of a double circuit strain transmission tower supporting the Liapootah – Palmerston – Waddamana 220 kV lines.

The subsequent movement of the strain tower resulted in the failure of the top section of an adjacent suspension tower, causing the line conductors to clash, tripping both lines.

2.4 Analysis of the event and power system response

2.4.1 Protection systems operation.

The Liapootah – Palmerston – Waddamana No 1 and No 2 220 kV lines are protected by three-ended current differential protection (A protection) and distance protection (B protection) with accelerated Zone 2 and permissive intertrip (PIT).

The following protection and control schemes operated, consistent with expected performance:

- Trip of Liapootah – Palmerston – Waddamana No 1 220 kV line:

  - White phase to earth fault detected triggering single-phase tripping by the A and B protection schemes and initiation of the automatic reclosing sequence.
  - Blue phase to earth fault occurred while the line reclose was in progress.
  - The protection correctly tripped all three phases of the line and the auto reclose sequence was stopped.
- Trip of Liapootah – Palmerston – Waddamana No 2 220 kV line:
  - White and Blue phase to earth fault detected correctly triggering three pole tripping by the A and B protection schemes. Auto reclose was correctly not initiated as faults on multiple phases were detected.

2.4.2 Remedial Action Scheme operation

During the event, the disturbance caused both the Frequency Control System Protection Scheme (FCSPS) and the Adaptive Under Frequency Load Shedding 2 (AUFLS2) scheme to operate and trip industrial load as expected. The AUFLS2 scheme operates in similar way to under frequency load shedding (UFLS) and uses load blocks to provide switched R6 FCAS[3].

3.1.1 (see Section 3) shows a sharp decline in Tasmanian frequency following the trip of 220 kV lines, generation and Basslink. The operation of the FCSPS and AUFLS2 schemes tripped 480 MW of industrial load from the total of 530 MW total load which tripped in this event. The remedial action schemes effectively arrested the frequency drop with the frequency recovering over the following three minutes.

TasNetworks have confirmed all the industrial load that tripped as part of this event was armed by both the FCSPS and AUFLS2.

AEMO has reviewed operation both control schemes and concluded that all operations were as expected.

2.4.3 Response of distributed PV and distributed load

Distributed PV was generating approximately 96 MW in Tasmania at the time of the incident. It is estimated that distributed PV reduced by approximately 28% or 26 MW (18 – 33 MW) in response to the disturbance[4]. The observed distributed PV disconnections may be in response to low voltages (below 0.8pu), multiple subsequent voltage disturbances, low frequency (below 49Hz), or high RoCoF (exceeding ±1Hz/s), all of which were observed in this event, and have been observed to cause distributed PV disconnections[5].

After accounting for known tripping of industrial loads, total operational demand in Tasmania was estimated to reduce by approximately 50 MW in response to the disturbance, suggesting there may have been a reduction in underlying load of approximately 75 MW (accounting for estimated distributed PV disconnections). High speed monitoring is only available at a limited number of radial network locations with residential and commercial load in Tasmania. At these sites, the measured change in active power flows was less than 1 MW, and voltages remained above 0.7pu (in the range that would not typically lead to measurable load drop-off).

[3] The R6 FCAS is the 6 second fast raise ancillary service, referred in NER 3.11.2(a).

[4] AEMO has limited visibility of distributed PV disturbance responses in Tasmania, with monitoring only available at a sample of 155 distributed sites. This estimate is based on observed disconnections in this limited sample set, with scaling to remove sample bias.

[5] AEMO (May 2021) *Behaviour of distributed resources during power system disturbances*, at https://aemo.com.au/-/media/files/initiatives/der/2021/capstone-report.pdf?la=en&hash=BF184AC51804652E268B3117EC12327A.

3 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[6].

3.1 Frequency and voltage performance

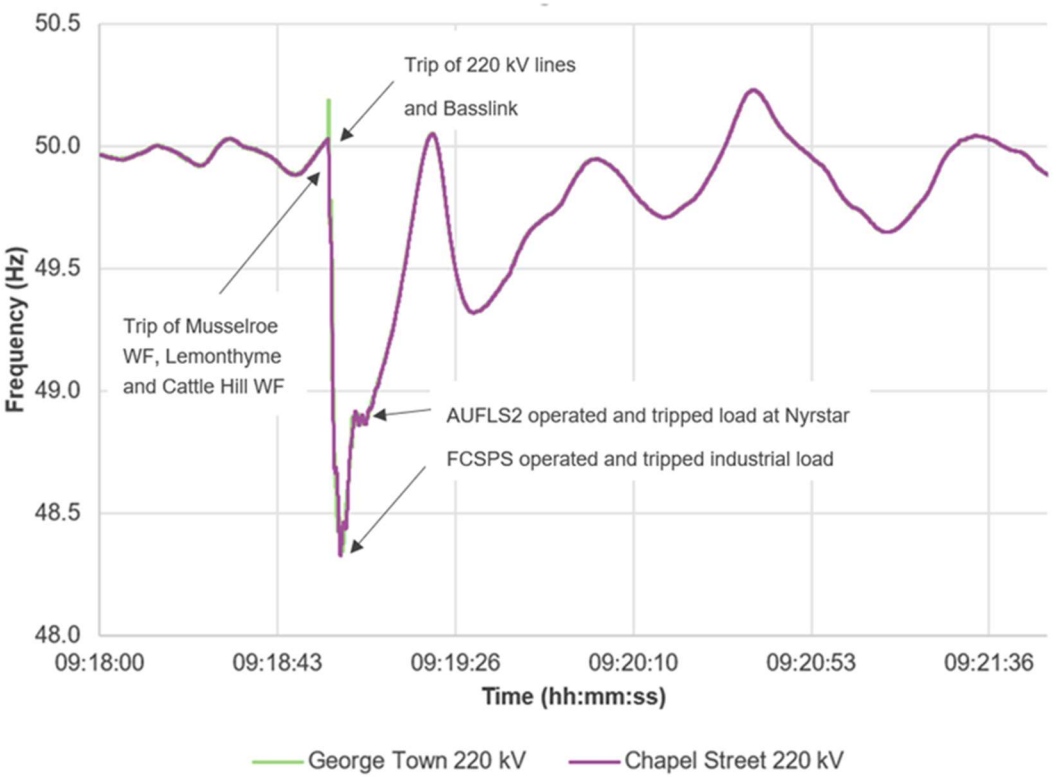
3.1.1 Frequency response

The disturbance caused by the trip of the Liapootah – Palmerston – Waddamana No 1 and No 2 220 kV lines resulted in the trip of Basslink (425 MW import to Tasmania) and the trip of Tasmanian generation (234 MW). In response to the incident, the Tasmanian frequency fell to 48.35 hertz (Hz). The AUFLS2 scheme and FCSPS operated correctly, tripping 480 MW of industrial load and allowing the frequency to recover over the following 3 minutes.

3.1.1 below shows Tasmanian frequency during the event. It shows that measured frequencies were closely aligned across the island (as measured at George Town and Chapel Street substations). This was expected given that North and South Tasmania remained electrically connected throughout the incident. The frequency declined to a minimum of 48.35 Hz and began recovering after the frequency remedial action schemes had operated. Mainland NEM measured frequency remained within the normal operating frequency band during the incident.

[6] 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.

Figure 2 Tasmanian frequency during the incident (PMU recordings)



The power system remained in a secure operating state and the Frequency Operating Standard[7] was met throughout this incident.

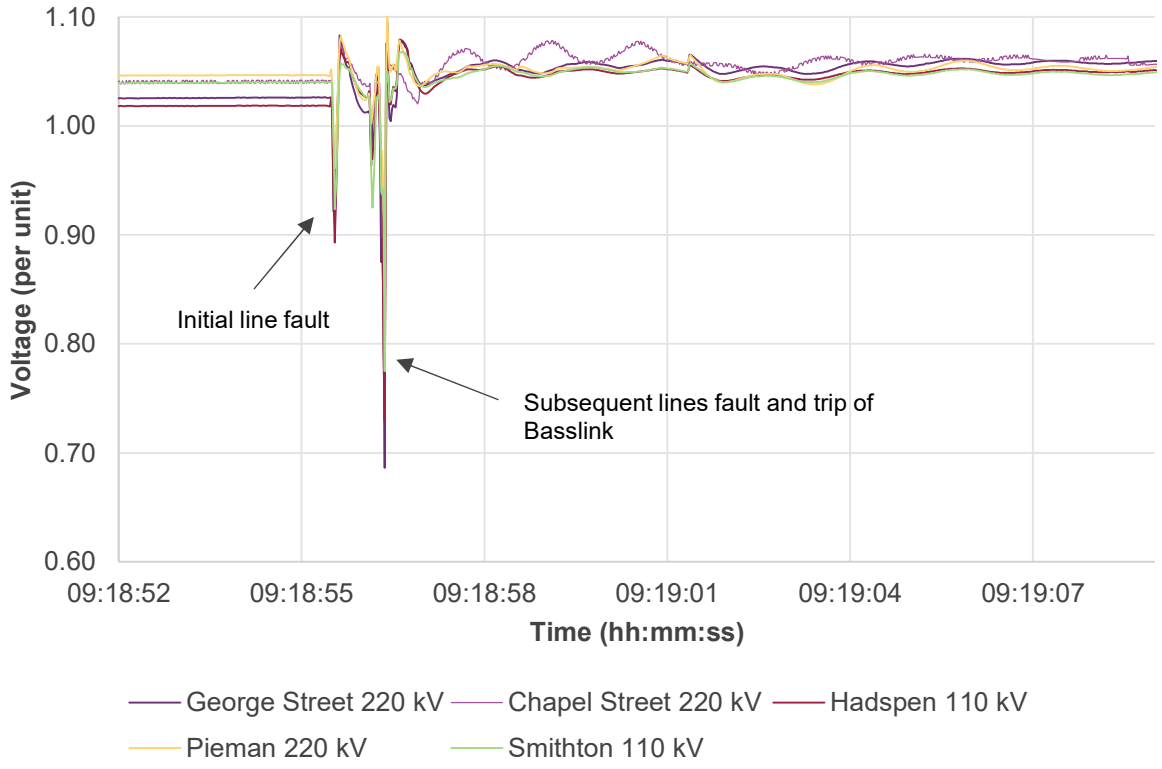
3.1.2 Voltage response

Figure 3 shows voltages at various locations across Tasmania during the incident. It shows the initial voltage dipping to approximately 0.89 per unit (pu) (195.8 kV) followed by a more severe dip 1 second later to 0.68 pu (149.6 kV). The trace indicates there were some post fault voltage oscillations that damped out over approximately 10 seconds.

The first shallow voltage disturbance aligns with the initial 220 kV line fault, followed by a deeper disturbance approximately 1 second later when Basslink tripped coincident with the second 220 kV line trip.

[7] At https://www.aemc.gov.au/sites/default/files/2020-01/Frequency%20operating%20standard%20-%20effective%201%20January%202020%20-%20TYPO%20corrected%2019DEC2019.PDF.

Figure 3 Voltages during incident (PMU recordings)



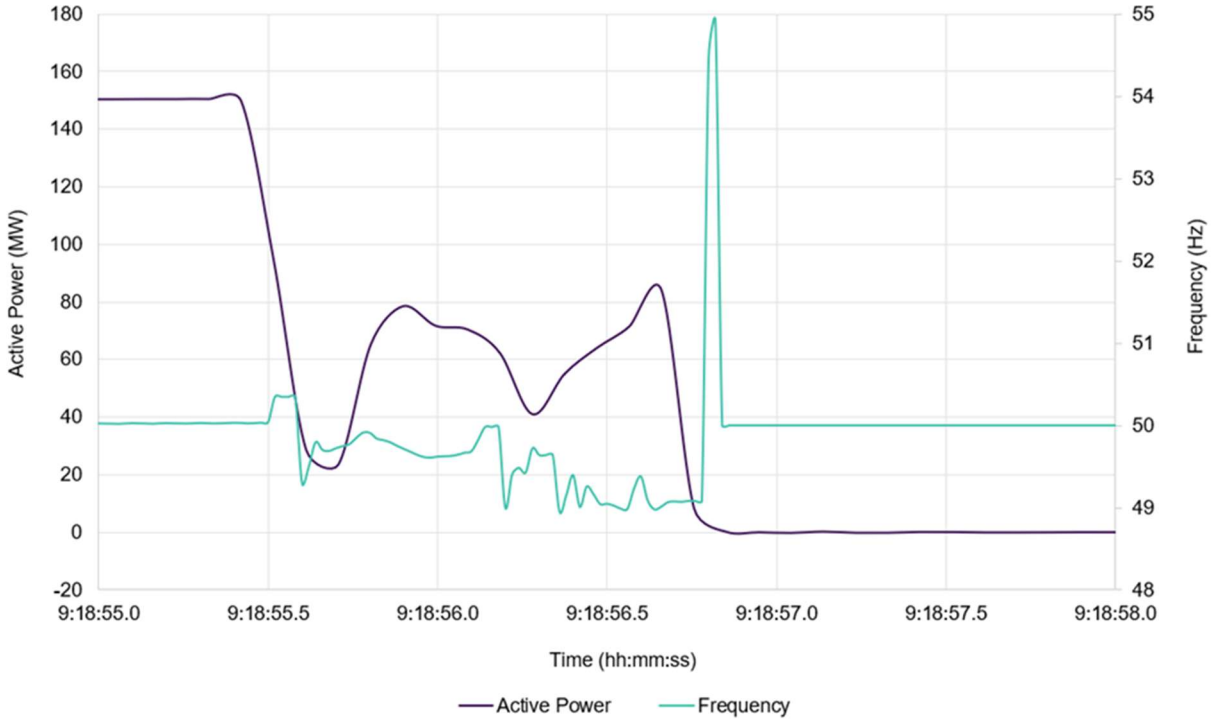
3.2 Generator and Basslink performance

As part of AEMO's investigation of this incident, AEMO analysed the performance of certain generators and Basslink which responded to the trip of Liapootah – Palmerston – Waddamana No 1 and No 2 220 kV lines.

3.2.1 Musselroe Wind Farm

Musselroe Wind Farm (MRWF) tripped due to operation of anti-islanding protection. At the time of the event the wind farm was operating at 148 MW.

Figure 4 Musselroe Wind Farm active power and frequency



The Anti-Islanding Scheme (AIS) has two logical inputs which are utilised for Absolute Bus Angle Difference and rate of Frequency Difference change (similar to RoCoF). The MRWF tripped due the operation of the Slip Difference function associated with its AIS during this event.

Absolute Bus Angle Difference and Slip Acceleration are currently set to 28 degrees and 1 Hz/s respectively. The trip logic requires one of the two logical inputs to be true. The scheme is set up such that the Bus Angle Difference will primarily operate before the Slip Acceleration (hence being the back-up logic). The Absolute bus angle difference compares the angles between Derby and Hadspen[8] substations. Once active for approximately 10 ms, a time delay of 500 ms is triggered and the trip is sent to the circuit breaker at Derby substation.

AEMO notes the sudden drop in active power output from the wind farm from the beginning of the system disturbance before tripping on AIS. TasNetworks has confirmed that if significant voltage drops occur during network faults, the wind farm will enter its multiple fault ride-through mode and cause the active power to drop significantly to maintain connection (without tripping).

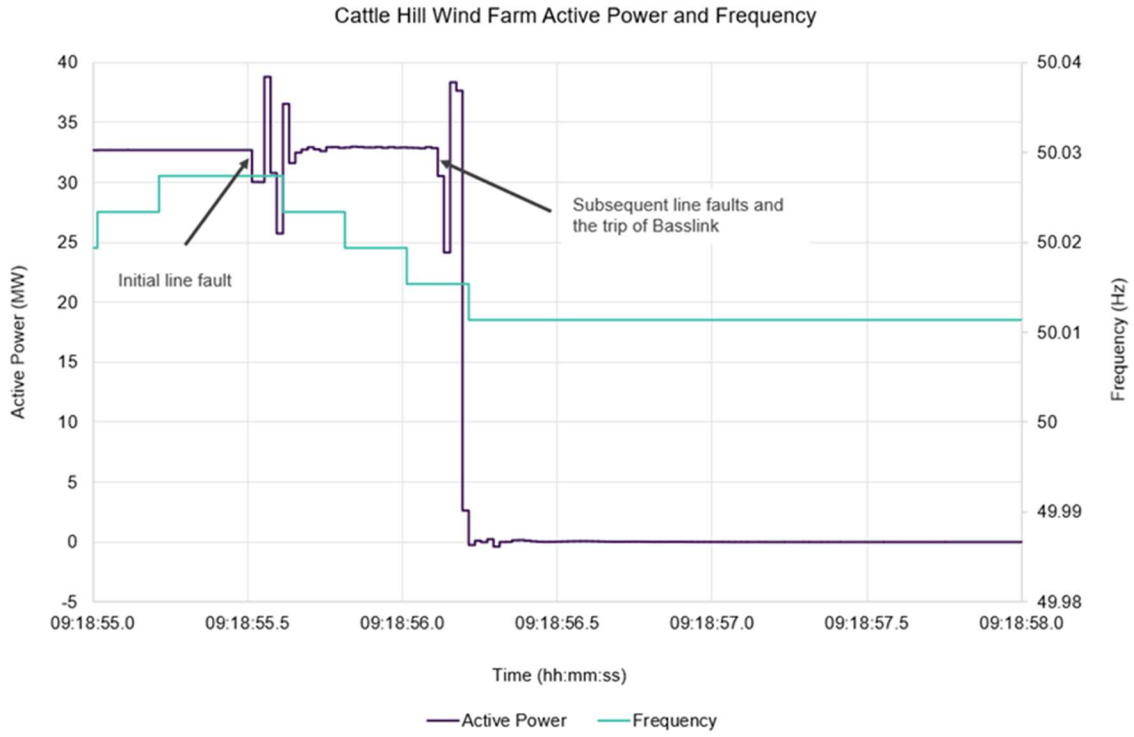
The initial disturbance caused the voltage at Hadspen substation to drop below 0.9 pu which coincides with the active power ramp down by the wind farm. This is because the threshold for Low Voltage Ride-Through (LVRT) had been exceeded and the wind farm began to prioritise reactive power control. Since LVRT suspends normal operation of the plant, control over the active power during LVRT is given low priority. This behaviour has been checked by TasNetworks and verified against the control parameters supplied in the plants releasable user guide (RUG).

[8] Musselroe Wind Farm is connected radially to the main system via Derby to Hadspen substations.

3.2.2 Cattle Hill Wind Farm

Cattle Hill Wind Farm (CHWF) disconnected as expected due to the circuit breaker configuration at Waddamana substation. The circuit breakers are configured such that clearance of a fault on the Liapootah – Palmerston – Waddamana 220 kV lines also trips the Waddamana – Cattle Hill 220 kV line.

Figure 5 Cattle Hill Wind Farm active power and frequency



3.2.3 Lemonthyme Power Station

Lemonthyme Power Station (LMPS) tripped due to operation of its under-excitation protection during the event.

Figure 6 shows the bus voltage at Sheffield substation pre and post fault. The bus voltage went from approximately 1.04 pu (228 kV) and increased significantly to 1.06 pu (233.2kV).

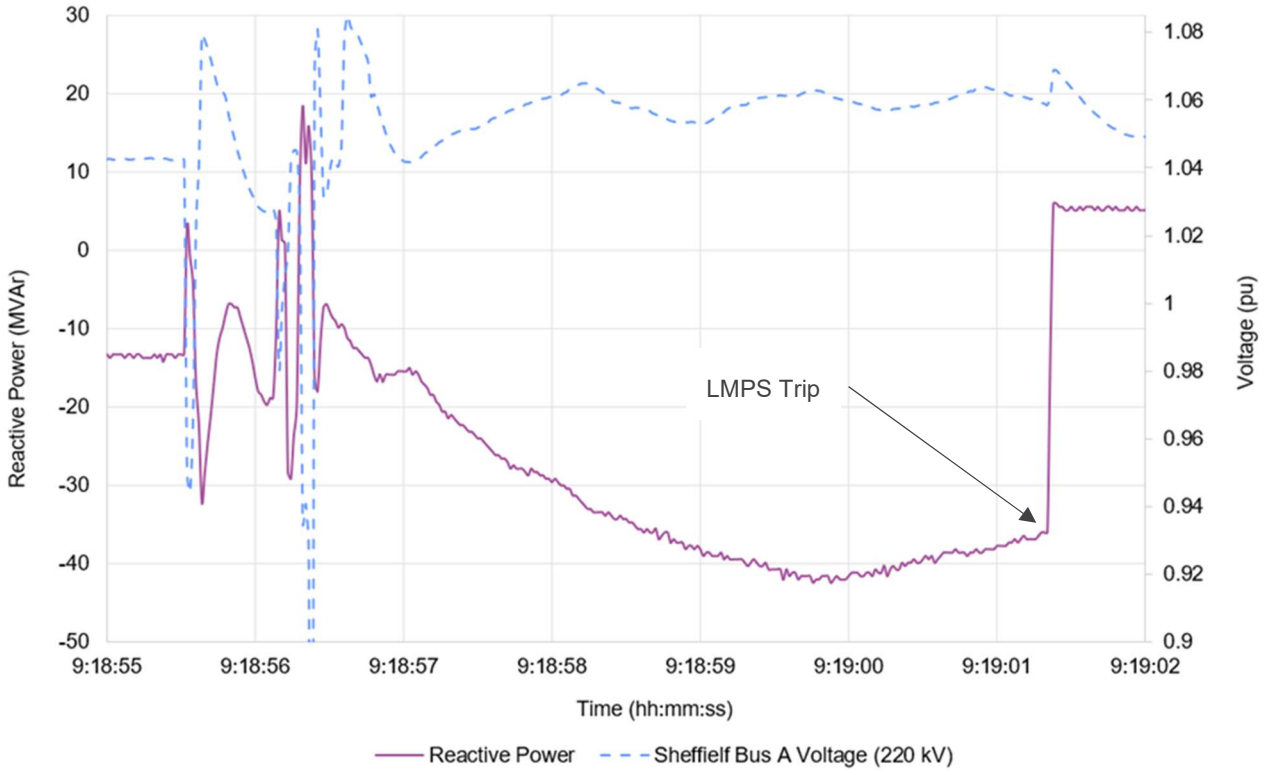
Hydro Tasmania has indicated that immediately prior to the event, LMPS was operating with high reactive power import at 0.957 pu terminal voltage. Immediately after the trip of the 220 kV transmission lines, LMPS' reactive output increased to oppose Sheffield bus voltage reduction and continued to act in opposition to the subsequent voltage oscillations until approximately 09:18:57 when the LMPS operating point had reached, if not crossed the under-excitation protection 3-second characteristics.

In any case, from this time the further increase of Sheffield bus voltage caused LMPS operating point to further cross into this under-excitation protection characteristic and hence tripped the unit.

It has been noted that the LMPS unit does not have an Under-Excitation Limiter (UEL). With sufficient time, the dispatch voltage control scheme could have otherwise re-dispatched LMPS' target VARs to return to within operational limits. However, this did not occur prior to the 3-second delay for protection operation.

Hydro Tasmania has indicated that LMPS unit has an Automatic Voltage Regulator (AVR) upgrade as part of the machine modernisation scheduled in 2024, replacing the existing AVR. This upgrade will allow the machine to operate with a UEL.

Figure 6 Lemonthyme Power Station reactive power and voltage



3.2.4 Basslink

Basslink high voltage direct current (HVDC) interconnector was importing 425 MW to Tasmania at the time of the event. The trip of the Liapootah – Palmerston – Waddamana 220 kV lines resulted in two disturbances approximately 1 second apart between 09:18:55.580 and 09:18:56.385. Data from High Speed Monitoring (HSM) records shows the tripping of Basslink at 09:18:56.445 on 14 October 2022. This time coincides with second disturbance caused by the 220 kV line faults. Due to this second disturbance, the voltage recorded at George Town dropped to 0.68 per unit (149.6 kV) (see 3.1.13 above).

The Tasmanian system voltage during this event was below that required to maintain commutation of Basslink's HVDC converter, and during this period of extended commutation failure, the loss of thyristor redundancy protection operated as expected and tripped Basslink.

After the extended commutation failure trip, Basslink was returned to service at 0949 hrs on the same day. However, at 0959 hrs, Basslink tripped due to high voltages on the AC network (with voltages more than 232 kV). For Basslink to operate, the AC filters must be available to be connected to the facility once Basslink deblock is active. The high bus voltage at George Town substation inhibited the AC filters from being switched. Under this scenario, Basslink was unable to operate and tripped.

Basslink was restored successfully at 1005 hrs on 14 October 2022. Basslink power transfer was constrained to 0 MW until 1200 hrs based on the load blocks available for FCSPS (see Section 4). Flow limits on Basslink continued to be managed via constraints until 1510 hrs, at which point Basslink resumed normal operation.

While the Basslink protection operated as designed under this condition, AEMO recommended Basslink modify its operating procedure for returning Basslink to service to highlight the risk that high bus voltages, >231 kV in Tasmania or >544 kV in Victoria, will inhibit the AC filters from being switched which, during the Basslink deblock sequence, will result in a trip of Basslink.

AEMO was advised by Basslink on 9 June 2023 that it has updated its operating procedure.

3.3 Power system security following the trip of the 220 kV lines

Due to the trip of the Liapootah – Palmerston – Waddamana No 1 and No 2 220 kV Lines at 0919 hrs on 14 October 2022, North and South Tasmania remained connected via only a single 110 kV line between Palmerston and Waddamana. As a result, the separation of North and South Tasmania into separate synchronous islands was considered a credible contingency. AEMO implemented appropriate system constraints to reflect this operating arrangement and maintain power system security.

AEMO has concluded that the power system remained secure, and the Frequency Operating Standard was met in response to this incident and during the subsequent operation of Tasmania while temporary circuit repairs were ongoing.

3.4 Reclassification

Prior to the event, the coincident trip of Basslink with any transmission line in Tasmania was reclassified as a credible contingency event, for Basslink flow in the direction of Victoria to Tasmania only, as advised in market notice (MN) 83081[9] dated 1 March 2021.

A reclassification was also in place for coincident trip of any 220 kV line from Waddamana with a quantity of load[10], as advised in MN 68408 dated 17 May 2019.

AEMO correctly identified that a reclassification of the Liapootah – Waddamana – Palmerston 220 kV lines was not required as the lines were not returned to service.

TasNetworks initially disconnected the impacted sections of lines, allowing the Liapootah – Waddamana lines to be returned to service five days later on the 19 October 2022. The line sections affected by the tower damage were re-strung to effectively bypass the impacted towers, and on 2 December 2022 the Liapootah – Palmerston – Waddamana No 1 and No 2 220 kV Lines returned to normal service[11]. The damaged towers are located in a valley and were ultimately abandoned. The lines were re-strung to a slightly higher tension, avoiding the need to replace the damaged towers.

Following the incident on 18 October 2022, AEMO updated an existing reclassification under Market Notice (MN) 68408, to reclassify the loss of any 220 kV or 110 kV line in Southern Tasmania in conjunction with a

[9] Published at https://aemo.com.au/market-notices.

[10] The load at risk of tripping with a 220 kV Waddamana line trip, was quantified as = (total Nystar load measured by SCADA – 25 MW of stable load) + 5 MW of Boyer load.

[11] AEMO is required to assess whether or not to reclassify a non-credible contingency event as a credible contingency event – NER clause 4.2.3A(c) – and to report how the reclassification criteria were applied – NER clause 4.8.15(ca).

quantity of load[12] as a credible contingency event. This reclassification was put in place because AEMO considered simultaneous trip of any Southern Tasmanian 220 kV or 110 kV circuit[13] and the respective load to be reasonably possible.

This reclassification update was applied at 1535 hrs on 18 October 2022, and applied until further notice, as documented in MN 102360.

On 30 January 2023, AEMO issued MN 105392 removing the reclassification of the coincident trip of Basslink with any transmission line in Tasmania for Basslink flow in the direction of Victoria to Tasmania as a credible contingency event. The reclassification removal was made based on information from TasNetworks following setting changes applied on the George Town end of Basslink on 21 December 2022.

[12] The load at risk of tripping with a 220 kV or 110 kV Southern Tasmanian line trip, is quantified as = (total Nystar load measured by SCADA – 25 MW of stable load) + 5 MW of Boyer load.

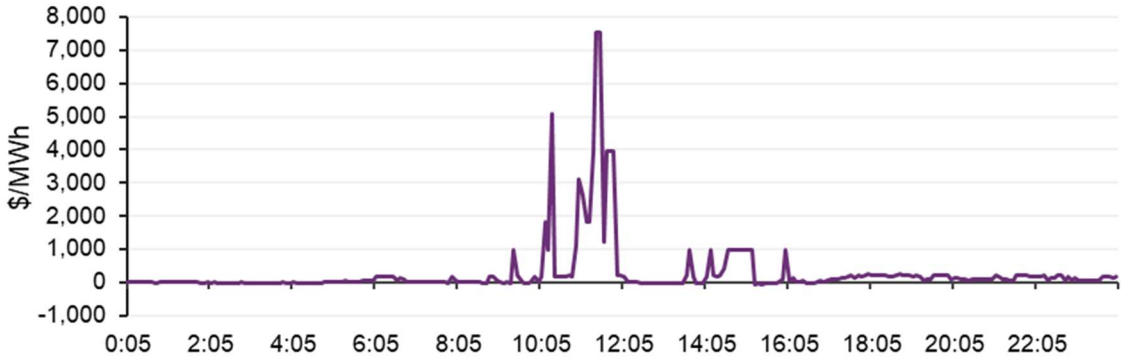
[13] The previous reclassification was for trip of any 220 kV line from Waddamana, and the same load.

4 Market information

In the energy market, spot prices in the region spiked above $1,000/megawatt hour (MWh) on 14 October 2022 for 14 trading intervals between 1010 hrs and 1150 hrs, peaking at $7,522/MWh for 10 minutes in the 1125 hrs and 1130 hrs dispatch intervals.

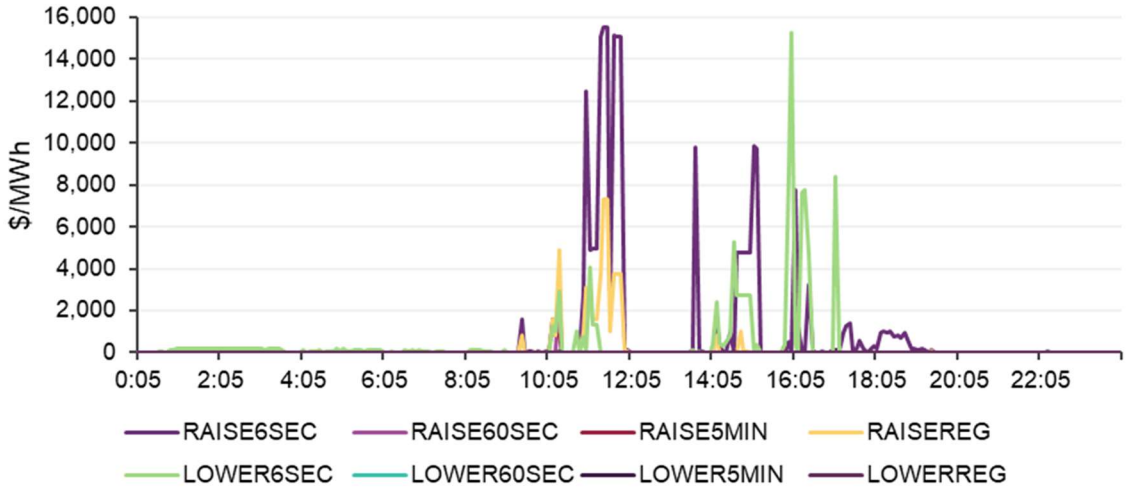
Figure 7 below illustrates the 5-minute Tasmanian energy price outcomes on 14 October 2022.

Figure 7 Tasmania energy price on 14 October 2022



Tasmanian prices in all Raise services (Raise 6 second, Raise 60 second, Raise 5 minute and Raise Regulation) and Lower 6 Second service also exceeded $1000/MW at various trading intervals following the incident. Raise 6 second market prices were particularly volatile, reaching Market Price Cap of $15,500/MW between 1125 hrs and 1130 hrs, while Lower 6 second market reached $15,239/MW at 1600 hrs on the same day (See Figure 8).

Figure 8 Tasmania FCAS prices on 14 November 2022

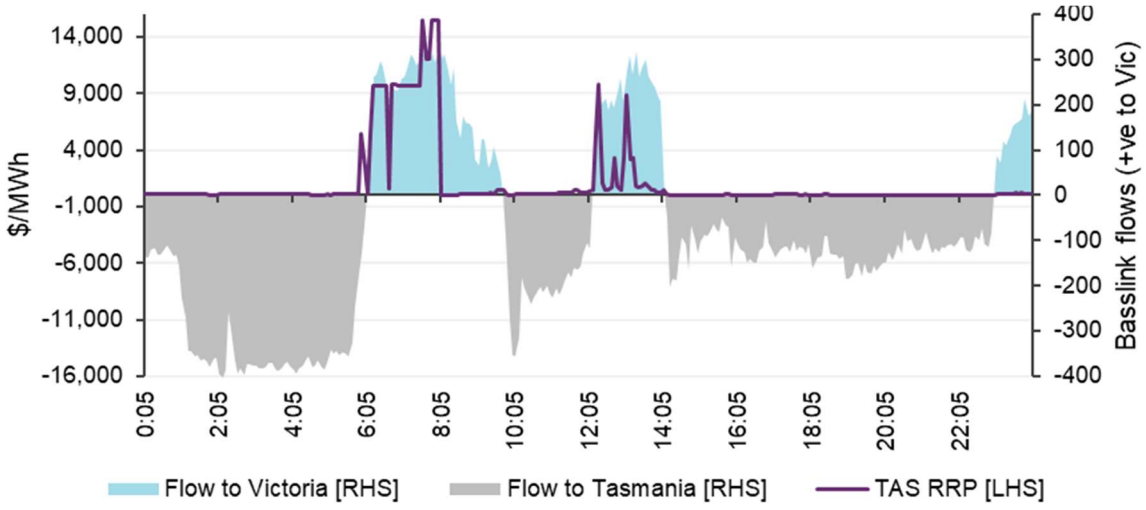


Several factors led to the high price volatility across both energy and FCAS markets following the incident, including:

- The loss of supply to Tasmania from the mainland via Basslink interconnector from 0919 hrs until 1200 hrs (as Basslink flows were limited to zero after Basslink's return to service at 1010 hrs until 1200 hrs to maintain system security),
- The loss of 234 MW of supply from the tripping of Tasmanian generation (Musselroe Wind Farm, Cattle Hill Wind Farm and Lemonthyme Power Station), and
- High local FCAS requirements, especially Raise 6 and Lower 6 second services, due to Basslink being limited to zero and the need to manage contingencies within Tasmania with a heavily constrained network.

From 12 to 19 November 2022, severe storms in South Australia resulted in damage to lines connecting South Australia and Victoria. On 14 November 2022, constraints required flows from Tasmania into Victoria from northern Tasmanian generation while constraints limited southern generation to avoid an overload on the remaining 110 kV transmission line connecting North and South Tasmania. These two requirements resulted in further volatility in Tasmania. One month after the incident and prior to the Liapootah – Palmerston lines being returned to service, the Regional Reference Price (RRP) exceeded $1,000/MWh for 33 trading intervals across the day (see Figure 9).

Figure 9 Tasmania energy price and Basslink flow on 14 November 2022



The constraint sets that were invoked on 14 October 2022 to manage the incident are listed in Table 5 below.

Table 5 Constraints set invoked on 14 October 2022 in response to the incident

Set name	Time invoked (hrs)	Time revoked* (hrs)	Description
I-BL_ZERO	0930	0955	Limit Basslink to zero in either direction as it was out of service.
T-X_LIPM_WACB	0935	1045	Set to manage outage of both Liapootah – Waddamana – Palmerston 220 kV lines, with associated 220 kV circuit breaker at Waddamana out of service.
T-WIND_100	1005	N/A	Discretionary 100 MW upper limit on Tas Wind Generation, applied based on limit advice for operating Tasmania at credible risk of separation between North and South.
T-LIPM_PMWA_N-3	1005	1600	Set to manage outage of both Liapootah – Waddamana – Palmerston 220 kV lines and

Set name	Time invoked (hrs)	Time revoked* (hrs)	Description
			the Palmerston - Waddamana 110 kV line as a credible contingency.
F-TAS_NTH_STH_ISLE	1005	1915	FCAS constraint set to manage North/South separation between Palmerston and Liapootah/Waddamana.
I-BL_ZERO	1005	1015	Limit Basslink to zero in either direction as it was out of service.
I-TV_150	1005	15/10/2022 0815	Flow from Tasmania to Victoria on Basslink upper limit of 150 MW. Constraint based on limit advice for operating Tasmania during credible risk of separation between North and South.
I-VT_000	1005	1200	Flow from Victoria to Tasmania on Basslink upper limit of 0 MW. Level of constraint based on load blocks available for FCSPS.
I-VT_050	1200	1240	Flow from Victoria to Tasmania on Basslink upper limit of 50 MW. Level of constraint based on load blocks available for FCSPS.
I-VT_100	1240	1510	Flow from Victoria to Tasmania on Basslink upper limit of 100 MW. Level of constraint based on load blocks available for FCSPS.
T-X_LIPM_WACB	1600	N/A	Set to manage outage of both Liapootah – Waddamana – Palmerston 220 kV lines, with associated 220 kV circuit breaker at Waddamana out of service.
F-TAS_NTH_STH_RISK	1900	N/A	FCAS constraint to manage credible risk of Tasmania North/South separation between Palmerston and Liapootah/Waddamana. Ensures a distribution of Tasmania dispatched FCAS between North and South Tasmania.

* All revocations were on 14 October 2022, unless otherwise specified.

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[14] over the course of this incident.

For this incident, AEMO informed the market on the following matters related to the event[15]:

- **Notification of a non-credible contingency event – notify within two hours of the event**[16].
  - AEMO issued MN 102213 at 0942 hrs on 14 October 2022, 23 minutes after the event, to advise of the non-credible contingency event involving the trip of Liapootah – Waddamana – Palmerston 220 kV lines, Basslink and approximately 530 MW of electrical load.
  - An update (MN 102266) was subsequently issued at 1222 hrs on the same day to advise that Basslink had returned to service, that the Liapootah – Waddamana – Palmerston 220 kV lines remained out of service and noted the constraint sets invoked to manage the outage.
- **Reclassification, details, and cancellation of a non-credible contingency – notify as soon as practical**[17].

[14] AEMO generally informs the market about operating incidents as they progress by issuing Market Notices – see https://www.aemo.com.au/Market-Notices.

[15] Published at https://aemo.com.au/market-notices.

[16] AEMO is required to notify the market of a non-credible contingency event within two hours of the event – AEMO, Power System Security Guidelines, Section 7.3.

[17] AEMO is required to notify the market of a reclassification – NER clause 4.2.3(g), details of the reclassification – 4.2.3(c), and when AEMO cancels the reclassification – 4.2.3(h).

  - AEMO issued MN 102360 at 1532 hrs on 18 October 2022 to advise that AEMO had reclassified the trip of any 220 kV line in southern Tasmania and the coincident reduction of industrial load in Tasmania as a credible contingency.

- **Intervention**:
  - AEMO issued MN 102263 at 1153 hrs on 14 October 2022 to advise that AEMO had issued a direction to a participant in the Tasmanian region to maintain the power system in a secure operating state.
  - AEMO issued MN 104130 at 1346 hrs on 2 December 2022 to advise of the cancellation of the intervention event in the Tasmanian region and all associated directions from 1350 hrs, following the return of Liapootah – Palmerston 220 kV lines.
- **Constraints invoked with interconnector terms on left hand side**[18].
  - AEMO issued MN 102234 at 1027 hrs on 14 October 2022 to advise that the constraint set I-BL_zero had been applied from 0930 hrs to 1015 hrs. This constraint set limits Basslink to zero in either direction.
- **Details of low reserve conditions**.
  - Market notices were issued to advise of low reserve conditions in Tasmania and provide updates on these conditions.
  - AEMO issued MN 102285 at 1528 hrs on 14 October 2022 to declare a forecast lack of reserve (LOR) 1 condition for Tasmania from 0630 hrs to 0800 hrs on 17 October 2022. The forecast capacity reserve requirement was 723 MW and the minimum capacity reserve available was 692 MW.

In total there were 72 such market notices, from the time of the event on 14 October 2022 until the return of the Liapootah – Palmerston lines on 2 December 2022. For further details refer to Table 7 in Appendix A2 and the AEMO LOR quarterly report[19].

[18] For short notice outages, AEMO is required to notify the Market of variances to interconnector transfer limits as per section 22 of AEMO's Power System Security Guidelines.

[19] AEMO Lack of Reserve Quarterly Report: https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/power_system_ops/lack-of-reserve-framework-quarterly-reports/2022/q4-report.pdf?la=en.

5 Operation of Tasmania following the event

With both Liapootah – Palmerston – Waddamana 220 kV Lines out of service, North and South Tasmania were connected via a single 110 kV line from Palmerston to Waddamana. Therefore, the separation of North and South Tasmania into separate synchronous islands was considered a credible contingency.

To ensure system security was maintained during this network configuration, the following operational measures were implemented:

1. Active power flow on the Palmerston – Waddamana 110 kV line was constrained below 15 MW in both directions.
2. Constraints invoked included an equation that constrained South Tasmania generation to less than (or equal to) South Tasmania demand. This constraint ensured the published pre-dispatch (PD) and short-term (ST) projected assessment of system adequacy (PASA) reserves for Tasmania reflected reserves in North Tasmania where the regional reference node is located.
3. Additional reporting tools were developed to assess system reliability for South Tasmania. AEMO closely monitored the power system in South Tasmania during the abnormal network configuration prior to one of the failed 220 kV lines being returned to service.
4. AEMO discussed a planned outage of the Gordon hydro power station (432 MW capacity) with Hydro Tasmania given the network configuration following this event and ongoing risk to system security. The planned outage was subsequently cancelled to maximise available generation and FCAS in South Tasmania.
5. On 19 October 2022, the damaged sections of the 220 kV lines were disconnected allowing the Liapootah – Waddamana line to be returned to service.
6. On 2 December 2022, permanent line repairs were completed and the Liapootah – Palmerston – Waddamana No 1 and No 2 220 kV Lines were returned to service.

6 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:

1. The trip of Liapootah – Palmerston – Waddamana No 1 and No 2 220 kV lines was caused by a landslide impacting the footings and structure of a double circuit strain tower supporting these lines.
2. The trip of Basslink while transferring 425 MW to Tasmania was due to low Tasmanian power system voltages at the time of the 220 kV line faults. These low voltages caused the Basslink converter to experience a period of extended commutation failure. In response to this, Basslink's loss of thyristor redundancy protection operated and tripped Basslink. Basslink tripped in line with expected performance.
3. The Adaptive Under Frequency Load Shedding scheme 2 (AUFLS2) and the Frequency Control System Protection Scheme (FCSPS) operated as expected during this event.
4. Musselroe Wind Farm tripped when generating 148 MW. Musselroe Wind Farm initially reduced its active power output at the inception of the event. TasNetworks has confirmed that if significant voltage drops occur during network faults, the wind farm will enter its multiple fault ride-through mode, causing the active power to drop significantly to maintain connection without tripping. The wind farm finally tripped due to the operation of its Anti-Islanding Scheme triggered by the Slip Acceleration (RoCoF) input.
5. Lemonthyme Power Station tripped when generating 54 MW. Lemonthyme tripped on under-excitation protection due to operating with high reactive import and low terminal voltage immediately prior to the high bus voltage at Sheffield. The existing Automatic Voltage Regulator (AVR) at Lemonthyme does not include the Under-Excitation Limiter (UEL) function. The AVR is planned for replacement in 2024 and will include the UEL function.
6. The trip of the Waddamana – Lindisfarne No 1 and No 2 220 kV lines at the Waddamana end only was as expected due to the circuit breaker switching arrangements at Waddamana substation and the trip of the Liapootah – Palmerston – Waddamana 220 kV lines.
7. Cattle Hill Wind Farm disconnected at Waddamana when generating 32 MW due the circuit breaker switching arrangements at Waddamana substation and the trip of the Liapootah – Palmerston – Waddamana 220 kV lines.
8. The trip of Basslink while transferring 0 MW at 0959 hrs on 14 October 2022 following restoration to service was due to high 220 kV bus voltages, more than 1.06 pu (above 232 kV), at George Town substation inhibiting the AC filters from being available to switch into service. Under this scenario. Basslink was unable to operate and tripped as designed. AEMO was advised by Basslink on 6 June 2023 that it had updated its operating procedure.

7 Recommendations

During the review of this incident, AEMO identified opportunities to improve the performance and operation of some connected generators and the HVDC interconnector that tripped during this incident. Some improvements have already been implemented, and further opportunities recommended by AEMO are detailed below.

Improvements implemented

- Following the approval of TasNetworks on 15 December 2022 and AEMO on 19 December 2022, a change was implemented by Basslink on 21 December 2022 that added a 100 ms inhibit of thyristor monitoring after commutation failure. This effectively removes the Basslink extended commutation failure trip mechanism and reduces the risk of a Basslink trip under similar conditions as resulted during this event.
- While the Basslink protection operated as designed under this condition, AEMO recommended Basslink modify its operating procedure for returning Basslink to service to highlight the risk that high bus voltages, >231 kV in Tasmania or >544 kV in Victoria, will inhibit the AC filters from being switched which, during the Basslink deblock sequence, will result in a trip of Basslink. AEMO was advised by Basslink on 9 June 2023 that it has updated its operating procedure.

Further recommendations

AEMO recommends:

1. Hydro Tasmania implement the UEL function in the AVR replacement planned by Hydro Tasmania at Lemonthyme Power Station during 2024. This function should minimise the risk of the power station tripping under similar network fault conditions.
2. TasNetworks and Musselroe Wind Farm review the inputs to the Anti-Islanding Scheme to minimise the risk the wind farm disconnects due to Slip Acceleration under similar network fault conditions.
3. TasNetworks to consider the installation of line circuit breakers and any associated works to enable the Liapootah – Waddamana and the Waddamana – Palmerston circuits to be sectionalised at Waddamana as part of its plans for Waddamana substation to improve security for the loss of any of the line sections.

A1. List of participants who provided data

Table 6 List of participants who provided data

Company	Details
TasNetworks	TasNetworks is the Transmission Network Service Provider for the Tasmanian region.
APA Group	APA Group owns and operates the Basslink interconnector.
Hydro Tasmania	Hydro Tasmania owns and operates all the hydro power stations in Tasmania including Lemonthyme Power Station.
Woolnorth Renewables	Woolnorth Renewables owns and operates Musselroe Wind Farm.
Wild Cattle Hill Pty Ltd	Wild Cattle Hill Pty Ltd owns and operates Cattle Hill Wind Farm.

A2. Details of low reserve conditions

Table 7 List of low reserve conditions

MN issue	Description	MN cancellation
MN 102285 14 October 2022 at 1528 hrs	To declare a forecast LOR1 condition for Tasmania from 0630 hrs to 0800 hrs on 17 October 2022. The forecast capacity reserve requirement was 723 MW and the minimum capacity reserve available was 692 MW.	*MN 102297* – 15 October 2022 LOR1 forecast cancelled at 1400 hrs
MN 102325 17 October 2022 at 0103 hrs	To declare a forecast LOR1 condition for Tasmania from 0730 hrs to 0830 hrs on 17 October 2022. The forecast capacity reserve requirement was 725 MW and the minimum capacity reserve available was 711 MW.	*MN 102326* – 17 October 2022 LOR1 forecast cancelled at 0200 hrs
MN 102352 18 October 2022 at 0104 hrs	To declare a forecast LOR1 condition for Tasmania from 0730 hrs to 0830 hrs on 18 October 2022. The forecast capacity reserve requirement was 723 MW and the minimum capacity reserve available was 706 MW.	*MN 102353* – 18 October 2022 LOR1 forecast cancelled at 0130 hrs
MN 102362 18 October 2022 at 1507 hrs	To declare a forecast LOR1 condition for Tasmania from 0630 hrs to 0730 hrs on 19 October 2022. The forecast capacity reserve requirement was 682 MW and the minimum capacity reserve available was 679 MW.	*MN 102364* – 18 October 2022 LOR1 forecast cancelled at 1555 hrs
MN 102371 19 October 2022 at 0118 hrs	To declare a forecast LOR1 condition for Tasmania from 0700 hrs to 0800 hrs on 19 October 2022. The forecast capacity reserve requirement was 723 MW and the minimum capacity reserve available was 718 MW.	*MN 102372* – 19 October 2022 LOR1 forecast cancelled at 0200 hrs
MN 102373 19 October 2022 at 0350 hrs	To declare a forecast LOR1 condition for Tasmania from 0730 hrs to 0800 hrs on 19 October 2022. The forecast capacity reserve requirement was 723 MW and the minimum capacity reserve available was 719 MW.	*MN 102374* – 19 October 2022 LOR1 forecast cancelled at 0430 hrs
MN 102583 26 October 2022 at 1321 hrs	To declare a forecast LOR1 condition for Tasmania for the following periods on 27 October 2022: • From 0800 hrs to 0930 hrs, the forecast capacity reserve requirement was 575 MW and the minimum capacity reserve available was 559 MW. • From 1030 hrs to 1430 hrs, the forecast capacity reserve requirement was 441 MW and the minimum capacity reserve available was 443 MW.	*MN 102590* – 26 October 2022 LOR1 forecast cancelled at 1600 hrs
MN 102595 26 October 2022 at 1937 hrs	To declare a forecast LOR1 condition for Tasmania for the following periods on 27 October 2022: • From 1030 hrs to 1200 hrs, the forecast capacity reserve requirement was 480 MW and the minimum capacity reserve available was 467 MW. • From 1300 hrs to 1500 hrs, the forecast capacity reserve requirement was 480 MW and the minimum capacity reserve available was 467 MW.	*MN 102597* – 26 October 2022 LOR1 forecast cancelled at 2230 hrs
MN 102598 27 October 2022 at 0252 hrs	To declare a forecast LOR1 condition for Tasmania for the following periods on 27 October 2022: • From 0800 hrs to 0830 hrs, the forecast capacity reserve requirement was 709 MW and the minimum capacity reserve available was 683 MW. • From 1030 hrs to 1100 hrs, the forecast capacity reserve requirement was 622 MW and the minimum capacity reserve available was 620 MW.	*MN 102597* – 27 October 2022 LOR1 forecast cancelled at 0530 hrs
MN 102613 27 October 2022 at 1211 hrs *MN 102615*	To declare a forecast LOR1 condition for Tasmania from 1300 hrs to 1500 hrs on 27 October 2022. The forecast capacity reserve requirement was 497 MW and the minimum capacity reserve available was 472 MW.	*MN 102616* – 27 October 2022 LOR1 forecast cancelled at 1345 hrs

MN issue	Description	MN cancellation
27 October 2022 at 1320 hrs (update)	An update of the LOR1 forecast was subsequently issued at 1320 hrs.	
MN 102879 4 November 2022 at 1525 hrs	To declare a forecast LOR1 condition for Tasmania for the following periods on 11 November 2022: • From 0630 hrs to 1100 hrs, the forecast capacity reserve requirement was 662 MW and the minimum capacity reserve available was 607 MW. • From 1300 hrs to 1530 hrs, the forecast capacity reserve requirement was 662 MW and the minimum capacity reserve available was 639 MW.	*MN 102943* – 7 November 2022 LOR1 forecast cancelled at 1400 hrs
MN 102944 7 November 2022 at 1501 hrs *MN 102973* 8 November 2022 at 1508 hrs (update)	To declare a forecast LOR1 condition for Tasmania from 0730 hrs to 0800 hrs on 14 November 2022. The forecast capacity reserve requirement was 583 MW and the minimum capacity reserve available was 573 MW. An update to the LOR1 forecast was subsequently issued at 1508 hrs on 8 November.	*MN 102993* – 9 November 2022 LOR1 forecast cancelled at 1400 hrs
MN 102961 8 November 2022 at 0028 hrs	To declare a forecast LOR1 condition for Tasmania from 0700 hrs to 0730 hrs on 8 November 2022. The forecast capacity reserve requirement was 507 MW and the minimum capacity reserve available was 494 MW.	*MN 102962* – 8 November 2022 LOR1 forecast cancelled at 0515 hrs
MN 102972 8 November 2022 at 1507 hrs *MN 102992* 9 November 2022 at 1457 hrs (update)	To declare a forecast LOR1 condition for Tasmania from 0600 hrs to 0800 hrs on 11 November 2022. The forecast capacity reserve requirement was 662 MW and the minimum capacity reserve available was 639 MW. An update to the LOR1 forecast was subsequently issued on 9 November (1457 hrs).	*An update was provided in MN 103018*
MN 102974 4 November 2022 at 1525 hrs *MN 102994* 9 November 2022 at 1459 hrs (update) *MN 103013* 10 November 2022 at 1513 hrs (update)	To declare a forecast LOR1 condition for Tasmania for the following periods on 15 November 2022: • From 0630 hrs to 1200 hrs, the forecast capacity reserve requirement was 662 MW and the minimum capacity reserve available was 586 MW. • From 1400 hrs to 1500 hrs, the forecast capacity reserve requirement was 662 MW and the minimum capacity reserve available was 655 MW. Two updates to the LOR1 forecast were subsequently issued on 9 November (1459 hrs) and 10 November (1513 hrs)	*MN 103031* – 11 November 2022 LOR1 forecast cancelled at 1400 hrs
MN 102979 8 November 2022 at 1620 hrs	To declare a forecast LOR1 condition for Tasmania from 0600 hrs to 0800 hrs on 9 November 2022. The forecast capacity reserve requirement was 520 MW and the minimum capacity reserve available was 497 MW.	*MN 102980* – 8 November 2022 LOR1 forecast cancelled at 1645 hrs
MN 102985 9 November 2022 at 0447 hrs	To declare a forecast LOR1 condition for Tasmania from 0830 hrs to 0900 hrs on 9 November 2022. The forecast capacity reserve requirement was 633 MW and the minimum capacity reserve available was 617 MW.	*MN 102986* – 9 November 2022 LOR1 forecast cancelled at 0550 hrs
MN 102987 9 November 2022 at 0558 hrs	To declare a forecast LOR2 condition for Tasmania from 0800 hrs to 0830 hrs on 15 November 2022. The forecast capacity reserve requirement was 529 MW and the minimum capacity reserve available was 527 MW.	*MN 102988* – 9 November 2022 LOR2 forecast cancelled at 1000 hrs
MN 102995	To declare a forecast LOR1 condition for Tasmania from 0800 hrs to 0830 hrs on 16 November 2022. The forecast capacity reserve	*MN 103191* – 15 November 2022

MN issue	Description	MN cancellation
9 November 2022 at 1500 hrs *MN 103008* 10 November 2022 at 1314 hrs *MN 103020* 11 November 2022 at 0538 hrs (update)	requirement was 662 MW and the minimum capacity reserve available was 647 MW. A forecast LOR2 condition for Tasmania was subsequently declared for 0900 hrs to 1100 hrs on 16 November 2022. The forecast capacity reserve requirement was 462 MW and the minimum capacity reserve available was 441 MW. An update to the LOR2 forecast was subsequently issued 11 November (0538 hrs).	LOR2 forecast cancelled at 1100 hrs
MN 103018 11 November 2022 at 0118 hrs	To declare a forecast LOR1 condition for Tasmania from 0600 hrs to 0800 hrs on 11 November 2022. The forecast capacity reserve requirement was 662 MW and the minimum capacity reserve available was 634 MW.	*MN 103019* – 11 November 2022 LOR1 forecast cancelled at 0515 hrs
MN 103032 11 November 2022 at 1528 hrs *MN 103050* 12 November 2022 at 1432 hrs (update) *MN 103101* 13 November 2022 at 1457 hrs (update) *MN 103167* 14 November 2022 at 1448 hrs (update)	To declare a forecast LOR1 condition for Tasmania from 0800 hrs to 0830 hrs on 17 November 2022. The forecast capacity reserve requirement was 662 MW and the minimum capacity reserve available was 661 MW. Three updates to the LOR1 forecast were subsequently issued on 12 November (1432 hrs), 13 November (1457 hrs) and 14 November (1448 hrs)	*MN 103247* – 15 November 2022 LOR1 forecast cancelled at 1400 hrs
MN 103118 14 November 2022 at 0253 hrs	To declare a forecast LOR1 condition for Tasmania from 0630 hrs to 0700 hrs on 14 November 2022. The forecast capacity reserve requirement was 517 MW and the minimum capacity reserve available was 480 MW.	*MN 103123* – 14 November 2022 LOR1 forecast cancelled at 0620 hrs
MN 103249 15 November 2022 at 1512 hrs	To declare a forecast LOR1 condition for Tasmania from 0900 hrs to 1000 hrs on 19 November 2022. The forecast capacity reserve requirement was 492 MW and the minimum capacity reserve available was 488 MW.	*MN 103331* – 16 November 2022 LOR1 forecast cancelled at 1543 hrs
MN 103264 15 November 2022 at 2351 hrs	To declare a forecast LOR1 condition for Tasmania from 0630 hrs to 0730 hrs on 16 November 2022. The forecast capacity reserve requirement was 662 MW and the minimum capacity reserve available was 645 MW.	*Updated in MN 103332*
MN 103332 16 November 2022 at 1544 hrs	To declare a forecast LOR1 condition for Tasmania from 0630 hrs to 0730 hrs on 18 November 2022. The forecast capacity reserve requirement was 662 MW and the minimum capacity reserve available was 657 MW.	*Updated in MN 103492*
MN 103346 16 November 2022 at 1934 hrs	To declare a forecast LOR1 condition for Tasmania for the following periods on 17 November 2022: • From 0700 hrs to 0800 hrs, the forecast capacity reserve requirement was 662 MW and the minimum capacity reserve available was 641 MW. • From 0900 hrs to 0930 hrs, the forecast capacity reserve requirement was 662 MW and the minimum capacity reserve available was 651 MW.	*MN 103356* – 17 November 2022 LOR1 forecast cancelled at 0600 hrs
MN 103357	To declare a forecast LOR1 condition for Tasmania from 0730 hrs to 0800 hrs on 17 November 2022. The forecast capacity reserve requirement was 662 MW and the minimum capacity reserve available was 622 MW.	*Event had concluded.*

MN issue	Description	MN cancellation
17 November 2022 at 0706 hrs		
MN 103492 18 November 2022 at 0507 hrs	To declare a forecast LOR1 condition for Tasmania from 0630 hrs to 0730 hrs on 18 November 2022. The forecast capacity reserve requirement was 662 MW and the minimum capacity reserve available was 633 MW.	*MN 103494* – 18 November 2022 LOR1 forecast cancelled at 0758 hrs
MN 103996 26 November 2022 at 1424 hrs *MN 104011* 27 November 2022 at 1526 hrs (update)	To declare a forecast LOR1 condition for Tasmania for the following periods on 1 December 2022: • From 0700 hrs to 0730 hrs, the forecast capacity reserve requirement was 662 MW and the minimum capacity reserve available was 646 MW. • From 0830 hrs to 0900 hrs, the forecast capacity reserve requirement was 662 MW and the minimum capacity reserve available was 659 MW. An update to the LOR1 forecast was subsequently issued on 27 November (1526 hrs).	*MN 104079* – 29 November 2022 LOR1 forecast cancelled at 1518 hrs
MN 104080 29 November 2022 at 1519 hrs	To declare a forecast LOR1 condition for Tasmania from 0700 hrs to 0930 hrs on 2 December 2022. The forecast capacity reserve requirement was 662 MW and the minimum capacity reserve available was 618 MW.	*MN 104101* – 30 November 2022 LOR1 forecast cancelled at 1400 hrs
MN 104110 1 December 2022 at 0223 hrs	To declare a forecast LOR1 condition for Tasmania from 0630 hrs to 0700 hrs on 1 December 2022. The forecast capacity reserve requirement was 662 MW and the minimum capacity reserve available was 658 MW.	*MN 104111* – 1 December 2022 LOR1 forecast cancelled at 0310 hrs
MN 104120 2 December 2022 at 0050 hrs	To declare a forecast LOR1 condition for Tasmania from 0630 hrs to 0700 hrs on 2 December 2022. The forecast capacity reserve requirement was 662 MW and the minimum capacity reserve available was 657 MW.	*MN 104120* – 2 December 2022 LOR1 forecast cancelled at 0120 hrs

A3. System diagrams

Figure 10 provides an overview of part of the power system immediately prior to the incident.

Figure 10 Pre-incident network configuration part diagram

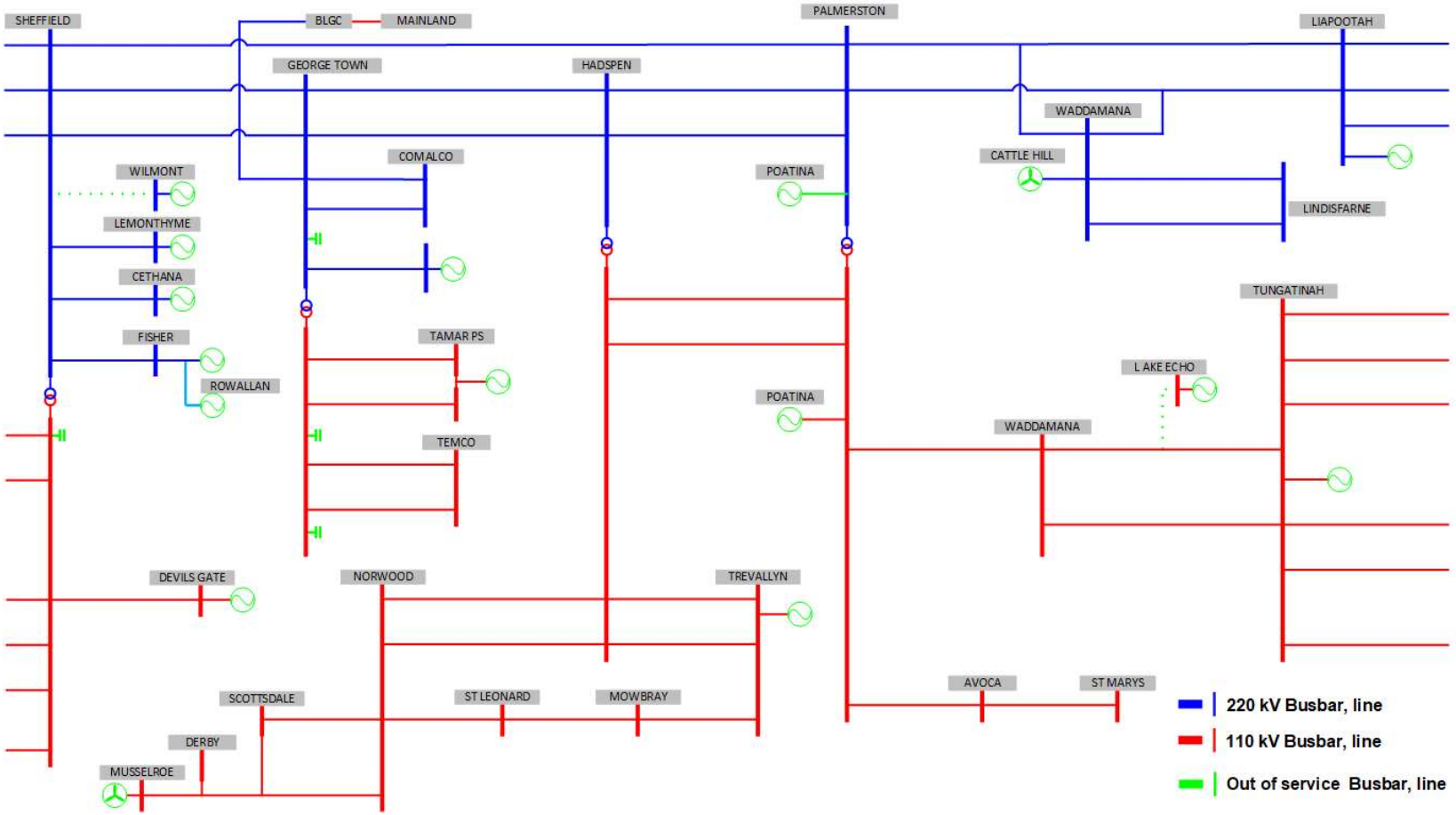


Figure 11 provides an overview of part of the power system immediately after the incident.

Figure 11 Post-incident network configuration part diagram

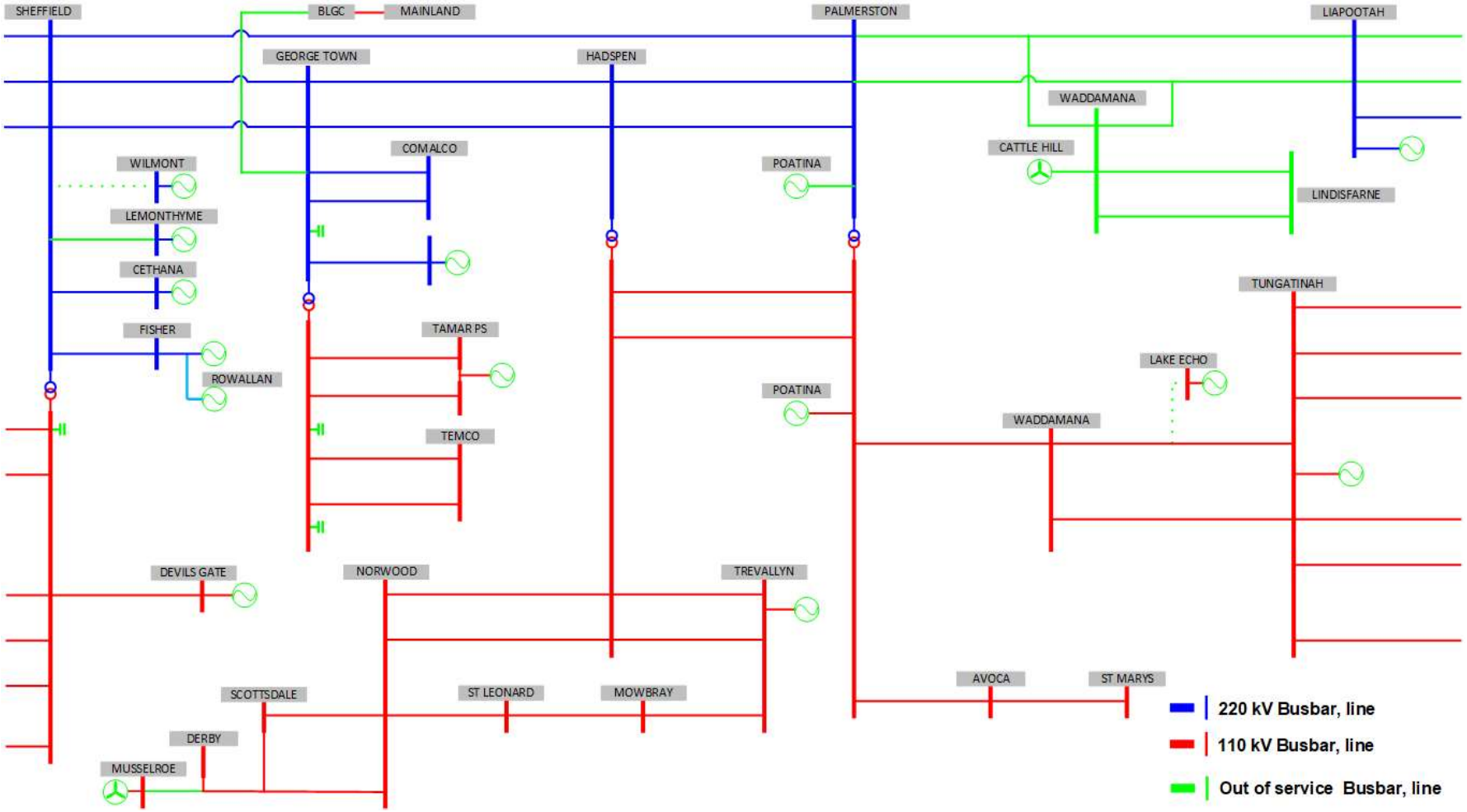


Figure 12 provides an overview of part of the power system on 19 October following the Liapootah – Waddamana 220 kV lines after TasNetworks disconnected the section of lines where the tower was damaged by the landslide.

Figure 12 Restoration Liapootah – Waddamana 220 kV lines on 19 October 2022