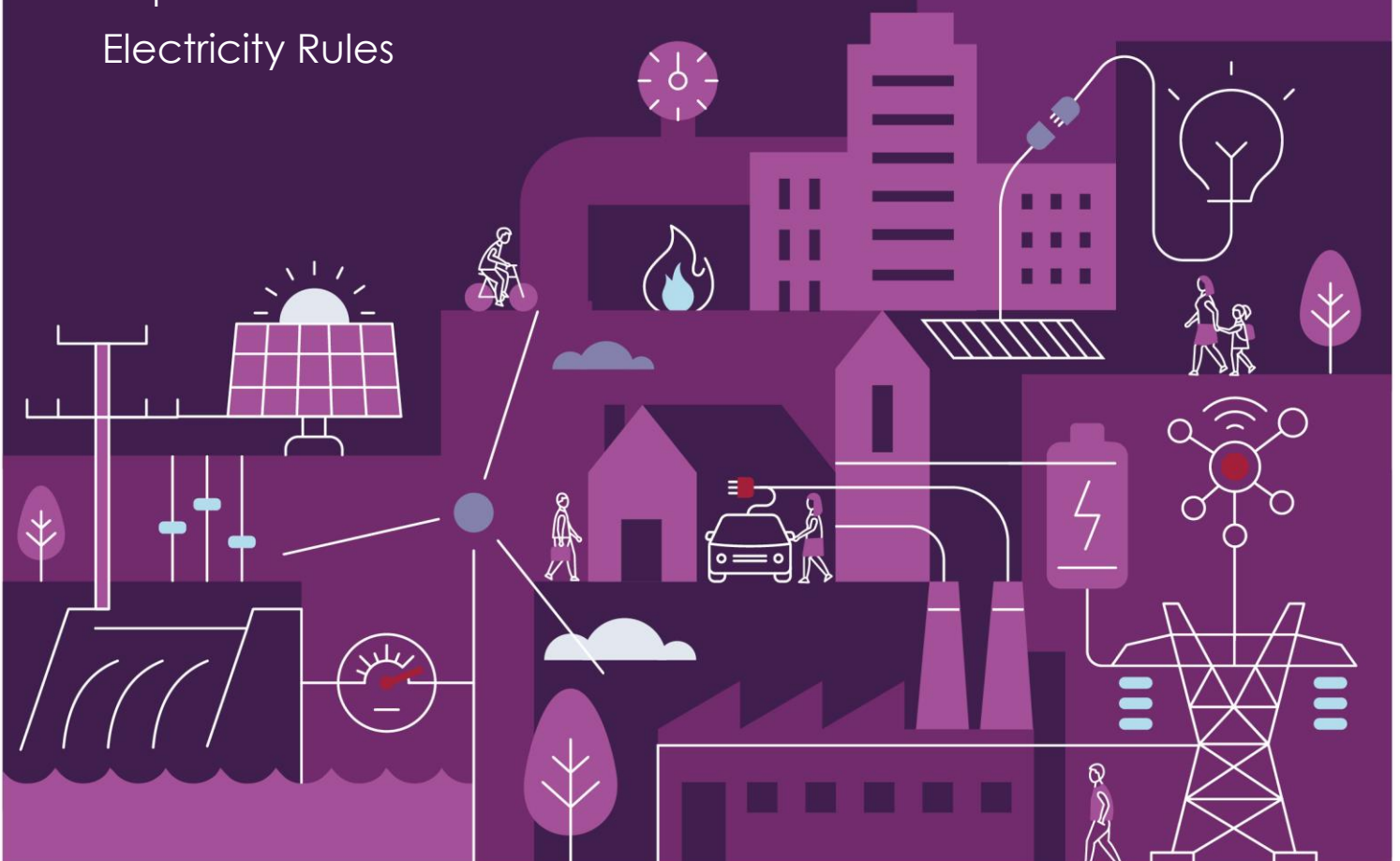
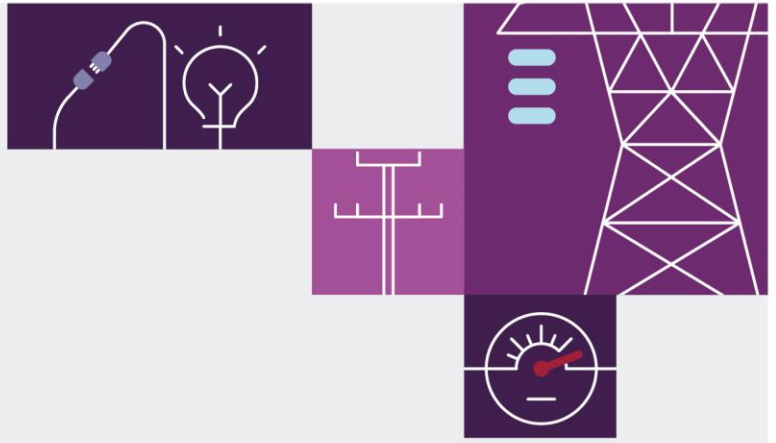


Trip of Robertstown – Tungkillo 275 kV No. 1 line at the Tungkillo end only and the Robertstown No. 1 and No. 2 Synchronous Condensers on 28 November 2023

May 2024

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.

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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Incident classifications

Classification	Detail
Time and date of Incident	28 November 2023 05:34 hrs
Region of incident	South Australia
Affected regions	South Australia
Event type	Environmental – lightning and protection-control system failure or mal-operation
Generation impact	No
Customer load impact	50 MW

Abbreviations

Abbreviation	Term
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AEST	Australian Eastern Standard Time
BESS	battery energy storage system
CB	circuit breaker
DPV	distributed photovoltaic
DC	direct current
FOS	Frequency Operating Standard
Hz	hertz
kV	kilovolt/s
LHS	left-hand side
MN	market notice
ms	millisecond/s
MW	megawatt/s
NEM	National Electricity Market
NER	National Electricity Rules
NSP	Network Service Provider
PSSWG	Power System Security Working Group
p.u.	per unit
PV	photovoltaic
s	second/s
SAPN	South Australia Power Networks
SC	synchronous condenser
SCADA	Supervisory Control and Data Acquisition
SPAR	single pole trip and auto reclose
TNSP	Transmission Network Service Provider

Contents

1	Overview	6
2	The incident	8
2.1	Pre-event conditions	8
2.2	The incident	9
2.3	Analysis	9
2.4	Potential impact of the incident	13
3	Power system security	13
3.1	Frequency	13
3.2	Voltage	14
3.3	Reclassification	15
4	Market information	16
5	Conclusions	18
A1.	System diagram	20

Tables

Table 1	Summary of conclusions and recommendations	6
Table 2	South Australia key system conditions for the trading interval commencing at 05:30 hrs, 28 November 2023	8
Table 3	Sequence of events	9
Table 4	Protection and fault information for Robertstown – Tungkillo 275 kV No. 1 line	10
Table 5	Protection and fault information for Robertstown – Tungkillo 275 kV No. 2 line	11
Table 6	Constraint sets invoked during the incident	17

Figures

Figure 1	South Australia frequency on 28 November 2023	14
Figure 2	Voltage at Tungkillo 275 kV busbar of the Robertstown – Tungkillo 275 kV No. 1 line on 28 November 2023 – high speed monitoring data	15
Figure 3	Pre-incident network diagram	20




Figure 4	Network diagram immediately following the trip of Robertstown – Tungkillo 275 kV No. 1 line and SPAR of No. 2 line	21
Figure 5	Network diagram immediately following the trip of Robertstown SCs	22

1 Overview

This report relates to a reviewable operating incident¹ that occurred on 28 November 2023 in South Australia. The incident comprised a non-credible contingency event impacting critical transmission elements involving the single pole trip and auto reclose (SPAR) of Robertstown – Tungkillo 275 kilovolts (kV) No. 2 line, three-phase trip of Robertstown – Tungkillo 275 kilovolts (kV) No. 1 line at the Tungkillo end only and trip of Robertstown No. 1 and No. 2 Synchronous Condensers (SCs).

There was no loss of generation as a result of this incident, however, 50 megawatts (MW) of customer load reduction was recorded. This reduction of load was primarily related to the industrial load connected to the high-voltage network.

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 security².

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

Table 1 Summary of conclusions and recommendations

Finding	Recommendations/actions
Lightning during a storm caused two simultaneous single-phase faults on the Robertstown – Tungkillo 275 kV No. 1 and No. 2 lines, which share a common tower structure. A W phase to earth fault occurred on Robertstown – Tungkillo 275 kV No. 1 line and a U phase to earth fault occurred on Robertstown – Tungkillo 275 kV No. 2 line.	No action required.
The single-phase to earth fault in the U phase of the Robertstown – Tungkillo 275 kV No. 2 line led to the tripping and auto reclosing ³ of the faulted pole of the corresponding circuit breakers (CBs) at both ends of the Robertstown – Tungkillo 275 kV No. 2 line.	No action required.
<ul style="list-style-type: none">All three poles of the corresponding CB at Tungkillo end of the Robertstown – Tungkillo 275 kV No. 1 line tripped and remained locked out as the two simultaneous faults occurred on two different phases and both faults were within the Zone 2 reach of the distance protection⁴ used at Tungkillo.ElectraNet noted that there's an opportunity to redesign the distance protection scheme used on Robertstown – Tungkillo 275 kV No. 1 line to prevent the phase-to-phase fault tripping at Tungkillo in these circumstances, however, the redesign must consider the NER requirements for in-zone line faults as well.	AEMO supports ElectraNet's plan to further consider the distance protection scheme used on Robertstown – Tungkillo 275 kV No. 1 line and to share key findings with AEMO and, where relevant, the Power System Security Working Group (PSSWG).

¹ See NER clause 4.8.15(a)(1)(i), as the event relates to a non-credible contingency event; and the AEMC Reliability Panel Guidelines for Identifying Reviewable Operating Incidents.

² See NER clause 4.8.15(b).

³ Robertstown – Tungkillo 275 kV No. 2 line is protected by Set 1 and Set 2 differential protection with single phase tripping and auto reclose.

⁴ Robertstown – Tungkillo 275 kV No. 1 line is protected by Set 1 differential protection and Set 2 distance protection with blocking scheme and single-phase tripping and auto reclose.

Finding	Recommendations/actions
<p>Robertstown No. 1 and No. 2 SCs tripped shortly after the faults on Robertstown – Tungkillo 275 kV No. 1 and No. 2 lines. Robertstown SCs tripped due to flywheel housing vacuum pump drive failure. The close-in simultaneous faults on Robertstown – Tungkillo 275 kV No. 1 and No. 2 lines caused a large voltage dip resulting in the vacuum pump drives signalling a ‘Drive Failed’ latching event, which had to be manually reset before the vacuum pumps could be returned to service.</p>	<ul style="list-style-type: none"> • ElectraNet’s design/build contractor of the Robertstown No. 1 and No. 2 SCs added an automatic restart capability to both SCs on 14 February 2024 to improve their ride-through capability. • ElectraNet has confirmed that the SCs are expected to ride through credible contingency events and meet the performance standards. • ElectraNet to share the key findings of the investigation of the incident with the PSSWG by Q3 2024.
<p>The power system remained in a secure operating state and the Frequency Operating Standard (FOS) was met throughout the incident.</p>	<p>None</p>
<p>At the time of the incident, AEMO appropriately reclassified the contingency event as credible as AEMO was not satisfied that this non-credible contingency event was unlikely to re-occur. AEMO issued market notice (MN) 111795 at 13:53 hrs on 28 November 2023 to advise the market.</p>	<ul style="list-style-type: none"> • On 14 December 2023, following confirmation from ElectraNet that the Robertstown – Tungkillo 275 kV No. 1 trip and No. 2 SPAR were caused by lightning, the Robertstown – Tungkillo 275 kV No. 1 and No. 2 lines and the Robertstown No. 1 and No. 2 SCs were added to the special reclassification of transmission plant during lightning list⁵ in accordance with the Power System Security Guidelines (SO_OP_3715). AEMO issued MN 112320 at 14:04 hrs on 14 December 2023 to advise of this change. Subsequently, AEMO cancelled the reclassification of the simultaneous trip of the Robertstown – Tungkillo 275 kV No. 1 and No. 2 lines and the Robertstown No. 1 and No. 2 SCs and reverted to a non-credible contingency as there was no lightning activity in the vicinity of the lines. AEMO issued MN 112321 at 14:02 hrs on 14 December 2024 to advise of this cancellation. • On 6 March 2024, following ElectraNet’s confirmation that automatic restart capability had been added to the SCs’ vacuum pump control systems, the Tungkillo – Robertstown No. 1 and No. 2 275 kV lines and the Robertstown No. 1 and No. 2 SCs were removed from the special reclassification of transmission plant during lightning list⁵ in accordance with the Power System Security Guidelines (SO_OP_3715), as AEMO considered the simultaneous trip of the Robertstown – Tungkillo No. 1 and No. 2 275 kV lines and the Robertstown No. 1 and No. 2 SCs was no longer reasonably possible in those conditions.
<p>ElectraNet has reviewed maintenance records for the Robertstown – Tungkillo 275 kV No. 1 and No. 2 lines and confirmed that there are no recent results available for tower to earth impedance for towers around the fault location.</p>	<p>AEMO supports ElectraNet’s plan to conduct the tower footing impedance measurements for towers around the fault location by Q4 2024 and to undertake necessary remediations. AEMO recommends ElectraNet share key findings with AEMO and, where relevant, the PSSWG.</p>

This report is prepared in accordance with clause 4.8.15(c) of the National Electricity Rules (NER). It is based on information provided by ElectraNet, South Australia Power Networks (SAPN) and AEMO.

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

⁵ Vulnerable Transmission Lines, at https://www.aemo.com.au/-/media/files/electricity/nem/security_and_reliability/power_system_ops/procedures/op-supporting-docs/vulnerable-lines.pdf?la=en.

2 The incident

2.1 Pre-event conditions

2.1.1 Weather conditions and prior outages

In the early hours of 28 November 2023, a severe storm passed across South Australia resulting in seven faults on the ElectraNet network from 02:18 hrs to 05:34 hrs, in the lead up to this event. The affected circuits successfully auto reclosed for five of the faults, and for one of the faults on the 132 kV network, the corresponding line tripped.

The remaining fault, which occurred at 05:34 hrs, is the subject of this incident review and it involved the SPAR of Robertstown – Tungkillo 275 kV No. 2 line, three-phase trip of Robertstown – Tungkillo 275 kV No. 1 line at the Tungkillo end only, and the trip of Robertstown No. 1 and No. 2 SCs.

Prior to the incident at 05:34 hrs, all circuits were in service at Tungkillo 275 kV substation. Only CB 8128 and 8129 for future Goyder wind farm, CB 8127 and 8126 for future Goyder wind farm 2, and CB 6574 and 6573 for future Bunday 2 line were on planned outages at Robertstown 275 kV substation (see Figure 3).

2.1.2 Generation dispatch and demand in South Australia

Table 2 provides an overview of the key system conditions in South Australia prior to the incident.

Table 2 South Australia key system conditions for the trading interval commencing at 05:30 hrs, 28 November 2023

Quantity description	Value (MW)
South Australia operational demand	1,317
South Australia dispatched generation	1,105
South Australia distribution photovoltaic (DPV) generation	0
Heywood interconnector flow into South Australia	155
Murraylink flow into South Australia	59

A direction had been issued at 17:00 hrs on 25 November 2023 to Mintaro Power Station to synchronise for system security purposes⁶. This direction applied⁷ from 07:00 hrs on 26 November 2023 to 04:00 hrs on 30 November 2023. AEMO also issued a direction at 15:00 hrs on 27 November 2023 to Torrens Island Power Station B3 to synchronise for system security purposes, however, this direction applied only from 09:30 hrs on 28 November 2023 to 04:00 hrs on 29 November 2023. As a result, Mintaro and Pelican Point power plants were the only synchronous generator plants in South Australia dispatched at the time of the incident and were generating 30 MW and 170 MW, respectively.

⁶ The current minimum South Australia synchronous generator requirement is two large synchronous units with four SCs in operation. See South Australia minimum synchronous generator requirements – August 2023 update, at https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/congestion-information/2023/sa-minimum-synchronous-generator-requirements-august-2023-update.pdf?la=en.

⁷ Applied refers to the time period over which the direction required this participant to be online.

2.2 The incident

The sequence of events on 28 November 2023 is outlined in Table 3.

Table 3 Sequence of events

Time (HH:MM)	Event
05:34	All three phases tripped in Robertstown – Tungkillo 275 kV No. 1 line at Tungkillo end only. The faulted phase of Robertstown – Tungkillo 275 kV No. 2 line tripped and auto reclosed at both ends to restore the line within 1 second (s).
05:36	Robertstown No. 1 and No. 2 SCs tripped.
05:45	<ul style="list-style-type: none"> Constraint set S-RBTU was invoked to: <ul style="list-style-type: none"> – Manage thermal overloads in the 275 kV and 132 kV network in Mid North South Australia, – Meet system strength requirements in South Australia, and – Manage the voltage and transient stability of the Heywood interconnector. Constraint set S-X_DV+RB_2SYNCON was invoked to meet system strength requirements when the Robertstown No. 1 and No. 2 SCs were out of service.
05:47	Robertstown – Tungkillo 275 kV No. 1 line returned to service. ElectraNet control room closed the 6546 and 6506 CBs at Tungkillo to restore the Robertstown – Tungkillo 275 kV No. 1 line.
11:02	Robertstown No. 1 SC returned to service.
13:53	Trip of Robertstown – Tungkillo 275 kV No. 1 and No. 2 lines and the Robertstown No. 1 and No. 2 SCs was reclassified as a credible contingency.
14:20	Robertstown No. 2 SC returned to service.
17:45	Constraint set S-RBTU+SCON_N-2 was invoked to: <ul style="list-style-type: none"> • Meet system strength requirements in South Australia, • Prevent the thermal overload of 275 kV and 132 kV lines, and • Manage the voltage collapse in Mid North South Australia for the loss of Robertstown – Tungkillo 275 kV No. 1 and No. 2 lines and Robertstown No. 1 and No. 2 SCs.

2.3 Analysis

Based on information provided by registered participants and available from AEMO systems, AEMO has outlined its findings in the following section.

2.3.1 Trip of Robertstown – Tungkillo No. 1 and No. 2 275kV lines

ElectraNet confirmed that lightning was detected close to the Robertstown – Tungkillo 275 kV No. 1 and No. 2 lines approximately 20 milliseconds (ms) after the faults being detected by fault recorders and protection relays. Four strikes were recorded by weather monitoring systems between 05:34:54.755 hrs and 05:34:54.794 hrs near the tower structures between Robertstown and Tungkillo.

Trip of Robertstown – Tungkillo 275 kV No. 1 line at Tungkillo end only

ElectraNet’s post incident review has concluded that, due to lightning, a W phase to earth fault occurred on Robertstown – Tungkillo 275 kV No. 1 line and a U phase to earth fault occurred on Robertstown – Tungkillo 275 kV No. 2 line.



The W phase to earth fault was detected on the Set 1 differential protection at Robertstown and the Set X differential protection at Tungkillio. However, the Set 2 distance protection scheme at Robertstown also detected the W phase to earth fault in Zone 1, while the Set Y distance protection scheme at Tungkillio detected a phase-to-phase fault in Zone 2 due to the two line faults being within the Zone 2 reach.

The operation of Set Y protection at Tungkillio and Set 2 protection at Robertstown for the Robertstown – Tungkillio 275 kV No. 1 line is via stepped distance protection with a blocking scheme enabled. The Set 2 protection at Robertstown end only detected a single-phase fault within Zone 1 and prioritised tripping for the close in fault, therefore no blocking signal was generated. With no blocking signal being received at Tungkillio end, the Set Y protection at Tungkillio end was free to trip after the blocking scheme time delay of 35 ms.

As such, the W phase of CB 6571 and 6572 at Robertstown tripped to clear the fault and the W phase of the same CBs successfully auto reclosed within 1 second (s). All three phases of CBs 6506 and 6546 at Tungkillio tripped and locked out to clear the fault (see Figure 4).

The protection for Robertstown – Tungkillio 275 kV No. 1 line at Robertstown and Tungkillio operated as designed. ElectraNet noted that the phase-to-phase fault tripping at Tungkillio in these circumstances could be prevented by extending the blocking scheme time delay, allowing sufficient time for the fault on the Robertstown – Tungkillio 275 kV No. 2 line to be cleared before tripping, therefore the relay would reselect the fault as single phase after the Robertstown – Tungkillio 275 kV No. 2 line fault was cleared. This would prevent tripping for this type of fault, however, it would also delay tripping for in-zone line faults, possibly resulting in trip times that exceed the NER requirements⁸. ElectraNet plans to further consider the distance protection scheme used on the Robertstown – Tungkillio 275 kV No. 1 line.

Information on protection systems at Robertstown and Tungkillio ends of Robertstown – Tungkillio 275 kV No. 1 line and details of protection operation, fault clearance time and indicative fault location for this incident are given in Table 4 below.

Table 4 Protection and fault information for Robertstown – Tungkillio 275 kV No. 1 line

Tungkillio end	
Set X protection	Differential trip, resulted in trip of W phase
Set Y protection	Phase Distance Zone 2 – Blocking scheme trip, resulted in trip of all three phases
Fault clearance time	78.4 ms
Fault distance from substation	101.11 km
Result	Three phase tripping of 6506 and 6546 CBs (see Figure 4)
Robertstown end	
Set 1 protection	Differential trip, trip of W phase
Set 2 protection	Earth Distance Zone 1 trip, resulted in trip of W phase
Fault clearance time	67.6 ms
Fault distance from substation	5.45 km
Result	Trip and reclose of W phase of 6571 and 6572 CBs (see Figure 4)

⁸ NER Clause S5.1a.8 Fault clearance times <https://energy-rules.aemc.gov.au/ner/519/352233#5.1a>

SPAR of Robertstown – Tungkillio 275 kV No. 2 line

The Set 1 and Set 2 protection of Robertstown – Tungkillio 275 kV No. 2 line at Robertstown end and Tungkillio end operated as designed. The differential protection detected a U phase fault, resulting in tripping the U phase poles of corresponding CBs at Robertstown and Tungkillio. The fault was cleared within 56 ms and all tripped poles were successfully reclosed within 1 s to restore the Robertstown – Tungkillio 275 kV No. 2 line.

Information on the protection systems at Robertstown and Tungkillio ends of Robertstown – Tungkillio 275 kV No. 2 line and details of protection operation, fault clearance time and indicative fault location for this incident are given in Table 5.

Table 5 Protection and fault information for Robertstown – Tungkillio 275 kV No. 2 line

Tungkillio end	
Set 1 protection	Differential trip, resulted in trip of U phase
Set 2 protection	Differential trip, resulted in trip of U phase
Fault clearance time	55.4 ms
Fault distance from substation	100.13 km
Result	Trip and reclose of U phase of 6571 and 6572 CBs (see Figure 4Figure 4)
Robertstown end	
Set 1 protection	Differential trip, resulted in trip of U phase
Set 2 protection	Differential trip, resulted in trip of U phase
Fault clearance time	55.1 ms
Fault distance from substation	6.46 km
Result	Trip and reclose of U phase of 6575 CB (see Figure 4Figure 4)

Line maintenance


ElectraNet has checked the maintenance records for the Robertstown – Tungkillio 275 kV No. 1 and No. 2 lines and confirmed that there are no recent results available for tower to earth impedance for towers around the fault location. As such, ElectraNet plans to conduct tower to earth impedance measurements by Q4 2024.

The tower to earth impedance, which is the resistance between the metallic parts of the tower and the ground, is one of the factors that impacts the susceptibility of the phase conductors to lightning strikes due to back-flashover.

2.3.2 Trip of Robertstown No. 1 and No. 2 SCs

Associated with this event, Robertstown No. 1 and No. 2 SCs tripped at 05:36:04 hrs and 05:36:13 hrs respectively (see Figure 5). The trip condition opened the 15.75 kV machine CBs, leaving the SC step up transformers energised. Upon further investigation, ElectraNet determined that the tripping was due to the failure of each SC's flywheel housing vacuum pump drive.

Each SC has three vacuum pumps, one of which runs continuously whilst the other two are in standby. The drive units for each of the vacuum pumps signalled a "Vacuum Pump Drive Failed" latching event condition within 6 s of the Robertstown – Tungkillio 275 kV No.1 and No. 2 line faults and caused the SCs to trip. The latching event condition had to be manually reset before the vacuum pumps (and associated SC) could be returned to service.



ElectraNet confirmed that this vacuum pump drive failure was not expected and is undesirable. As such, on 14 February 2024, the design/build contractor of the Robertstown No. 1 and No. 2 SCs recommended and applied modifications to the control system of the Robertstown No. 1 and No. 2 SCs to introduce an automatic reset for a “Vacuum Pump Drive Failed” condition, which would prevent a failure of vacuum pump pressure and improve the ride-through capability of SCs. ElectraNet has confirmed that the SCs are expected to ride through credible contingency events and meet the performance standard.

2.3.3 Restoration

The Robertstown – Tungkillo 275 kV No. 2 line was restored automatically due to the auto reclose action of the tripped U phase of the 6574 and 6575 CBs at Robertstown and 8106 and 8107 CBs at Tungkillo. The Robertstown – Tungkillo 275 kV No. 1 line was re-energised due to the auto reclose action of W phase of the corresponding CBs at Robertstown but remained open at the Tungkillo end due to the 6506 and 6546 CBs tripping and locking out. The ElectraNet control room closed the corresponding CBs at Tungkillo end at 05:46 hrs to restore the Robertstown – Tungkillo 275 kV No. 1 line.

During a post fault aerial patrol on 29 November 2023, ElectraNet detected flashed insulators at one of the tower structures on both circuits affecting the top insulator string on each side of the structure. ElectraNet confirmed that the flashed insulators found were consistent with the faulted phases for each circuit.

The staff on site reset the latching condition via the SC human machine interface screens and the Robertstown No. 1 and No. 2 SCs were returned to service on the day of the incident at 11:02 hrs and 14:20 hrs respectively.

2.3.4 Response of distributed battery energy storage system (BESS)

Based on observations from a small sample⁹ of battery energy storage system (BESS) inverters in South Australia, 10-20% of systems on AS/NZS4777.2:2015 (the 2015 Standard) appeared to disconnect in response to the disturbance, with an additional 5% of systems on the 2015 Standard reducing output by more than 65%. This disconnection behaviour appears consistent with the behaviour of distributed photovoltaic (PV) inverters on the 2015 standard in other disturbances¹⁰, given the conditions in the transmission network during this event (two single phase faults with a minimum of 0.75 per unit (p.u.) positive sequence voltage for approximately 80 ms at Para).


Output reduction was also observed at one site on AS/NZS4777.2:2020 (the 2020 Standard), however, only two sites in the dataset were installed since the 2020 Standard was introduced and the sample size is too small to produce any conclusions on ride-through behaviour for new BESS. This data gap indicates a need for new datasets and improved data collection to analyse disturbance response behaviours for BESS in the NEM, which AEMO will consider further.

2.3.5 Load response

Based on Supervisory Control and Data Acquisition (SCADA) observations of total operational demand in South Australia, an overall 50 MW of load reduction was observed within 30 s of the fault occurrence. Most of the load

⁹ Sixty-second resolution data was collected from a sample of 39 BESS circuits in South Australia collected by Solar Analytics, provided under the Australian Renewable Energy Agency (ARENA)-funded Project MATCH led by the University of New South Wales.

¹⁰ Comprehensive disturbance ride-through requirements were introduced in the 2020 Standard.



reduction appears to be from large industrial loads connected to the high voltage network in close electrical proximity to the fault. One industrial load showed a 10-15% reduction in active power post fault. **Error! Reference source not found.** Load loss post-fault was not observed at voltages below 132 kV in metropolitan Adelaide. AEMO will use this information to further refine dynamic power system models used to represent loads in power system studies.

2.4 Potential impact of the incident

The Robertstown SCs were commissioned by ElectraNet to address a declared system strength gap in South Australia¹¹. Progressively more SCs are likely to be commissioned across the NEM in future to provide critical system services such as system strength, inertial support and voltage control. As such, unplanned/non-credible outages of SCs could disrupt the services provided by SCs and present an increasing risk to the secure and reliable operation of the power system. Therefore, it is important to ensure the risk of inadvertent trips of SCs is appropriately considered in line with their performance requirements and minimised in the SC design phase. Further, it is imperative to ensure that sufficient redundancy is installed in all SCs and a full audit of protection settings including auxiliary systems is carried out to enable high reliability and uninterrupted operation.

3 Power system security

AEMO is responsible for power system security in the 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 NER¹².

3.1 Frequency

As shown below in Figure 1, as a result of the non-credible contingency at 05:34 hrs, the system frequency reached a minimum of 49.95 hertz (Hz). The frequency did not leave the normal operating frequency band throughout the incident. The power system remained in a secure operating state throughout this incident and the Frequency Operating Standard (FOS)¹³ was met throughout this incident.

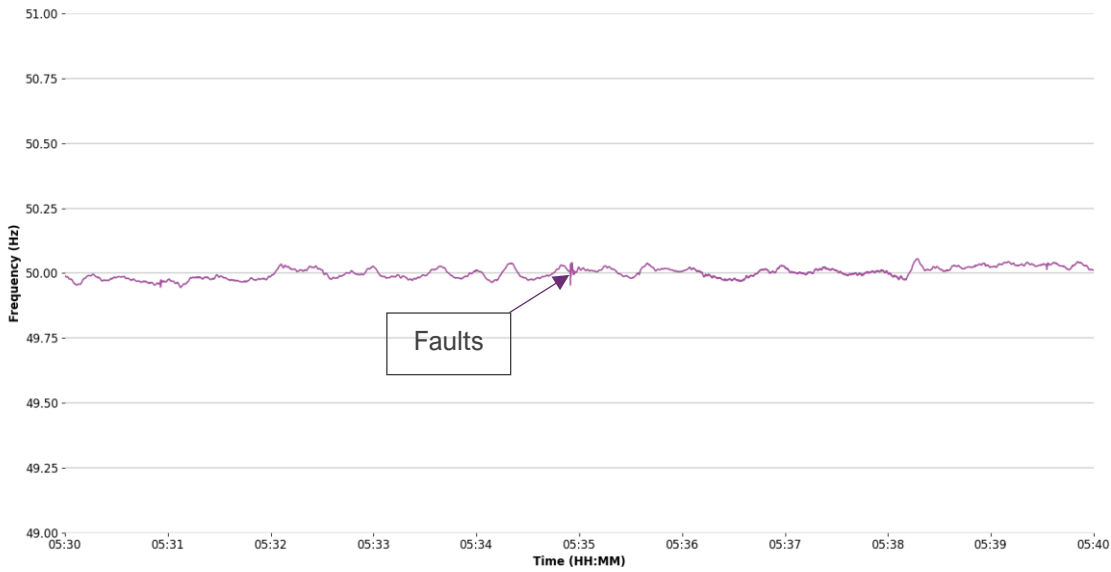
¹¹ On 13 October 2017: https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/NTNDP/2017/Second_Update_to_the_2016_NTNDP.pdf

¹² Refer to AEMO's functions in section 49 of the National Electricity Law, clause 4.3.2 of the NER and the power system security principles in clause 4.2.6 of the NER.

¹³ Frequency Operating Standard, effective 1 January 2020, available at <https://www.aemc.gov.au/media/87484>.



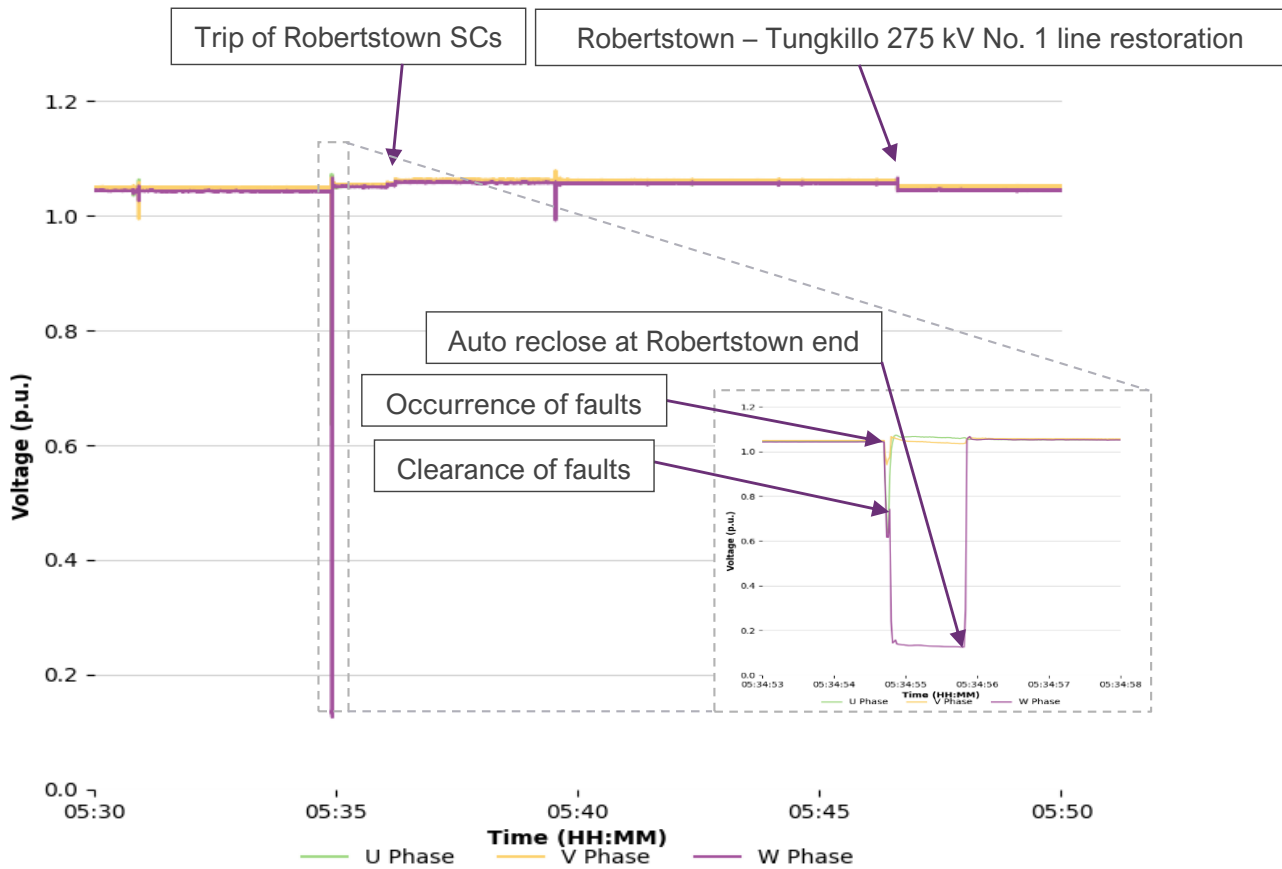
Figure 1 South Australia frequency on 28 November 2023



3.2 Voltage

At no point during this incident were transmission system voltages outside of relevant voltage limits defined in the NER, or as specified by Network Service Providers (NSPs) in their limits advice to AEMO. Figure 2 shows the voltage at Tungkillio 275 kV busbar of the Robertstown – Tungkillio 275 kV No. 1 line on 28 November 2023 as recorded by high-speed monitoring systems. Figure 2 shows that voltage at Tungkillio 275 kV bus slightly increased around 05:36 hrs following the trip of Robertstown No. 1 and Robertstown No. 2 SCs. The voltage comes slightly down to the pre-contingent level following the restoration of Robertstown – Tungkillio 275kV No. 1 line.

Figure 2 Voltage at Tungkillo 275 kV busbar of the Robertstown – Tungkillo 275 kV No. 1 line on 28 November 2023 – high speed monitoring data



3.3 Reclassification


AEMO assessed whether to reclassify this incident as a credible contingency event¹⁴.

Following the incident AEMO sought additional information from ElectraNet and upon receipt of revised information at 13:52 hrs on 28 November 2023 that the Robertstown – Tungkillo 275 kV No. 1 and No. 2 lines tripped simultaneously, AEMO reclassified the event as credible as it was unable to obtain the appropriate level of assurance to determine that re-occurrence of this incident was not reasonably possible. Therefore, at the time AEMO appropriately reclassified the contingency as credible.

On 14 December 2023, following confirmation from ElectraNet that the line trips were caused by lightning, the Robertstown – Tungkillo 275 kV No. 1 and No. 2 lines and the Robertstown No. 1 and No. 2 SCs were added to the special reclassification of transmission plant during lightning list⁵. At that time, in accordance with Appendix B to the Power System Security Guidelines (SO_OP_3715)¹⁵, AEMO considered Robertstown – Tungkillo 275 kV No. 1 and No. 2 lines and the Robertstown No. 1 and No. 2 SCs to be vulnerable in the event of lightning activity.

¹⁴ 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).

¹⁵ The Power System Security Guidelines (SO_OP_3715), effective at 6 November 2023, available at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Power_System_Ops/Procedures/SO_OP_3715%20Power-System-Security-Guidelines.pdf.



AEMO issued a market notice (MN) 112320 on 14 December 2023 to inform the market of this update to the vulnerable lines in South Australia region. Subsequently, AEMO cancelled the reclassification of the simultaneous trip of the Robertstown – Tungkillo 275 kV No. 1 and No. 2 lines and the Robertstown No. 1 and No. 2 SCs and reverted to a non-credible contingency as there was no lightning activity in the vicinity of the lines. AEMO issued MN 112321 at 14:02 hrs on 14 December 2024 to advise of this cancellation.

On 6 March 2024, following ElectraNet’s confirmation that automatic restart capability had been added to the SCs’ vacuum pump control systems, the Tungkillo – Robertstown No. 1 and No. 2 275 kV lines and the Robertstown No. 1 and No. 2 SCs were removed from the special reclassification of transmission plant during lightning list⁵, as AEMO considered the simultaneous trip of the Robertstown – Tungkillo No. 1 and No. 2 275 kV lines and the Robertstown No. 1 and No. 2 SCs was no longer possible.

4 Market information

AEMO is required by the NER and operating procedures to inform the market about incidents as they progress. This section assesses how AEMO informed the market¹⁶ over the course of this incident.

For this incident, AEMO informed the market on the following matters:

- AEMO issued MN 111778 at 05:52 hrs on 28 November 2023 to advise that it had invoked constraint set S-RBTU between 05:45 hrs and 06:00 hrs on 28 November 2023. This constraint set contains constraint equations with interconnector terms on the left-hand side (LHS).
- AEMO issued MN 111779 at 05:53 hrs on 28 November 2023 to advise the market of the non-credible contingency event – at 05:36 hrs the Robertstown No. 1 and No. 2 SCs tripped simultaneously.
- AEMO issued MN 111780 at 05:59 hrs on 28 November 2023 to advise that at 05:47 hrs on 28 November 2023 the Robertstown – Tungkillo 275 kV No. 1 line was returned to service, and it had revoked constraint set S-RBTU at 06:00 hrs. This constraint set contains constraint equations with interconnector terms on the LHS.
- AEMO issued MN 111796 at 13:52 hrs on 28 November 2023 to advise that, based on revised information, at 05:34 hrs the Robertstown – Tungkillo 275 kV No. 1 and No. 2 lines tripped simultaneously and that as a result at 05:36 hrs the Robertstown No. 1 and No. 2 SCs also tripped simultaneously.
- AEMO issued MN 111795 at 13:53 hrs on 28 November 2023 to advise that it had reclassified the incident as a credible contingency as AEMO was not satisfied that this non credible contingency event is unlikely to re-occur.
- AEMO issued MN 111818 at 18:20 hrs on 28 November 2023 to advise that it had reclassified the incident as a credible contingency and invoked constraint S-RBTU+SCON_N-2 from 17:45 hrs.
- AEMO issued MN 112320 at 14:04 hrs on 14 December 2023 to advise that the following elements were now considered to be vulnerable due to lightning: Robertstown – Tungkillo 275 kV No. 1 line, Robertstown – Tungkillo 275 kV No. 2 line, Robertstown No. 1 and No. 2 SCs.

¹⁶ AEMO generally informs the market about operating incidents as they progress by issuing Market Notices – see <https://www.aemo.com.au/Market-Notices>.

- AEMO issued MN 112321 at 14:02 hrs on 14 December 2023 to advise that it had cancelled the reclassification of the non-credible contingency event as a credible contingency event due to lightning.
- AEMO issued MN 115514 at 14:23 hrs on 6 March 2023 to advise that the simultaneous trip of the following elements was now considered no longer reasonably possible in the event of lightning activity and therefore, removed from the special reclassification of transmission plant during lightning list⁵: Robertstown – Tungkillo No. 1 and No. 2 275 kV lines and the Robertstown No. 1 and No. 2 SCs.

The MN 115514 also refers to cancellation of a reclassification however, the reclassification for this incident was previously cancelled via MN 11232. MN 115514 should have referred to removal of these elements from the special reclassification of transmission plant during lightning list⁵. Although issuing this MN is not a rules requirement, AEMO has reinforced the need to ensure the accuracy of the market notices with the operators.

Table 6 provides a summary of the constraint sets AEMO invoked for this incident.

Table 6 Constraint sets invoked during the incident

Constraint Set	Start Date (Date Month Year HH:MM)	End Date (Date Month Year HH:MM)	Interconnector terms on the LHS
S-RBTU	28 November 2023 05:45	28 November 2023 06:00	Murraylink and Heywood
S-X_DV+RB_2SYNCON	28 November 2023 05:45	28 November 2023 11:15	None
S-RBTU+SCON_N-2	28 November 2023 17:45	14 December 2023 14:10	Murraylink

As shown in Table 6, S-RBTU contains both Heywood interconnector and Murraylink direct current (DC) interconnector terms and S-RBTU+SCON_N-2 contains a Murraylink DC interconnector term on the LHS. The Power System Security Guidelines (SO_OP_3715)¹⁷ indicate that AEMO should issue a MN in these circumstances. AEMO issued the relevant MN for S-RBTU but not for S-RBTU+SCON_N-2. AEMO implemented constraint S-RBTU+SCON_N-2 following this incident to manage potential voltage collapse in Mid North South Australia for the loss of Robertstown – Tungkillo 275 kV No. 1 and No. 2 lines and Robertstown No. 1 and No. 2 SCs. However, AEMO did not issue a corresponding MN.

While AEMO has reinforced the requirement to publish MNs in such circumstances, challenges with identifying the need for a market notice highlight the potential benefit of an automated solution. AEMO will investigate opportunities to automate publication of market notices when there are constraints invoked with interconnector terms on the LHS.

¹⁷ The Power System Security Guidelines (SO_OP_3715), effective at 6 November 2023, available at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Power_System_Ops/Procedures/SO_OP_3715%20Power-System-Security-Guidelines.pdf.

5 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's conclusions, recommendations, and actions arising from its review are summarised in Table 7.

Table 7 Summary of conclusions and recommendations

Finding	Recommendations/actions
Lightning during a storm caused two simultaneous single-phase faults on the Robertstown – Tungkillio 275 kV No. 1 and No. 2 lines, which share a common tower structure. A W phase to earth fault occurred on Robertstown – Tungkillio 275 kV No. 1 line and a U phase to earth fault occurred on Robertstown – Tungkillio 275 kV No. 2 line.	No action required.
The single-phase to earth fault in the U phase of the Robertstown – Tungkillio 275 kV No. 2 line led to the tripping and auto reclosing ¹⁸ of the faulted pole of the corresponding CBs at both ends of the Robertstown – Tungkillio 275 kV No. 2 line.	No action required.
<ul style="list-style-type: none"> All three poles of the corresponding CB at Tungkillio end of the Robertstown – Tungkillio 275 kV No. 1 line tripped and remained locked out as the two simultaneous faults occurred on two different phases and both faults were within the Zone 2 reach of the distance protection¹⁹ used at Tungkillio. ElectraNet noted that there's an opportunity to redesign the distance protection scheme used on Robertstown – Tungkillio 275 kV No. 1 line to prevent the phase-to-phase fault tripping at Tungkillio in these circumstances, however, the redesign must consider the NER requirements for in-zone line faults as well. 	AEMO supports ElectraNet's plan to further consider the distance protection scheme used on Robertstown – Tungkillio 275 kV No. 1 line and to share key findings with AEMO and, where relevant, the PSSWG.
Robertstown No. 1 and No. 2 SCs tripped shortly after the faults on Robertstown – Tungkillio 275 kV No. 1 and No. 2 lines. Robertstown SCs tripped due to flywheel housing vacuum pump drive failure. The close-in simultaneous faults on Robertstown – Tungkillio 275 kV No. 1 and No. 2 lines caused a large voltage dip resulting in the vacuum pump drives signalling a 'Drive Failed' latching event, which had to be manually reset before the vacuum pumps could be returned to service.	<ul style="list-style-type: none"> ElectraNet's design/build contractor of the Robertstown No. 1 and No. 2 SCs added an automatic restart capability to both SCs on 14 February 2024 to improve their ride-through capability. ElectraNet has confirmed that the SCs are expected to ride through credible contingency events and meet the performance standards. ElectraNet to share the key findings of the investigation of the incident with the PSSWG by Q3 2024.
The power system remained in a secure operating state and the FOS was met throughout the incident.	None
At the time of the incident, AEMO appropriately reclassified the contingency event as credible as AEMO was not satisfied that this non-credible contingency event was unlikely to re-occur. AEMO issued MN 111795 at 13:53 hrs on 28 November 2023 to advise the market.	<ul style="list-style-type: none"> On 14 December 2023, following confirmation from ElectraNet that the Robertstown – Tungkillio 275 kV No. 1 trip and No. 2 SPAR were caused by lightning, the Robertstown – Tungkillio 275 kV No. 1 and No. 2 lines and the Robertstown No. 1 and No. 2 SCs were added to the special reclassification of transmission plant during lightning list⁵ in accordance with the Power System Security Guidelines (SO_OP_3715). AEMO issued MN 112320 at 14:04 hrs on 14 December 2023 to advise of this change. Subsequently, AEMO cancelled the reclassification of the simultaneous trip of the Robertstown – Tungkillio 275 kV No. 1 and No. 2

¹⁸ Robertstown – Tungkillio 275 kV No. 2 line is protected by Set 1 and Set 2 differential protection with single phase tripping and auto reclose.

¹⁹ Robertstown – Tungkillio 275 kV No. 1 line is protected by Set 1 differential protection and Set 2 distance protection with blocking scheme and single-phase tripping and auto reclose.

Finding	Recommendations/actions
	<p>lines and the Robertstown No. 1 and No. 2 SCs and reverted to a non-credible contingency as there was no lightning activity in the vicinity of the lines. AEMO issued MN 112321 at 14:02 hrs on 14 December 2024 to advise of this cancellation.</p> <ul style="list-style-type: none"> On 6 March 2024, following ElectraNet's confirmation that automatic restart capability had been added to the SCs' vacuum pump control systems, the Tungkillio – Robertstown No. 1 and No. 2 275 kV lines and the Robertstown No. 1 and No. 2 SCs due to lightning were removed from the special reclassification of transmission plant during lightning list⁵ in accordance with the Power System Security Guidelines (SO_OP_3715), as AEMO considered the simultaneous trip of the Robertstown – Tungkillio No. 1 and No. 2 275 kV lines and the Robertstown No. 1 and No. 2 SCs was no longer reasonably possible in those conditions.
<p>ElectraNet has reviewed maintenance records for the Robertstown – Tungkillio 275 kV No. 1 and No. 2 lines and confirmed that there are no recent results available for tower to earth impedance for towers around the fault location.</p>	<p>AEMO supports ElectraNet's plan to conduct the tower footing impedance measurements for towers around the fault location by Q4 2024 and to undertake necessary remediations. AEMO recommends ElectraNet share key findings with AEMO and, where relevant, the PSSWG.</p>

A1. System diagram

Figure 3 provides an overview of the key transmission elements relevant to the event immediately prior to the incident.

Figure 3 Pre-incident network diagram

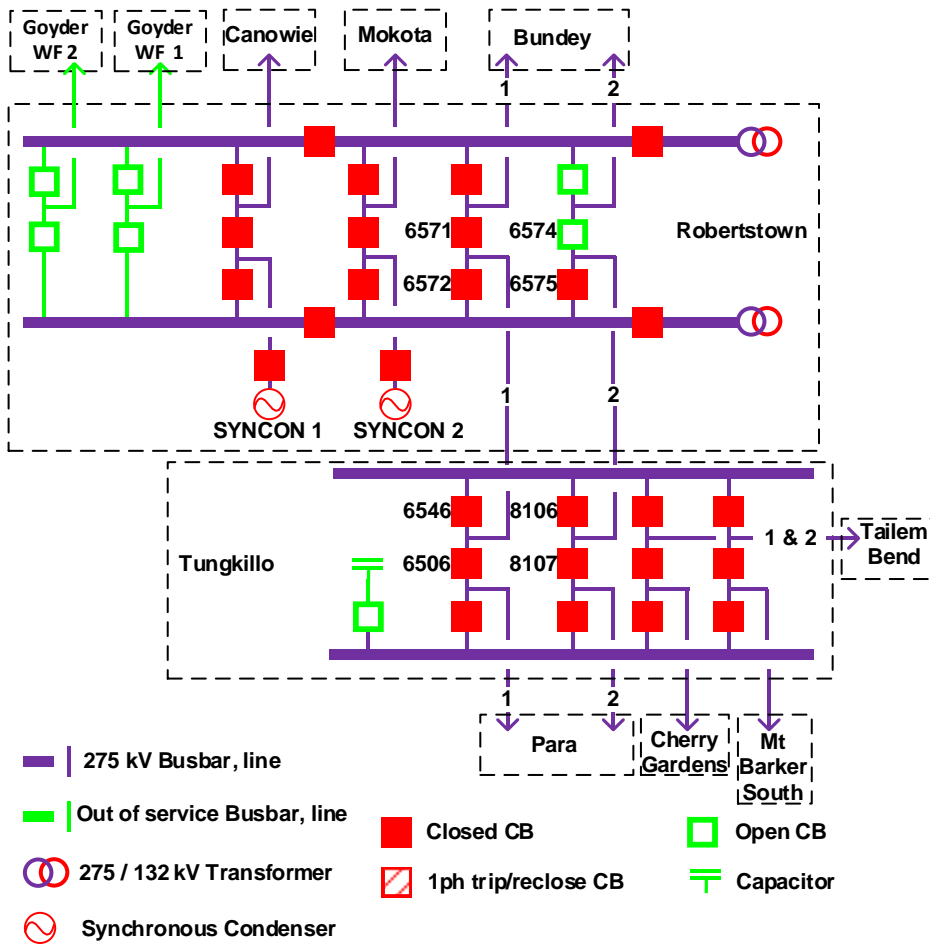




Figure 4 provides an overview of the key transmission elements relevant to the event immediately after the trip of Robertstown – Tungkillo 275 kV No. 1 and No. 2 lines at approximately 05:34:55 hrs.

Figure 4 Network diagram immediately following the trip of Robertstown – Tungkillo 275 kV No. 1 line and SPAR of No. 2 line

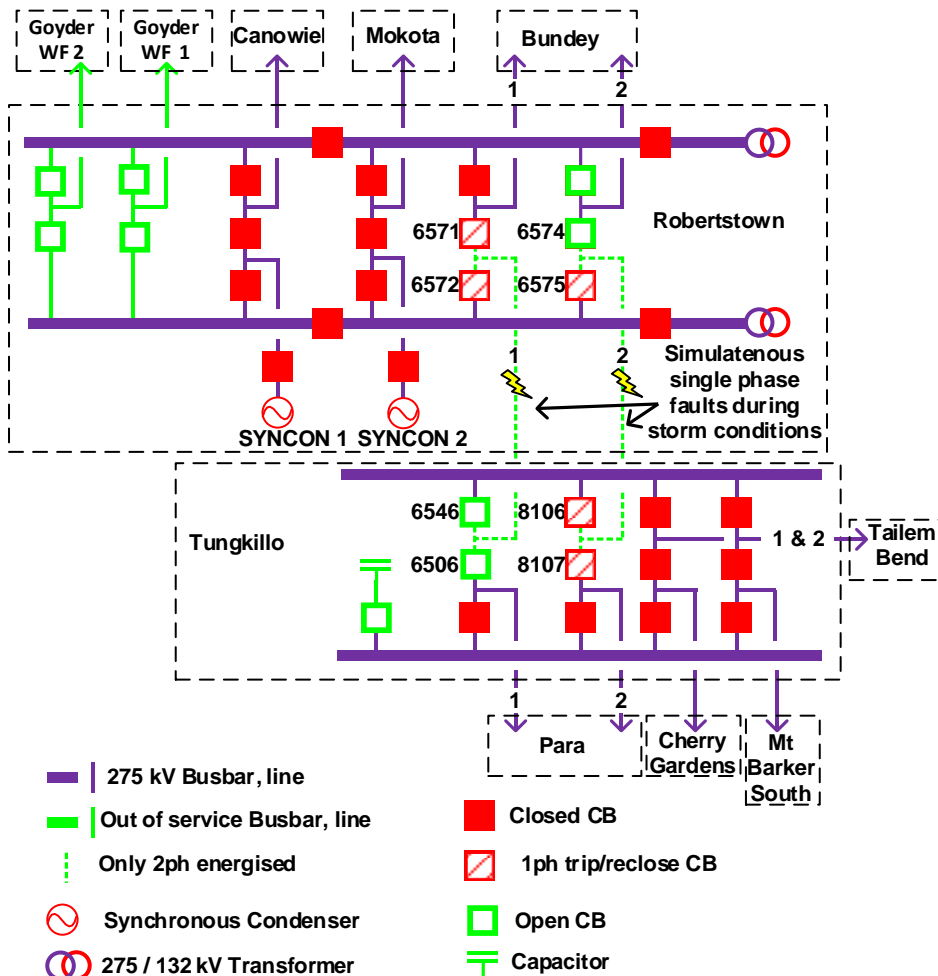




Figure 5 provides an overview of the key transmission elements relevant to the event immediately after the trip of the Robertstown SCs at approximately 05:36:05 hrs.

Figure 5 Network diagram immediately following the trip of Robertstown SCs

